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NORM G. DUCHARME

Farm Animal Surgery

SECOND EDITION







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SECOND EDITION

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To our Cornell "family" of colleagues, residents, technicians, staff, and students for their advice, friendship and guidance.

And in honor of the memory of Dr. W.C. Rebhun and Dr. F.H. Fox for all they taught us and so many others- and for the care they provided to so many animals in Upstate NY and surrounding areas.

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Preface

In the 2nd Edition of *Farm Animal Surgery* we strive to update, correct, and improve upon the first edition. The contributors to our efforts include outstanding veterinary surgeons and clinicians from around the globe. We are so grateful for their input and shared experience.

We hope this serves as a useful tool for veterinary students, practitioners, and residents-in-training as well as individuals dealing with comparative species such as zoo medicine and surgery. We have attempted to provide a comprehensive array of surgical options for the most common conditions of farm animals, with an emphasis on dairy cattle. In the past, single-animal treatment in commercial herds and hobby farms formed the basis of our emphasis in traditional farm animals. The advent of rescue organizations has been a major event since the last edition that has "pushed us" at Cornell University Nemo Hospital for Farm Animals to develop and deliver a level of care that was not previously possible in production animals. Therefore, sophisticated procedures are appearing in all farm animal species and are reflected in this edition. Some of the described procedures may not be appropriate in management of traditional farm animals versus zoo animal versus animals at rescue centers. The readers should take this into account.

We feel fortunate to have spent the majority of our professional careers at Cornell University and would like to acknowledge our colleagues in our own and all associated specialties, who provide us with advice, guidance, and friendship every day and willingly share their expertise. We could not practice our specialty at the desired level without the advice and recommendations of fellow anesthesiologists, internists, radiologists, ophthalmologists, and theriogenologists. We encourage readers to seek advice and consultation from appropriate veterinarians, specialists, and paramedical support (veterinary technicians, surgical nurses, physical therapists, and orthotists).

We also want to recognize our surgical residents. We have, over many years, been fortunate to have these unique, extraordinarily talented young veterinarians to work with. They have gone on to outstanding careers, and we are very proud of their accomplishments. We also work day in and day out with our veterinary technicians, who are such an integral part of our team. Our students are bright and engaging, keeping us on our toes and challenging us every day. Both residents and students offer a promising view of the future of veterinary medicine

This edition would not have been possible without the substantial efforts of the team at Elsevier: Penny Rudolph, Brian Loehr, and Cindy Mosher. Patty Reynolds from Cornell's imaging section has been invaluable in finding radiographs. Lisa Mitchell from Cornell helped immensely with editing text and arranging figures for each chapter.

We want to mention two of the farm animal clinicians who have come before us from Cornell University. They were "giants" in the field of Farm Animal Medicine and Surgery and truly pioneers in their time. These include Dr. Bill Rebhun, our beloved friend, an internist and ophthalmologist, whom we miss every day. Dr. Francis Fox, recently passed, was an iconic figure in ambulatory medicine, with astonishing powers of observation, all the while being sly and mischievous. With this book we honor them and all they taught us and so many generations of veterinarians.

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PART I

GENERAL CONSIDERATIONS TO ALL SPECIES

CHAPTER 1

Examination of the Surgical Patient

Gillian A. Perkins, Thomas J. Divers, Mary C. Smith and Robert J. Callan

EXAMINATION OF ADULT CATTLE

Gillian A. Perkins

PHYSICAL EXAMINATION

This section focuses on examination of the adult cow with emphasis on the abdomen. Examination of the other body systems is discussed in the relevant chapters. Every good physical examination begins with a complete history. The basic information consists of the cow's lactation number, days in milk, diet, and pregnancy status. The herd person typically provides this information and any additional information, including any fever, ketosis, mastitis, metritis, previous medications or surgery, feed intake, changes in ration, and manure production.

The physical examination should begin with an evaluation of the overall well-being of the cow and her attitude. Simply noting if the cow is cleaning her nose and passing manure provides a quick assessment of her condition. Many diseases in the cow present as merely a decrease in milk production and appetite (e.g., left-displaced abomasum [LDA], right-displaced abomasum [RDA], and ruminal distention), and the cow often appears quiet yet somewhat normal. The more acute, severe disorders, such as lactic acidosis, abomasal volvulus (RVA), cecal volvulus, and hardware disease typically show more severe signs, including evidence of dehydration, abdominal pain, and general malaise. A history of colic and/or the presence of abdominal pain at the time of physical examination should alert the veterinarian to act quickly and suspect causes such as indigestion or diseases that require surgical attention, including intestinal obstruction or cecal disorders.

Hydration can be estimated by evaluating a palpebral or cervical skin tent, moistness of the nose, and depth of the eye within the socket. A packed cell volume (PCV) and total protein quantitates the hydration status of the cow. The temperature, pulse, and respiratory rates will indicate the systemic health of the patient. One must also look for evidence of hypocalcemia, such as muscle fasciculations, weakness, sluggish papillary light reflexes, and cold extremities (e.g., the pinna), which could result in rumen and intestinal hypomotility.

The paralumbar fossas and the right paramedian abdomen should be evaluated for evidence of previous surgery or toggle-pin fixation. A quick oral examination should be performed to check for oral ulceration and abnormal breath (ketosis or lung abscess). Concurrent periparturient disorders, such as mastitis and ketosis, often exist. Therefore an examination of the udder that includes palpation, a California mastitis test (CMT), and strip-plate analysis, along with a urine ketone test, is indicated for completeness.

Examination of the gastrointestinal tract includes evaluation of the abdominal shape for distention, auscultation of the rumen and intestinal motility, simultaneous auscultation and percussion (pinging), succussion, and rectal examination. Ancillary diagnostic tests, such as abdominocentesis, rumen-fluid analysis, and passage of an ororumen tube, can be performed to help differentiate the exact diagnosis. This chapter will now be divided into two main categories preceded by a discussion of ancillary diagnostic tests: disorders that cause abdominal distention and those that cause tympanic resonance.

DIAGNOSTIC PROCEDURES

Rumen-Fluid Analysis

Rumen fluid can be obtained by passing an ororumen tube (a stomach tube into the rumen) or a weighted tube or by rumenocentesis. The smell and color of the fluid obtained can be evaluated subjectively. Rumen fluid is generally aromatic, and, depending on the diet of the cow, the color can range from green to yellow to brown. A milky-to-brown color with a very pungent sour or acidic odor indicates grain engorgement (Figure 1-1). The presence of multiple small bubbles gives rise to a foamy appearance that is usually termed *frothy bloat*. Depending on the diet, the normal pH ranges from 5.5 to 7.5; pH below 5.5 indicates rumen acidosis. Contamination of the rumen fluid with bicarbonate-rich saliva is the most common reason for a high rumen-fluid pH. Pathologic reasons for a pH greater than 7.0 include decreased activity of the rumen flora, whereas a pH greater than 8.0 suggests urea toxicity. Other special tests—such as a Gram stain and direct microscopic examination for protozoa, methylene blue test, and sediment activity test—have been described but often do not have a practical application for

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Figure 1-1 Rumen fluid from a Brown Swiss steer that ingested excessive amounts of bagels 3 days before. The pH of the fluid was <5. It had a very pungent odor and was a chocolate milk consistency and color.

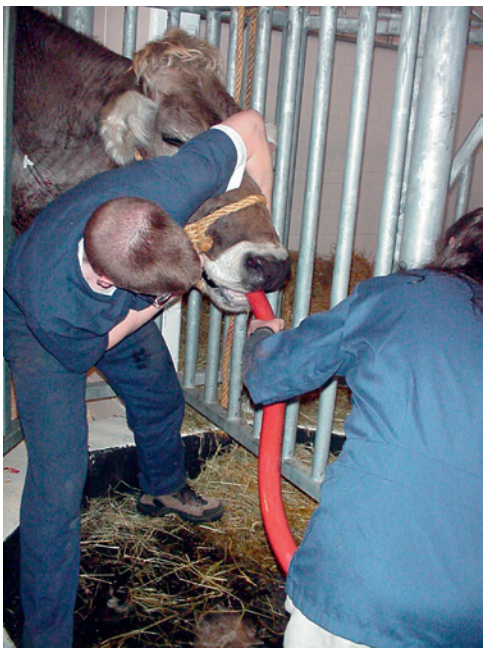


Figure 1-2 Passing a Kingman tube in a Brown Swiss steer with carbohydrate overload. The head should be kept straight to minimize pharyngeal trauma.

the veterinarian in the field and provide little information other than what can be gained from a good physical assessment of the cow. A high rumen chloride (>30-35 mEq/L, normal <25-30 mEq/L) is consistent with reflux of chloride from the abomasum into the forestomach compartments and supports a diagnosis of pyloric outflow obstruction (posterior functional stenosis).

Ororumen Tube

With a cow in a stanchion or head-gate, an ororumen tube can best be passed by the operator standing beside the cow's head. The arm closest to the cow is placed over the bridge of the nose, and the hand is placed in the oral cavity (dental space) by opening the mouth and lifting dorsally. The opposite hand (farthest away from the cow) is free to gently pass the Frick speculum into the mouth along the hard palate. The hand that is holding the mouth open can be used to guide the speculum caudally by placing the speculum between the hard palate and the cup of the hand. A slight resistance is palpated as the base of the tongue is reached. With continued gentle pressure, the speculum is advanced slightly into the oropharynx. Pressure should not be excessive as pharyngeal trauma can be a complication. The speculum is then stabilized by the hand that restrains the mouth and head. At this point, the tube can be passed through the speculum into the pharynx and advanced into the esophagus and the rumen. Simultaneously distending the esophagus with gas by blowing into the tube as it advances may make passing the tube easier. Once the rumen is entered, a characteristic odor and rush of gas is usually heard. To confirm placement of the tube, one can blow into the tube and have someone auscultate over the left paralumbar fossa for bubbling sounds in the rumen. Palpation of the tube in the cervical esophagus also confirms correct placement. The tube can be manipulated back and forth and manual pressure applied to the left paralumbar fossa to try to obtain fluid or gas. At this point, samples should be obtained and any therapy administered. This may include intraruminal fluids, rumenotorics, transfaunate, or electrolytes. Should the cow begin to regurgitate around the tube, the head should be flexed and lowered to prevent aspiration of rumen contents, and the tube should immediately be occluded and pulled with a steady stroke moving outward and ventrally. Kinking the end of the tube to prevent backflow of rumen contents into the pharynx of the cow decreases the risk of aspiration pneumonia. Unkinking the tube and holding the dependent aspect over a collection device (fecal cup, bucket, etc.) may permit retrieval of fluid from within the tube lumen.

The Kingman tube is a large-diameter tube that is used to evacuate abnormal rumen contents or for rumen lavage to alleviate the need for surgery or decrease abdominal distention in preparation for surgery. The cow's head must be held straight, forward, and slightly raised above horizontal. A speculum is placed in the oral cavity; copious lubrication is applied to the tube, and with gentle pressure, it is passed down the esophagus to the rumen (Figure 1-2).

Abdominocentesis

Analysis of peritoneal fluid can be helpful in establishing a diagnosis and determining a prognosis for many gastrointestinal disorders. Two sites are recommended for abdominocentesis in cattle. The first evaluates the right cranial abdomen and is most helpful in cases in which a localized peritonitis is suspected secondary to perforation of an abomasal ulcer. This area runs from the midline to the right milk vein just caudal to the xiphoid. The second site is located just above the udder on the right side under the fold of the flank. Alternatively, a site can be selected with the use of ultrasound to detect a fluid pocket. The planned site is clipped and prepared for an aseptic procedure. A tail jack is used for restraint and an 18-gauge, $1\frac{1}{2}$-inch needle is inserted through the skin and slowly advanced into the peritoneal cavity. Alternatively, the area can be infused with lidocaine, a small stab incision made in the body wall with a #15 blade, and a teat cannula used to obtain the abdominal fluid. Cattle have very strong abdominal musculature that can move the

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needle or teat cannula; therefore they should be held carefully and kept at a 90-degree angle to the ground. Because cows produce copious amounts of fibrinogen, the fluid may be difficult to obtain, and preparation of more than one site for abdominocentesis may be advisable. A normal abdominal fluid analysis in one location and an inflammatory tap in the other may indicate a localized problem. The fluid should be clear and colorless to yellow. The total protein should be <3.0 g/dL and the nucleated cell count <10,000/µL, consisting of neutrophils and mononuclear cells.

Laboratory Work

Gastrointestinal disorders of cattle, whether they are forestomach, abomasal, intestinal, or cecal in origin, most commonly show hypochloremic metabolic alkalosis accompanied by hypokalemia caused by inappetence. This means that while plasma electrolyte concentrations may help confirm clinical suspicions and aid in the formulation of a therapeutic plan, they are not all that helpful in localizing a specific problem.

A paradoxic aciduria often develops in cows with hypochloremic alkalosis. It is paradoxic because one would expect that the alkalotic cow would retain hydrogen ions to counteract the alkalosis. However, because of dehydration, the kidney retains sodium. Chloride is not available; therefore another positive ion needs to be excreted. Hypokalemia in these patients makes the hydrogen ion the only positive ion available, which is excreted in the urine in exchange for sodium, resulting in a low urine pH. Hypocalcemia is also commonly observed.

Strangulating lesions of the abomasum, cecum, or small intestine can result in bowel necrosis and accumulation of lactic acid. This can cause a high anion gap, with hypochloremic acidosis indicating a poor prognosis. Infrequently, a moderate to severe case of ketosis may result in a high–anion-gap acidosis caused by ketoacidemia. On a practical basis, easy-to-use cow-side tests such as the i-STAT[1] can determine plasma-electrolyte levels, ionized calcium, and creatinine in less than 2 minutes per test.

Complete blood cell counts can quantitate the degree of inflammation and be run sequentially to monitor the patient's response to a disease entity. A persistent lymphocytosis and clinical signs of pyloric obstruction could make the clinician suspicious that the cow is infected with bovine leukosis virus (BLV) and may have abomasal lymphoma. However, very few cattle infected with BLV (<4%) actually develop tumors. Increased concentrations of fibrinogen, an acute-phase protein along with globulins, contribute to an overall increase in total plasma protein and are typical of an inflammatory process such as an intraabdominal abscess or peritonitis. An increased PCV and total protein supports dehydration. Plasma-lactate measurement can be used as an indicator of perfusion and oxygenation status. Lactate will increase with either global (systemic hypotension) or local (e.g., strangulated bowel) diseases, and the magnitude of the increase can be used as a prognostic marker in some diseases such as RVA. More important than the measurement before surgery and/or resuscitation is the change that occurs after appropriate treatments. Measurement of L-lactate can be performed in the field with a handheld point-of-care instrument.

Abdominal Ultrasonography

Use of ultrasound equipment on the farm is becoming more commonplace. Clients are requesting pregnancy diagnosis with the aid of ultrasound. The same rectal 3.5-MHz ultrasound probe can be used to explore the abdomen either transrectally or transabdominally. A 5-MHz probe gives deeper penetration but may not be cost effective. The ultrasound has helped the author in the diagnosis of intraabdominal abscess associated with hardware disease, liver abscesses, abomasal ulceration, and other causes of gastrointestinal disturbances, including neoplasms, peritoneal effusion, omental bursitis, and intestinal disorders such as intussusceptions and strangulating obstructions of the small intestine. Ueli Braun has published numerous papers on ultrasonography of the bovine abdomen, which the reader should refer to for more detailed information.

DISORDERS CAUSING ABDOMINAL DISTENTION IN CATTLE

Vagus Indigestion

Vagus indigestion (VI) is rumen atony caused by damage or inflammatory changes to the vagus nerve as it courses through the pharynx, thoracic cavity, and perireticular and pyloric regions. The vagus nerve provides both sensory and motor innervation to the bovine forestomach compartments and abomasum. Like other neurologic disorders, the cause of VI is determined after localizing the lesion, and four types of vagal indigestion have been defined: 1) failure of eructation; 2) omasal transport failure or anterior functional stenosis; 3) pyloric outflow obstruction or posterior functional stenosis; and 4) indigestion of late pregnancy based on the site that the vagal nerve has been affected. The editors have modified this classification (see Chapter 14.) In Types II and III, the term *stenosis* is not entirely correct because there is no true narrowing of the tract; however, there is a functional blockage or paralysis and relaxation whereby ingesta is unable to traverse the omasum to the abomasum or the abomasum to the pylorus and duodenum, respectively. Alternatively, one could approach a cow with VI by examining the pharynx, neck, thorax, and cranial abdomen for lesions that may involve the nerve as it courses through those respective locations. Cows with VI may have low heart rates (40-60 beats per minute), and the rumen, on auscultation, will have frequent, small, uncoordinated contractions. Feces tend to be scant and pasty with larger particulate matter due to inappropriate passage of feedstuffs. The most common causes of VI include traumatic reticuloperitonitis or hardware disease, reticular abscess (usually involving the medial wall of the reticulum), liver abscesses, pneumonia, postabomasal volvulus, and abomasal ulcers.

A great deal of information can be gained from standing behind a cow and observing the abdominal contour. Viewing the cow from either side and evaluating the shape of the paralumbar fossa and rib cage can also be helpful. The "papple" shape is classic for a cow with rumen distention in which the distended dorsal sac of the rumen occupies the dorsal left flank and the ventral sac of the rumen distends not only to fill the left ventral abdomen but also to distend over into the right ventral abdomen, thus giving an apple shape to the left side and a pear shape to the right side (Figures 1-3 and 1-4). The challenge is to determine the type and cause of the distention (Table 1-1). Auscultation of rumen motility, palpation of the rumen in the paralumbar fossa, accompanied by simultaneous auscultation and percussion (pinging) and succussion, rectal examination, and rumen-fluid analysis can be helpful in differentiating between these disorders. Other less common rule-outs for distention of the entire left abdomen and right ventral abdomen include advanced pregnancy, hydrops, and abomasal impaction.

[1]VetScan i-STAT 1 Handheld Analyzer, Abaxis, Union City, CA 94587, USA.

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Table • **1-1**

Differential Diagnosis for Cows with a Papple-Shaped Abdomen

PAPPLE SHAPE			
VAGAL INDIGESTION			OTHER
TYPE I	TYPE II	TYPE III	
FAILURE OF ERUCTATION	FAILURE OF OMASAL TRANSPORT	PYLORIC OUTFLOW OBSTRUCTION	
Free-gas bloat	Hardware disease	Volvulus of the abomasum	Frothy bloat
Esophageal obstruction	Liver abscess	Right or left displacement of the abomasum	Lactic acidosis
Obstruction at the cardia Right-lateral recumbency	Reticular abscess, adhesion, peritonitis (without foreign body) Diffuse peritonitis Neoplasia of rumenoreticular fold and esophageal groove Inflammatory disease of reticular and rumen wall Papilloma or mass at reticulomasal orifice Herniation of reticulum through diaphragm	Inflammation or adhesions involving the reticulum and/or fundus of the abomasum Advanced pregnancy with a large fetus Abomasal impaction	Diffuse peritonitis Hydrops



Figure 1-3 Classic papple-shaped abdomen in a cow with rumen distention.



Figure 1-4 View of ruminal distention looking caudally from the withers region. Notice the marked distention of the left paralumbar fossa.

I—Failure of Eructation

With ruminal distention caused by free gas, a large ping can be heard dorsally on the left side of the abdomen beginning in the caudal left paralumbar fossa (as far back as the tuber coxae) and extending cranially to the 8th to 10th intercostal spaces (ICSs). The ping can also be heard dorsally over the midline (above the transverse processes of thoracic and lumbar vertebrae) with free-gas rumen bloat. The ventral border of a rumen ping commonly has a very distinct horizontal line that distinguishes it from the tympanic resonance of an LDA (Figure 1-5). The rumen tends to be static in cows with free-gas bloat, and the area of the ping corresponds to a palpably taut elastic tension on the external abdomen. The dorsal sac of the rumen on rectal examination will feel tight and rebounds when indented. It can extend to the right past the midline, and if one palpates the right side of the distended dorsal sac it can often be followed to the ventral sac, distended with feed material and some gas. This is significant because in the normal cow the ventral sac is not distinct on rectal examination. An ororumen tube (if passed in a manner that successfully reaches the trapped gas) can relieve the gas, and the ping and rumen distention palpated on rectal examination will decrease, thus confirming suspicion of free-gas bloat.

II—Failure of Omasal Transport

Omasal-transport failure results from impairment of the flow of ingesta from the reticulum through the omasal canal into the abomasum and is considered true forestomach disease. This is the most common form of VI; perireticular

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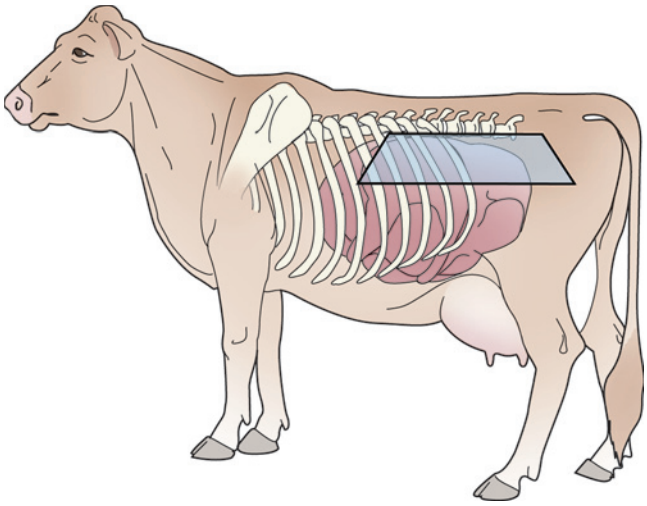


Figure 1-5 Rumen distention (*left side*). Area of tympanic resonance (*shaded*) heard with ruminal tympany.

or liver abscesses and traumatic reticuloperitonitis are the most likely causes. Toxic rumenitis, papilloma, and neoplasms of the rumenoreticular fold and esophageal groove have also been reported. The abomasum and omasum are relatively empty in cows with omasal-transport failure, and the forestomach compartments become progressively distended, with the rumen taking on an L shape or, as defined from external evaluation, a papple shape. A mild to moderate amount of gas may accumulate dorsally in the rumen, and multiple small (secondary) uncoordinated rumen contractions can be heard. Traumatic reticuloperitonitis deserves particular attention as a primary rule-out during examination of cows with VI. Cattle affected with hardware disease may stand with the elbows abducted, the back arched, and the abdominal wall tensed. Other signs include a dramatic drop in milk production and complete anorexia. Improvement in uncomplicated cases may be seen in 3 to 5 days and manifests as less obvious pain and improvement in appetite and milk production. Chronic cases may have prolonged decreases in feed intake, fecal output, and milk production. Rumen motility may be decreased to absent, and the rumen can be somewhat small because of the cows' inappetence or enlarged and bloated in more chronic cases in which the vagus nerve is involved.

Evaluating the cow for pain in the left cranial midabdomen should be performed by using the withers-pinch or grunt test. Firm pressure is applied over the withers (withers pinch) with both hands. A normal cow will flex her back ventrally in response to this, whereas a cow with cranial abdominal pain may wince, become somewhat agitated, throw her head around, stand tall, and resist changing back position. This is not a sensitive test, and further evidence for hardware disease may be needed. The clinician can perform the grunt test by kneeling beside the cow on the left cranial aspect near the xiphoid and placing one knee under the cow with the fist resting on the knee. The fist and knee are lifted together and pressed into the cow's cranial and ventral abdominal wall. The cow's head and neck are observed for signs of discomfort, and any movement away from the pressure should be noted. A stethoscope can also be held under the cow's trachea during the grunt test to listen for a grunt. Alternatively, a pole about 1 to 1.5 m long can be placed under the cow and held at each end by two assistants. Beginning at the xiphoid and moving caudally, the pole is pulled upward slowly and then allowed to fall suddenly. An area of tenderness near the reticulum would suggest traumatic reticuloperitonitis. To determine whether a magnet is already in place, the operator, facing caudally and holding a compass at the level of the elbow, stands beside the cow's left shoulder. The compass should be observed for deflection while the operator walks caudally beside the cow at the level of the elbow. If the compass passes a magnet, it will deflect but will maintain its bearing if no magnet is present. Ultrasonographic examination (3.5- or 5-MHz linear probe) of the cranial left paramedian abdomen and along the left thoracic wall to the point of the elbow between the 6th and 7th ICSs can be done to evaluate the perireticular region. The reticulum appears half-moon shaped and has biphasic contractions that occur at a rate of approximately 1 cycle per minute. The reticulum moves about 8 cm (ventral to dorsal) for the first incomplete contraction and then greater than 17.5 cm (ventral to dorsal) for the second contraction. The amplitude, speed, and frequency of these contractions are diminished in cases of traumatic reticuloperitonitis. Displacement of the reticulum, accompanied by inflammatory changes and/or abscesses, is visualized as echogenic structures with or without capsules and echolucent fluid. Neither free foreign bodies nor adhered foreign bodies are typically able to be imaged within the reticulum because of the interference of air. Lateral reticular radiographs can help locate a foreign body and magnet, outline the contour of the reticulum, show the presence of abscesses (gas accumulation or gas-fluid interface), and demonstrate involvement of other abdominal or thoracic structures. Repeat radiographs can be used if the foreign body appears to rest in the lumen of the reticulum to determine whether it is adhered in that position or the positioning is the result of a reticular contraction. A serum total protein >7.5 g/dL is suspicious for inflammatory conditions, particularly internal abscesses. However, a normal total protein does not rule out the possibility of an internal abscess and hardware disease.

III—Failure of Abomasal Outflow

Pyloric stenosis can result from damage to the vagus nerve and affect passage of feed material from the abomasum into the intestines. The abomasum and omasum fill initially, and no forestomach distention is observed. Then, as a result of overdistention of the abomasum, "internal vomiting" occurs, in which abomasal contents back up into the rumen, distention of the rumen results, and a papple-shaped abdomen may be observed. As a result, the rumen chloride concentrations may increase above 30 mEq/L. The lesions that contribute to this syndrome include abomasal lymphoma, inflammation, and adhesions of the reticulum and abomasal fundus as well as compression of the pyloric region by a large fetus and secondary to right-sided RVA. Pyloric lymphosarcoma can also cause a partial or complete obstruction and similar signs of forestomach compartment and abomasal distention.

OTHER CAUSES OF RUMINAL DISTENTION

Froth Accumulation in the Rumen

Cows with frothy bloat will have a papple shape but usually will not have a significant dorsal gas cap, and, therefore, they do not ping like the free-gas bloat. The rumen is usually palpably enlarged and doughy both externally and internally (per rectum), but when an ororumen tube is passed, the distention remains and the ingesta retrieved during evacuation of the tube will appear as its name suggests: "frothy" with lots of small bubbles. A recent history of ingestion of a ration high in legumes may suggest a true frothy bloat.

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However, cows with vagal syndrome and improper mixing and fermentation of feedstuffs within the reticulorumen can also develop frothy-type ingesta.

Rumen Acidosis

The cow with ruminal acidosis or grain overload has a decreased to absent appetite, general malaise, and dehydration and may have a dorsal accumulation of gas that results in variably sized rumen pings. The classic telltale sign is the remarkable sloshing of fluid in the rumen heard when succussion of the left abdomen is performed. Collection of a rumen fluid sample for pH is diagnostic. A metabolic acidosis caused by the absorption of volatile fatty acids from the rumen is observed along with evidence of dehydration with an increased PCV and total protein and prerenal azotemia. An abrupt change in ration or intake of high-carbohydrate feedstuffs is often determined from a complete history.

Abomasal Ulcers

Abomasal ulcers most commonly occur in cows in the first 60 days after calving. They are associated with high-carbohydrate or concentrated feeds, stress, nonsteroidal anti-inflammatory drug use, and bovine leukosis virus and can be secondary to abomasal displacement and prolonged accumulation of acid in the abomasum. Abomasal ulcers can be classified as nonperforating, nonperforating with severe blood loss, and perforating ulcers that result in either diffuse or localized peritonitis and sometimes omental bursitis. Nonperforating abomasal ulcers involve the mucosa and some of the submucosa. The cow may be asymptomatic or have partial anorexia and decreased rumen motility. Involvement of the submucosal blood vessels by the ulcer results in hemorrhage into the abomasum, and melena may be observed. Severe hemorrhage can result in signs of hemorrhagic shock with pale mucous membranes, tachycardia, anemia, and cool extremities. A localized peritonitis can occur secondary to an acute leakage of abomasal contents, generally from an ulcer along the ventral body of the abomasum. These ulcers usually become walled off by fibrinous adhesions that adhere to the abomasum, the parietal peritoneum, and/or the omasum. Acutely affected cows are anorexic, with a fever and decreased rumen motility; some may exhibit bruxism. The cow usually responds to deep palpation of the ventral cranial right abdomen. Ultrasonographic examination may show an area of variable echogenicity consistent with peritonitis. An abdominocentesis with an increased white blood cell count and total protein will confirm the diagnosis. Perforation of the abomasum with leakage of abdominal contents into the omental bursa results in a more chronic disease, in which a septic purulent process accumulates within the omental bursa but does not involve the intestines. The cow often will have a decreased appetite, weight loss, progressive abdominal distention bilaterally from rumen stasis, and accumulation of fluid in the omental bursa. The total serum protein may be low because of loss of protein into the third space. Perforation of the abomasum with massive leakage of abdominal contents will result in diffuse peritonitis and a cow with peracute signs of shock, such as tachycardia (100-120 beats per minute), tachypnea, and cool extremities. Complete anorexia, fever, rumen and intestinal atony, and scant manure will be noticed initially. As the inflammatory response ensues within the abdomen and the leakage of ingesta continues, the ventral abdomen will become distended, and sometimes a fluid wave can be balloted. The rumen may become distended secondary to atony. Rectal examination may reveal a pneumoperitoneum, and there may be crepitation on visceral surfaces. Free fluid with a variable echogenicity and sometimes echodense spots consistent with gas are seen on ultrasonographic examination. An abdominocentesis with a foul odor that contains visible as well as cytologic evidence of plant material engulfed by macrophages and bacteria can confirm the diagnosis.

DISORDERS THAT CAUSE TYMPANITIC RESONANCE (PINGS) IN CATTLE

Areas of tympanitic resonance caused by a gas-fluid interface, gaseous distention of abdominal viscera, and free air in the abdomen can be detected by simultaneous auscultation and percussion of the abdomen. This is done by placing the stethoscope on the abdomen and snapping the index or middle finger of the opposite hand to tap on the cow's abdominal wall around the stethoscope at variable distances. The finger must be tapped aggressively to elicit a detectable tympanic resonance. Alternatively, the whole hand can be used to illicit a ping. The stethoscope is moved systematically around the abdomen while the finger is snapped against the abdominal wall. Once an area of tympanic resonance is heard, the area of the entire ping should be carefully determined to differentiate the viscera involved. Simultaneous auscultation and succussion should be performed to elicit a splashing or wave sound, which confirms the presence of a distended viscus with a gas and fluid interface. Succussion involves placing the bell of the stethoscope over an area of tympanic resonance and simultaneously applying pressure with the opposite arm in a repeated motion (somewhat of a smooth punching motion) in the paralumbar fossa as close as possible to the ping (Figure 1-6). The fluid wave can sometimes be difficult to hear in less distended viscera, and repeated attempts should be performed to confirm the presence of a fluid wave.

Left-Sided Pings

Causes of a left-sided tympanic resonance include rumen tympany (discussed earlier), rumen collapse or void, left displacement of the abomasum, and pneumoperitoneum (Table 1-2).

Left Displacement of the Abomasum

The classic tympanic resonance consistent with an LDA is from the 9th to 13th ICSs on a line from the tuber coxae to the elbow. The abomasum can displace to the left and be lower down in the abdomen as well. The ping of an LDA commonly forms a somewhat circular pattern (Figure 1-7), which helps differentiate it from a distended-rumen ping (see Figure 1-5). Pressure applied to the flank with a fist

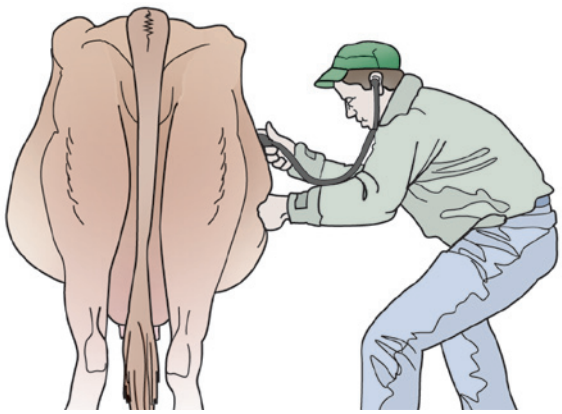


Figure 1-6 Succussion of the abdomen.

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Table • 1-2

Etiology of Right- and Left-Sided Tympanic Resonances

LEFT-SIDED PING	RIGHT-SIDED PING
Rumen tympany	Gas distention of the proximal colon
Rumen collapse or void	Cecal dilatation ± volvulus
Left-displaced abomasum	Right displacement ± volvulus of the abomasum
Pneumoperitoneum	Small intestinal distension
	Pneumoperitoneum
	Pneumorectum
	Ventral sac of rumen
	Physometra

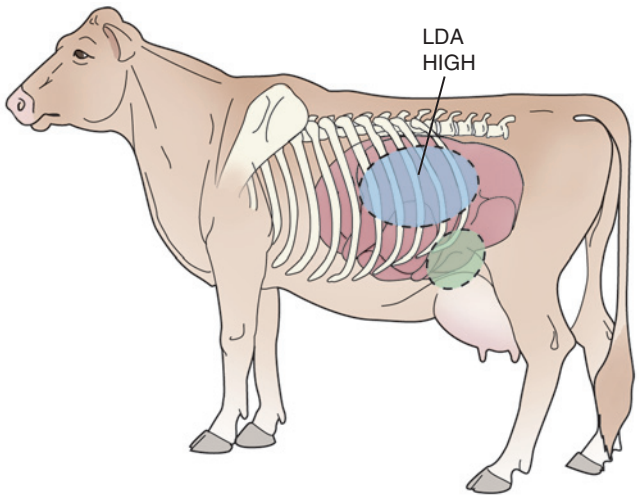


Figure 1-7 Left-displaced abomasum (LDA), high and low (*left side*). Area of tympanic resonance (*shaded*) heard with a typical LDA. Note that the pings can be heard at different levels on the left side of the abdomen.

accompanied by auscultation (see Figure 1-6) will confirm the presence of a large, fluid-filled viscus under the rib cage because a fluid wave creates a splashing sound with this technique. The location of the LDA often displaces the rumen medially and the abomasum balloons under the rib cage, giving the "sprung rib cage" appearance at the last two ribs. One can sometimes visualize a half-moon shape extending beyond the last rib into the paralumbar fossa. The entire left side of the cow should be evaluated for tympanic resonances because the abomasum may displace in a variety of places, including a much more caudoventral location along the costochondral junction. If the cow does not ping during the examination and no other illness is determined, the examination should be repeated after providing the cow with food and water. An LDA is not palpated per rectum except in the smallest cow, although the astute observer may feel the dorsal sac of the rumen somewhat displaced medially and pushing the left kidney beyond midline farther to the right of the abdomen.

Rumen-Void Ping

A rumen-void ping, or rumen collapse, is heard in the dorsal half to third of the abdomen on the left from the cranial paralumbar fossa extending forward to the 10th and 11th ICSs. This ping is thought to be caused by the vacuum produced in the peritoneum by the collapse of the dorsal sac of the rumen when the cow is anorexic and has poor rumen fill. The affected cow tends to have a sunken paralumbar fossa, and fluid cannot be detected when succussion is performed. On rectal palpation, the left kidney is pulled ventrally and to the left, and a collapsed dorsal sac of the rumen is felt. The clinician should search for an underlying disease entity, such as bronchopneumonia, metritis, or mastitis, to explain the rumen collapse.

Pneumoperitoneum

Pneumoperitoneum is defined as free air or gas in the peritoneal cavity, most commonly found after exploratory laparotomy. Other causes of pneumoperitoneum include a ruptured viscus, such as a perforating abomasal ulcer, ruptured uterus, or progression of pneumothorax and pneumomediastinum. Mild to marked bilateral dorsal abdominal distention is observed (apple shape), and an area of tympanic resonance can be heard bilaterally in the top third of the abdomen extending to the dorsal midline. Succussion does not reveal a fluid wave. The rumen motility is difficult to auscultate because free air lies between the parietal peritoneum and the visceral peritoneum of the rumen. On rectal examination, pneumoperitoneum can be very obvious in some cases in which the air in the abdomen causes the rectum to collapse around the clinician's hand, making palpation of abdominal structures frustrating and difficult. Crepitus and/or feed material can also be palpated in some instances in which the underlying disease is a ruptured or leaking intestinal viscus.

Right-Sided Pings

The right side of the cow is very complex. Pings on the right can be associated with an RDA, RVA, cecal dilation and/or volvulus, distention of the proximal colon, pneumorectum, pneumoperitoneum, distention of the small intestine, ventral sac of rumen, and physometra (see Table 1-2). Careful anatomic differentiation of these conditions must be made to pursue appropriate treatment.

Right Displacement and/or Volvulus of the Abomasum

An RDA is heard by simultaneous percussion and auscultation along a line from the tuber coxae to the right elbow extending cranially to the 9th ICS. The ping of an RDA extends cranially to the 9th rib (Figure 1-8). The caudal border of the viscus may reach the 13th rib or may extend slightly into the paralumbar fossa, creating a half-moon–shaped distention and a sprung rib cage, which can be seen when viewed from behind. A more caudal ping may be evident when the omentum has been torn and the abomasum is located more caudally. Succussion will confirm a fluid wave underneath the ribs. The right side of the abdomen will appear distended, and sometimes ruminal tympany may result secondary to mechanical outflow obstruction created by the abomasal displacement or volvulus and/or concurrent hypocalcemia. The area of tympanic resonance tends to be somewhat larger with greater fluid accumulation when the cow has an RVA. An RVA is more likely to be palpated per rectum at arm's length near the cranial aspect of the paralumbar fossa. It feels like the outer surface of a partially inflated inner tube that is covered by omentum. The dairy cow today is large, and often the RDA is beyond reach. The systemic condition of the cow can allow one to predict,

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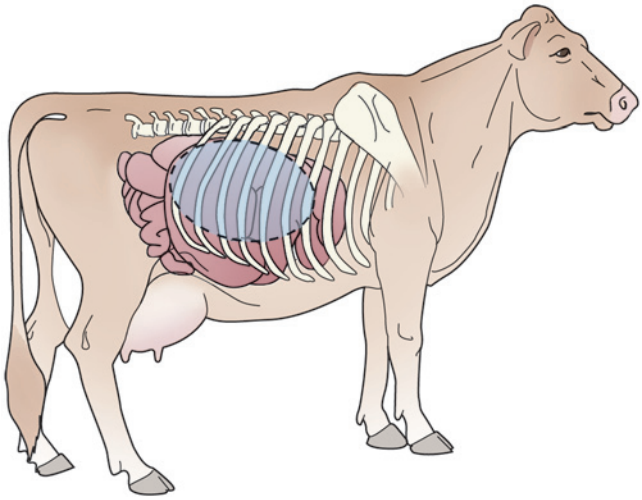


Figure 1-8 Abomasal volvulus (RVA). Area of tympanic resonance heard with right-displaced abomasum and RVA (*shaded*).

before surgery, whether the abomasum is displaced or twisted. Signs of hypovolemic shock (increased heart rate and dehydration) and endotoxemia, along with evidence of a shift from hypokalemic hypochloremic metabolic alkalosis to a high–anion-gap metabolic acidosis (lactic acidosis), are common indicators of RVA with a less favorable prognosis and a need for prompt intervention.

Cecal Dilatation and/or Volvulus

A cow with cecal dilatation and volvulus will have a tympanic resonance heard on the right midabdomen that extends cranially to the 10th or 11th ICSs and involves part or all of the paralumbar fossa (Figure 1-9A and B). The ping may vary considerably, depending on the amount of distention of the incredibly elastic cecum. Succussion of the involved area reveals a splashy washing-machine–type sound as a result of the fluid accumulation in the cecum. The distention of the right paralumbar fossa is noted from behind and from the side of the cow. The outline of the distended cecum in cases of dilatation and/or proximal colon with cecal volvulus can sometimes be visualized in the paralumbar fossa (Figure 1-10). On rectal examination, determining whether the cecum is dilated or progressed to a volvulus can be difficult. The distended cecum is easily palpable in the middle right and caudal abdomen lying horizontally in front of the pelvis in either instance, as a viscus that is about 6 to 9 inches in diameter and somewhat watermelon in shape and size (cylindrical/tubular). Sometimes the apex of the cecum is directed into the pelvic inlet so that it is obvious at the start of a rectal examination. A cecal volvulus is suspected if more than one loop of the cecum/proximal colon (folded tube) is palpable per rectum in the right central and caudal abdomen in the region of the paralumbar fossa because the apex has rotated cranially and because the body is palpable. Small intestinal distention may accompany cecal disorders and may be palpable as small bicycle-tire tubes on rectal examination in the right cranial and midabdomen. The differentiation between cecal distention and volvulus is important because cecal distention does not necessarily require surgery. Cattle with a normal heart rate, some manure production, mild dehydration, and mild to moderate distention of the cecum on rectal examination may be considered to have cecal dilatation and treated, at least initially, conservatively with fluids and cathartics. Cecal volvulus typically causes more severe systemic signs including colic, hypotension, tachycardia,

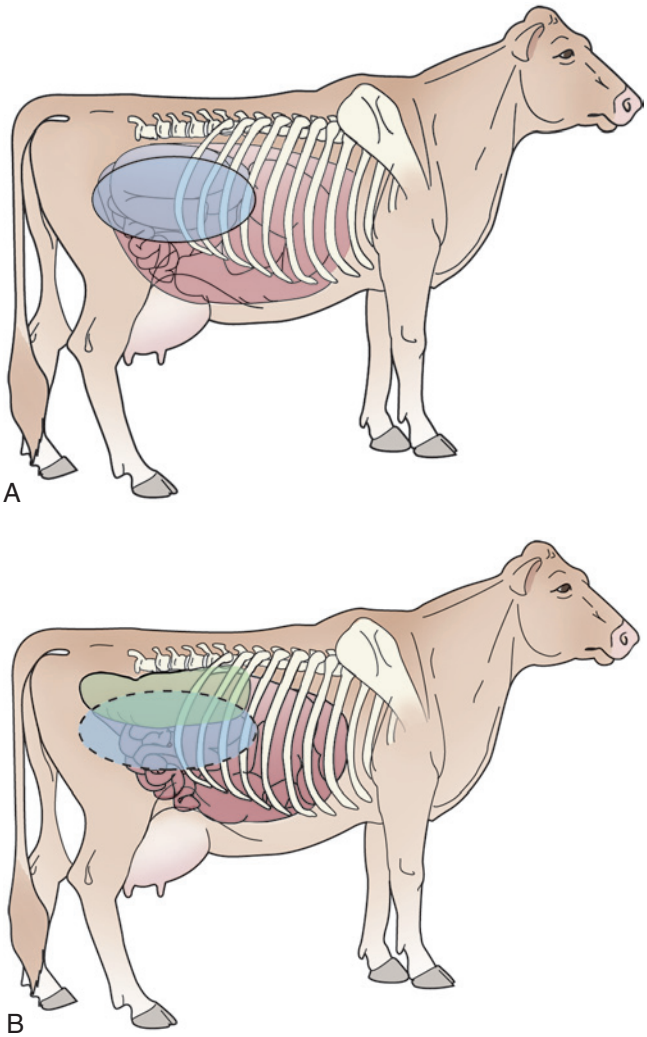


Figure 1-9 **A,** Cecal volvulus (*right side*). Area of tympanic resonance (*shaded*) heard in cows with a cecal volvulus. **B,** Cecal dilatation (*right side*). Area of tympanic resonance (*shaded*) heard in cows with cecal dilatation.



Figure 1-10 Right side of a Holstein cow with cecal volvulus displaying distended cecum and proximal colon.

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little or no manure production, dehydration, and palpation per rectum of the apex of cecum rotated cranially. These findings are indications for surgical intervention. Findings often are not straightforward, and the decision whether to operate is not easy. In most instances, a right-sided standing exploratory laparotomy should be performed because the risk of further compromise of a volvulus of the cecum outweighs the benefits of medical management of a moderate to severe cecal distention.

Distention of the Proximal Colon

An area of tympanitic resonance on the right side of the cow, in the dorsal paralumbar fossa, the width of a hand extending cranially for two to three rib spaces is caused by moderate distention of the proximal colon and is clinically insignificant. Neither abdominal distention nor succussible fluid is present.

Pneumorectum

Distention of the rectum and distal colon with air can cause a variably sized linear tympanic resonance in the right dorsal third of the caudal abdomen of the cow from the tuber coxae along the dorsal paralumbar fossa and, infrequently, cranial to the paralumbar fossa. Abdominal distention is not present and fluid cannot be heard on succussion. Rectal examination will reveal an air-filled rectum, making palpation of abdominal viscera difficult until the air is evacuated.

Distention of the Small Intestine

Distention of the small intestine with fluid and gas occurs in cattle affected with simple indigestion or obstruction of the small intestine and is secondary to cecal disorders. The most common obstructive disorders of the small intestine show acute onset of anorexia, decrease in milk production, abdominal pain, and gastrointestinal stasis. Differential diagnosis includes indigestion, volvulus of the small intestine, intussusception, and the more recently reported jejunal hemorrhage syndrome. *Clostridium perfringens* Type A has been isolated from cows with jejunal hemorrhage syndrome, although the etiology is debatable. Cows with obstructive lesions of the small intestine often display signs of colic, such as kicking at their abdomens and preferring recumbency. The cow will have progressive abdominal distention as the small intestines proximal to the obstruction become enlarged in the right middle and ventral abdomen, followed by decreased pyloric outflow with subsequent abomasal and forestomach enlargement and left-sided distention. Variable tympanic resonances may be heard on the right side of the abdomen. Succussion of the right lower abdomen will reveal tinkling and splashing sounds associated with fluid pooling in the small intestines. Feces are scant to absent. It is difficult to impossible to distinguish between intestinal volvulus and jejunal hemorrhage syndrome before exploratory laparotomy. A history of jejunal hemorrhage syndrome on the farm can be helpful. Frequently affected cows are profoundly dehydrated with blood in the manure. Cows with intussusception also pass small amounts of sticky, dark-red material that consists of blood from the sloughed mucosal surface of the intussusceptum ("raspberry jam"), mixed with mucus from the distal part of the gastrointestinal tract. Rectal examination in cows with intestinal disorders reveals multiple loops of small intestine that feel like bicycle inner tubes and range from 4 to 8 cm in diameter without any distention of the cecum. It has been reported that only 50% of cows with intussusception had distended loops of small intestine palpable per rectum and in only half of those could a firm mass, presumed to be the intussusception, be palpated. Ultrasonographic examination in some cases can reveal a bull's-eye sign (loop within a loop) consistent with an intussusception and distention of the small intestine with poor motility. Thick intestinal walls can be seen in cows with primary surgical lesions of the small intestine. The author has seen variable echogenicity structures, like thrombi, within the intestinal lumen of cows with jejunal hemorrhage syndrome.

Physometra

Endometritis that results in fluid and gas accumulation in the uterus (physometra), in particular the right horn, can cause a small tympanic resonance in the lower right paralumbar fossa. This is a very uncommon cause of right-sided ping in a cow. Abdominal distention is not present, and a fluid wave is difficult to elicit with succussion. Rectal and vaginal examinations will confirm the diagnosis.

Ventral Sac of Rumen

Gas in the distended ventral sac of the rumen to the point at which it causes a right-sided ping occurs infrequently. It can be confusing when present and can cause a clinician to do a right-sided exploratory laparotomy when it is not indicated. The general appearance of the cow should be that of a distended rumen—papple shaped. The ping may be fairly consistent to indiscrete and rests in the midabdomen in the right paralumbar fossa. A rectal examination will reveal a markedly enlarged ventral sac of the rumen, which is taut and gas distended.

EXAMINATION OF THE CALF

Thomas J. Divers

A complete clinical examination of the calf before surgery is important for several reasons. Foremost is to establish a correct diagnosis of the primary disorder and then that surgery is the best option for treatment. The clinical examination is also important to determine whether there are additional problems that would negate surgery, delay the procedure, or complicate the prognosis with surgery.

In most cases, a concise signalment and complaint should be obtained before or simultaneous with the clinical examination. Although the organ system involved in the disease may be obvious from the signalment, complaint, or clinical signs, a complete examination should be performed before surgery in virtually all cases.

In the initial stages of the examination, while signalment and history are being obtained, the calf should be observed from a distance to detect any obvious abnormalities in behavior, locomotion, breathing pattern, or noise (Figure 1-11). In addition, signs of colic, the presence or absence of manure in the stall and its appearance, appetite, cud chewing, and eructation can be noticed. As the rectal temperature is taken the perineal area should be observed for evidence of diarrhea. The mucous membranes of the mouth and eyes should be examined for color, vascular injection, ulcerations, or hemorrhage (large areas of scleral ecchymotic hemorrhages are not uncommon in healthy newborn calves). If the hemorrhages in the mouth and sclera are petechial, this is abnormal and suggests sepsis or thrombocytopenia (Figure 1-12). Vessels easily seen in the sclera bilaterally with no obvious evidence of ocular pain can suggest a septic condition with increased inflammatory cytokines and resulting vasodilatation. The membranes of the mouth should be blanched by finger pressure and then the speed of return to original color determined (capillary refill time) as an estimate of perfusion pressure (dehydration, vasomotor dilatation or cardiac output abnormalities may alter the capillary refill time). Palpation of the skin temperature of the distal limbs and ears may also provide some assessment of

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Figure 1-11 One-month-old calf with papular stomatitis lesions on the nose.

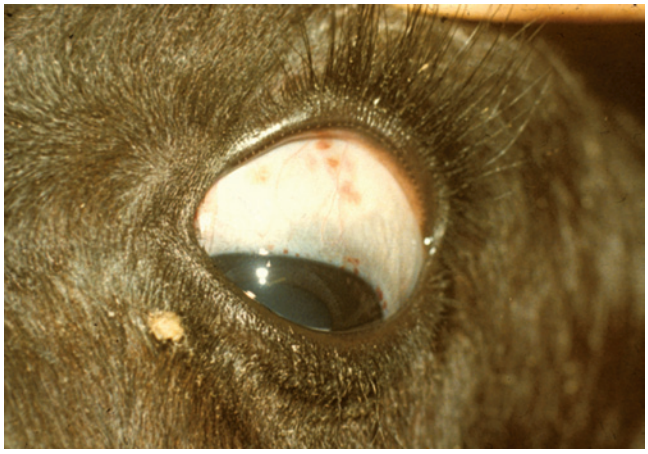


Figure 1-12 Two-month-old calf with petechial hemorrhages on the sclera.

peripheral perfusion, with cool or cold limbs and ears suggesting poor perfusion. Dehydration, which may differ from perfusion pressure, can be estimated by pinching the skin of the neck or eyelids, occluding the jugular vein near the thoracic inlet and looking for speed of jugular distention, and examining the mucus of the mouth for viscosity, the nose for wetness, and the position of the eyes in the orbit. All of these should be quickly performed because none of them has a high sensitivity and specificity for dehydration (sunken eyes may occur from severe weight loss alone, and skin turgor is an inconsistent indicator of dehydration in calves). Next, the heart should be auscultated to determine heart rate, rhythm, and presence or absence of murmurs. A general examination of the skin and hair may detect a variety of primary skin disorders, such as ringworm, frostbite, photosensitization, and others. The clinical examination of organ systems may then proceed directly to the body system believed to be causing the clinical signs, e.g., the intestinal tract, musculoskeletal system, and so on, to start the process of planning for surgery or determining whether surgery is the best option. After examining the organ system believed to be causing the most obvious clinical signs, all other body systems should be examined whenever possible.

Examination of the intestinal tract of calves is somewhat age dependent, according to whether the calf is already a ruminant. For young calves that have not developed a functional rumen, acute severe abdominal distention is generally a result of abomasal distention, e.g., abomasitis or peritonitis with or without pneumoperitoneum (e.g., perforated abomasal ulcers). With both increasing age and a functional rumen, severe abdominal distention is more likely to be due to ruminal distention. The abdomen of all calves, regardless of age, should be auscultated for pings via simultaneous auscultation and percussion techniques and for a sloshing sound upon simultaneous ballottement and auscultation. Pings in preruminant calves are most commonly caused by abomasitis, whereas in ruminant calves the ping may occur from rumenitis, peritonitis, abomasitis, cecal distention, or displacement of the abomasum. The ping in ruminant calves with LDA is often heard in a more caudal location on the abdominal wall than in adult cows. Upon simultaneous auscultation and ballottement, fluid distention of a viscus generally causes a different sound than the sloshing heard with acute peritonitis or ascites. The abomasum distended with both fluid and gas, such as occurs with abomasitis, results in both a ping and a slosh similar to the sound of fluid in an inner tube. If the abdominal distention is due to fluid accumulation in the small intestine from an extraluminal or intraluminal obstruction, colic is often present, a ping would likely be absent, and the slosh on abdominal ballottement would be more like that heard with movement of a group of water balloons. If obstruction of the small intestine is believed to be the cause of the abdominal distention, a digital rectal examination should be performed to check for patency of the anus and distal rectum and to determine if any manure is present. These examination procedures, along with signalment, are important in diagnosing atresia coli and other intestinal obstructive disorders. In older calves, intraluminal obstructions may occur from a number of extraluminal or intraluminal causes. Trichobezoars may be one cause of intraluminal obstruction and examination of the skin and hair of the calf for lice and evidence of excessive licking, which often predisposes to trichobezoars, should be performed. Another example of history and clinical examination used simultaneously to make a diagnosis occurs when a calf with diarrhea suddenly stops passing manure and has clinical and examination findings compatible with distal bowel obstruction of the small intestine; in these cases an intussusception of the spiral colon or small intestine should be considered. When an abdominal surgical disorder is being considered, the examination should ideally be complimented with an ultrasound examination plus electrolyte and lactate (serum and peritoneal fluid) measurements if possible. In calves with a functional rumen, the rumen area of the left abdomen should be examined for distention, ping, slosh, and rumen contractions. Predominantly left-side abdominal distention in calves is most commonly due to ruminal distention. In many cases of rumen distention, there may be an absence of a high-pitched ping or sloshing sound when the abdomen is balloted and the rumen will either be amotile or have weak movements based on palpation and auscultation. If the rumen is believed to be the cause of the abdominal distention, an ororuminal tube should be passed to help determine whether the distention is due to gas (gas bloat) or fluid (most commonly a result of ruminal drinkers, rumenitis, or secondary to peritonitis). Recurrent free-gas bloat that is easily and almost completely removed via the tube is generally best treated by surgically creating a temporary rumen fistula. Before this procedure is performed, examination (auscultation/percussion and ultrasound examination if possible) of the chest cavity for evidence of pneumonia or pleuritis and of the abdomen for peritonitis (absent intestinal sounds, pain on palpation) should be performed; if either is present then performing the rumen fistula may not resolve

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the bloat. Likewise, injury to the pharynx and esophagus should be ruled out as a cause of the free-gas bloat. Calves that are ruminal drinkers and that develop ruminal bloat very soon after drinking milk often have a fluid reflux when the ororuminal tube is passed. The fluid may be gray in color and is sometimes fetid. When ruminal drinking calves are fed milk, the milk can be heard going into the rumen upon auscultation. Ruminal drinking and bloat is not a surgical disease unless there is concurrent abomasitis. Whenever an ororuminal tube is passed in calves it is very important to use a correctly sized speculum so that pharyngeal trauma, including laceration of the soft palate (often fatal), does not occur!

The umbilicus should be palpated to determine whether there is an abdominal hernia and if the umbilical remnants seem normal; in growing calves, abnormal umbilical remnants can be a cause for extraluminal intestinal obstruction resulting from adhesions or entrapment of the bowel by the remnants. Umbilical structures are best palpated in the standing calf to determine whether a hernia is present and if intestinal loops are in the hernia and then by placing the calf in lateral recumbency to perform deep palpation of the abdomen and the umbilical vein coursing rostral toward the liver. In the normal calf, the umbilical arteries and urachus cannot be manually palpated or identified on ultrasound examination of the umbilical stump. If they can be palpated or observed on ultrasound examination at the stump or before the bladder, then they are likely abnormal. Examination of the urinary tract is best performed by observing the calf urinate while observing for signs of dysuria, patent urachus, or discolored urine and by collecting a urine sample for a urine dipstick examination. Calves can be stimulated to urinate simply by gently massaging the perineal area, just as one would do in adult cattle for urine collection. The kidneys, umbilical stump, and sometimes the urinary bladder can be felt by deep abdominal palpation in young calves.

Examination of the chest cavity is important before any surgical procedure. Heart rate and presence or absence of a murmur should be determined. Findings that may preclude continuing to surgery include heart rates of >140 beats per minute with a systolic murmur on both sides of the chest (often loudest on the right), which would suggest a ventricular septal defect (VSD). If the calf is a very young calf with a VSD, respiratory distress may also be noted. The defect can be confirmed in many cases by performing cardiac ultrasound while simultaneously injecting 10 mL of saline quickly into the jugular vein (a "bubble gram"), and looking for air bubbles traveling from the right to the left ventricle). Heart rate may also be abnormally increased with hypovolemia/hypotension, anemia, or pain. If hypovolemia or anemia is the cause of the elevated heart rate, these problems may need to be corrected before surgery. The lungs should be carefully auscultated to determine whether there might be significant pulmonary disease that could necessitate postponement of an elective surgery or lower the prognosis for an emergency surgery. The accuracy of auscultation to diagnose pneumonia has recently been shown to be poor, and ultrasound examination (linear probes can be used) is recommended whenever possible. I believe that if the pneumonia is severe, especially anterioventral consolidating pneumonia, most cases can be detected on auscultation. The characteristic "sucking soup through a straw" sound, which likely occurs from the sound of air moving elsewhere in the respiratory tract, and the referred sound into the open airways of the consolidated lung, can be heard in most calves with consolidating pneumonia. Crackles and wheezes are not particularly common in calves with consolidating pneumonia. For older calves, the diagnosis of pneumonia is best made by historical information (coughing after rising or, if not weaned, slow consumption of milk with some coughing), presence of nasal or ocular discharge and by backing the calf in a corner, holding the nostrils and mouth closed until the calf struggles, and then auscultating the lungs while the calf takes a deep breath (Figure 1-13). If a calf is in respiratory distress and there is no evidence of consolidating pneumonia, a cardiac defect, upper-airway obstruction, or diffuse interstitial lung disease (prematurity, meconium aspiration in young calves, or bovine respiratory syncytial virus [BRSV]) should be considered. Upper-airway obstructions should be ruled out by the absence of loud noise on breathing and normal airflow from both nostrils regardless of head or neck position. BRSV may cause a pneumomediastinum with air then moving subcutaneously (crepitus feel to the skin) or may rupture into the thorax, causing pneumothorax and absent or diminished lung sounds.



Figure 1-13 Holding off the air of a calf for a short time to elicit deep breaths.

An examination of the nervous system and eyes should always be part of the complete examination. Common problems of the nervous system that should be ruled out before recommending or performing surgery include otitis media-interna (Figure 1-14) (most common in calves 1-3 months of age), peripheral nerve injury (femoral paresis from calving or sciatic nerve injury from previous injections) (Figure 1-15), spinal cord ataxia (e.g., vertebral body abscess), or any cause of encephalitis/encephalopathy. The latter should be considered if the calf has seizure-like behavior, cortical blindness (no menace reflex but normal pupil response to light), or pronounced dullness and depression. Metabolic abnormalities such as severe acidosis may also cause marked dullness. It should be noted that the menace response in normal young calves may be slow or absent but gently smacking the eyelids with your hand often stimulates a quick development of this reflex. The eyes should be examined for the presence of corneal edema, corneal ulceration, abnormal pupil size, and opacity or discoloration within the globe; if abnormalities are found they would likely need treatment and in rare cases may affect prognosis of the surgical patient.

Examination of the musculoskeletal system is performed by observing the gait of the calf and by palpation of all four limbs, the back, and the neck. Calves with septic joints are

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many times not as obviously lame as one might expect and this is especially true if multiple limbs are involved (e.g., both carpi). Calves with septic joints often have difficulty in rising, which can be more dramatic than the gait abnormality. Palpation of each joint is important if septic arthritis is suspected and young calves may have severely septic joints with minimal effusion. Many times there is a "fibrin-like feel" to palpation of the infected joint. In older calves (usually older than 1 month), *Mycoplasma bovis* arthritis may cause a dramatic effusion and lameness that is sometimes accompanied by severe pneumonia and pleuritis. Palpation of the limbs, spine, and ribs for fractures should be performed. Likewise, palpation of the muscles (most often semimembranosus/tendinosis and cervical muscles) for evidence of injection-related abnormalities should be routine; the same should be performed on the jugular veins when intravenous (IV) injections have been previously administered. Congenital defects should be ruled out in all young calves by examining the spine, tail, head, mouth, heart, and eyes.



Figure 1-14 Young calf suffering from otitis media-interna.



Figure 1-15 Young calf with bilateral femoral paralysis following calving.

EXAMINATION OF THE SMALL RUMINANT

Mary C. Smith

The examination of the bovine surgical patient is described elsewhere in this text, but sheep and goats are not small cows. They are prone to different diseases and often show few signs of illness to strangers, including the examining veterinarian, until critically affected. Except for dairy animals and pets, few small ruminants are closely examined by their caretakers on a daily basis. The history supplied regarding duration of illness and diminished appetite may be incomplete or inaccurate. Also, the perceived monetary value of the sheep or goat is often less than that of a cow, and potential surgical patients need to be carefully screened for problems that would indicate a poor prognosis or warrant removal from the breeding population.

Because soremouth (contagious ecthyma, orf), caused by a parapox virus, is both common on the lips and skin and zoonotic, disposable gloves are recommended when handling sheep and goats. The initial examination should concentrate on detection of conditions that require medical rather than or in addition to surgical treatment. Some of the most important will be outlined here.

Color of the Conjunctiva and Sclera

The very first part of the examination is usually the observation of the conjunctiva of the ventral eyelid for paleness, quantified as a FAMACHA score. The color of the conjunctiva is a more accurate indication of the PCV than that of the oral mucous membranes. Light pressure through the upper lid encourages the animal to retract the globe while the lower lid is everted and compared with color blocks on a small card (Figure 1-16). This card is available through the University of Georgia using the following email address: famacha@uga.edu. The redness intensifies with exposure to air, so if a score cannot be assigned quickly or if ocular disease is present, the other eye should also be examined. The scale is 1 to 5, where 5 is fatal and very white. Small ruminants in many management systems that involve grazing are subject to severe hemonchosis from the presence of



Figure 1-16 Determining the FAMACHA score to evaluate a small ruminant patient for anemia.

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bloodsucking worms in the abomasum. A PCV of 5% to 10% is not uncommon in an animal that is walking and outwardly fairly normal, including being in good body condition. Because red cells of goats and sheep are small, the blood (obtained from the jugular vein) should be spun for 10 minutes to determine an accurate PCV. Any rough handling of the severely anemic animal could result in almost instantaneous death. Deworming, usually with drugs of two different classes, and a blood transfusion from a donor of the same species that is not anemic should be performed before surgery is contemplated on the animal with a PCV less than 12.

The color of the sclera should be noted, as icterus is usually prominent in copper toxicity, and the hemoglobinuric nephrosis that occurs with this condition can cause signs of colic. Some animals with copper poisoning will have methemoglobinemia, which imparts a muddy brown color to the conjunctiva and sclera. Dark urine with hemoglobinuria will support this diagnosis, more common in sheep than in goats.

Body-Condition Scoring

The next aspect of the physical examination is evaluation of body condition. Again the scale is 1 to 5, but for this scale 5 is fat. Sheep and goats are examined by palpating the loin area, behind the ribs, to determine how much muscle and fat covers the vertebrae. In addition to palpation of the loin, goats are also palpated between the front legs to evaluate fat deposits there. Dairy and fiber breeds of goats store less fat subcutaneously than do sheep. Animals with a score of 3 have tissue filling in the angle between the dorsal spinous processes and the transfer processes of the lumbar vertebrae, to create a straight line. A concavity is palpated in an animal with a score of 2, whereas a 1 is assigned if almost nothing except bone can be felt under the skin. Experienced examiners will quibble over quarter points, but an animal with a score of 2 or less has a chronic problem that needs to be addressed (parasites, malnutrition, bad teeth) or an underlying disease with a poor prognosis, such as a retroviral infection (ovine progressive pneumonia [OPP] or caprine arthritis encephalitis [CAE]), internal caseous lymphadenitis (CLA), paratuberculosis (Johne's disease; these animals usually do not show diarrhea), other chronic bacterial infection, or cancer. Ideally the animal should be compared with herdmates, and if the potential surgical patient is much thinner than the norm (Figure 1-17), an effort should be made to determine why. Note that if an exploratory laparotomy is performed, the presence of much omental fat does not equate with good body condition, as the animal that still has fat may be externally emaciated after using up all its muscle mass.



Figure 1-17 An animal with much poorer body condition than the rest of the herd has a chronic problem that needs to be addressed; culling may be indicated.

Further Examination of the Eyes

Vision should be evaluated because amaurosis (blindness with no lesion evident in the eye) is commonly present with polioencephalomalacia (cerebrocortical necrosis), a condition that can be contributing to clinical illness in a late pregnant animal or one that has experienced a grain overload. If the animal does not blink when menaced, it should be checked to be sure it can close the lids; a facial nerve deficit from listeriosis, otitis media, or trauma might be present instead. Normal lambs and kids under 3 weeks of age usually lack a menace response. Sheep and goats with decreased or absent vision or with a history of indigestion or grain overload or that "just don't seem right" should receive thiamin (vitamin B_1) at 10 mg/kg three times a day for several days.

Keratoconjunctivitis is common in small ruminants, with mycoplasma and chlamydia both incriminated as primary etiologic agents. Affected animals will show lachrymation and inflamed conjunctiva. Many will progress to a keratitis with neovascularization and ulcer or even descemetocele formation. Response to antibiotics such as oxytetracycline is usually good, but relapse is common after the antibiotics are stopped, and treatment of mild cases may actually delay the acquisition of immunity. Severe keratitis and even melting ulcers will often respond dramatically to topical 5% silver nitrate, such that surgery to preserve the cornea is rarely needed. If a young lamb or kid shows keratitis or blepharospasm it is very important to check the lid margins and correct an entropion if present.

Teeth

The incisor teeth, four pairs present on the lower jaw only, can be examined by simply opening the lips to estimate the age of the animal. The permanent incisors erupt at (very) approximately 1, 2, 3, and 4 years of age, beginning with the central pair. They may be absent in older animals, referred to as gummers, which will consequently have difficulty grazing enough, though hay and grain are consumed normally. The molar teeth are almost impossible to visualize in the unsedated animal. The rami of the mandibles should be palpated for any boney thickening or discharging tract that indicates a tooth root abscess. Also, feeling through the thin cheek muscle will give access to the upper arcade of molars. If these teeth are all present and level, the lower arcade will probably also be normal. If the upper arcade is markedly convex, it is likely that the middle premolars and molars on the lower jaw will be near the gum line or missing. If an upper molar is missing, the opposing lower tooth may be overgrown, interfering with mastication. Small ruminant molars should be sharp, with points, so avoid fingers in the mouth.

If a tooth problem is suggested by the physical examination or by difficulty chewing or cuds collecting in the cheeks, the animal can be sedated with 2 to 3 mg of xylazine (total dose) per 50 kg IV to allow approximately 10 minutes of unhindered examination and even floating with a flat file if indicated. Molar teeth are normally sharp and rarely require floating. The animal with difficulties chewing because of molar-tooth problems can be maintained on a diet of pelleted hay. Goats but not sheep (because of their susceptibility to copper poisoning) can be fed senior horse pellets.

Lymph Node Examination

External lymph nodes should be palpated systematically to detect enlargement or abscessation. The cause is frequently

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Corynebacterium pseudotuberculosis, and the disease is known as caseous lymphadenitis. Owners refer to this condition as CL or CLA. Goats most frequently have involvement of the parotid, mandibular, or superficial cervical nodes because of their propensity for skin abrasions from fighting, whereas abscessed lymph nodes in sheep are more commonly those that drain shearing wounds, such as superficial cervical, subiliac, and popliteal nodes. Either species may have enlargement of the retropharyngeal node, which can interfere with breathing and require marsupialization if removal of the entire node is impossible because of proximity to vital structures. If an abscess is lanced or ruptures on its own, the animal should be isolated until the skin has completely healed, to avoid transmission to others in the herd. Surgical removal of the infected node, when practical, avoids the need for quarantine. Systemic antibiotics will not resolve these abscesses but are often used after lancing to reduce the risk of spread via the lymphatics to another node. Tulathromycin at the cattle dosage is currently popular for this purpose but its use is off label and efficacy has not been documented.

Animals with only external abscesses are typically in good body condition and producing well, but involvement of internal organs such as lung, liver, or kidney is associated with a poor prognosis. Abdominal and thoracic ultrasound examination will aid in diagnosing these animals. Most animals with internal CLA will have positive serology using the synergistic hemolysis inhibition test, but a positive test can also occur with current or previous external abscesses or vaccination. Lymphosarcoma is not rare in small ruminants and must be considered as a differential for lymph node enlargement.

Lameness

The lame small ruminant warrants a careful orthopedic examination, but special attention should be paid to the interdigital space for a moist dermatitis (foot scald or early foot rot) and to the heels for evidence of underrunning of the sole caused by a synergistic infection with *Dichelobacter nodosus* and *Fusobacterium necrophorum*. Foot rot is a malodorous infectious condition that tends to be restricted to the interdigital space of goats but to progress to underrunning in sheep. Either animal is apt to graze on its carpi (Figure 1-18). Also common but not contagious is an abscess that will cause swelling and pain at the coronary band of one toe. Laminitis commonly occurs after abrupt dietary changes involving increased consumption of concentrate or lush forage and may lead to wall separation on all eight toes. Chronically laminitic feet are often misshapen, with long curved toes or very thick soles with poor delineation from the wall. Sheep, but not goats, have interdigital glands that normally appear as porelike openings between the toes but can become distended with secretion.

Goats with caprine arthritis-encephalitis CAE virus infection and occasionally sheep with OPP may present with swelling, pain, and eventually mineralization in one or more joints, especially carpi, and these animals may graze on their knees or be reluctant to rise. Tendon contracture occurs rapidly in small ruminants that do not get up every day and will contribute to the lameness. Some goats with advanced stages of the arthritic form of CAE will have enlargement of the atlanto-occipital bursa or abscesses over the sternum that may involve underlying bones. Because of the viral etiology, the prognosis for resolving these problems with surgery is poor.

Three other causes of lameness in small ruminants deserve specific mention. One is the apparent lameness in a hind limb of a ewe or doe with a painful mastitis on that side. In some parts of the United States, infection of small ruminants with migrating larvae of the meningeal worm of the whitetail deer, *Parelaphostrongylus tenuis*, may initially present as lameness before other neurologic signs resulting from damage to the spinal cord are noted. And finally, severe degenerative arthritis of one or both elbows can occur in the absence of fluid distention of the joint and often with no signs of pain on manipulation. Decreased flexion of the elbow joint can be ascertained and the presence of enthesophytes confirmed by radiography. As an aside, sheep are notorious for not demonstrating pain when in the presence of a predator/veterinarian, whereas goats may scream before anything is done to hurt them.



Figure 1-18 An animal resting or grazing on its carpi should be examined carefully for foot rot, foot abscess, laminitis, or retrovirus-induced arthritis.

Respiratory Examination

Dyspnea in small ruminants may have many causes, but few of these are considered to be surgical. Stertorous breathing can result from nasal bots, nasal adenocarcinoma (often caused by a retrovirus and not amenable to surgery), or enlargement of the retropharyngeal lymph node in the animal with CLA. This node often cannot be surgically removed safely but can be marsupialized to the skin to provide drainage. Labored breathing is a frequent sign of pneumonia and must be distinguished from the rapid but even respiration of a panting animal in a warm environment. Radiographs or ultrasound may help to determine the location and extent of pneumonia. Cranioventral pneumonia is usually most severe on the right side because of the presence of a separate bronchus to the right apical lung lobe. It may result from a bacterial infection such as *Mannheimia haemolytica*, sometimes complicated with *Mycoplasma ovipneumoniae*, but also commonly follows inhalation of dewormers or other oral medications or of rumen fluid regurgitated under anesthesia or after toxicity from grayanotoxins found in plants of the rhododendron and mountain laurel family. In the young lamb or kid with cranioventral pneumonia, white muscle disease that might hinder proper swallowing or the presence of a cleft palate should be considered.

If pneumonic lesions are concentrated in the diaphragmatic lobes or spread throughout the lungs in an interstitial pattern, lungworms, caseous lymphadenitis, retroviral

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pneumonias, and cancer should all be on the list of differential diagnoses. Rupture of a lung abscess into the pleural space may lead to unilateral pyothorax. Other than the lungworms, these conditions are not considered to be treatable and thus would usually disqualify an animal from surgery for another problem. One condition identifiable on examination of the thorax that might be addressed by surgery would be a space-occupying thymoma, a relatively common tumor located in front of the heart of older small ruminants.

Examination of the Abdomen

The animal's abdomen should be evaluated for shape and the presence of distention. Obese animals will have much fat in their omentum and may appear late pregnant to the owner. Pregnancy is best determined by ultrasonography, although radiographs can be helpful after 90 days. The ultrasound probe is placed in the right inguinal area. This area is fiberless in sheep, but examination may be easier in the goat if the hair is removed from just above the udder. Placentomes, a definitive sign of pregnancy, appear as cups or donuts, depending on their orientation relative to the ultrasound beam. Because pregnancy toxemia is common in small ruminants, testing the blood for beta-hydroxybutyrate or the urine for ketone bodies (less precise) should be a routine part of the physical examination of a depressed or anorectic animal late pregnant with multiple fetuses.

In goats, hydrometra is relatively common, even if the animal has never been bred. The uterus may be distended with clear or flocculent fluid, often appearing to be in multiple compartments, but fetus and placentomes are absent. This is not a surgical condition, as the uterus will empty within 48 hours after administration of prostaglandin (10 mg of prostaglandin F2α or 250 mcg of cloprostenol).

Ballottement of the abdomen should be performed, especially if an ultrasound machine is not available. It is often possible to detect fetuses after 3 months of gestation in the relaxed animal. If the sheep or goat has just given birth, a retained fetus can be detected by straddling the animal, facing its tail, and linking fingers together beneath its abdomen (Figure 1-19). A sharp upward pull will encounter the fetus (which feels like a frozen chicken), whereas the abdomen of the animal that has completed parturition will feel like a load of wet laundry.

In the male, ballottement may suggest the presence of a fluid wave and the need to evaluate for a ruptured bladder. A splashing sound produced by succussing the left side of the abdomen is suggestive of a toxic indigestion, as from grain overload, though the animal that has not eaten for several days but has continued to drink may also develop a splashy rumen. Rumen fluid can be aspirated through the abdominal wall using an 18-gauge, $1\frac{1}{2}$-inch needle. The pH will be less than 5, and protozoa will be dead if rumen acidosis has occurred recently. A Gram stain of the fluid obtained will demonstrate many gram-positive cocci and rods, whereas the healthy rumen has a diverse population of both gram-negative and gram-positive organisms and protozoa. It is also possible to obtain rumen fluid with an orogastric tube (passed through a speculum) or a nasogastric tube such as a stallion catheter. The Gram stain of the fluid thus obtained will be valid, but the pH is often elevated by contamination with saliva.

Examination of the abdomen for conditions other than pregnancy and false pregnancy is also greatly aided by the use of ultrasonography. A 3.5- or 5-MHz sector scanner is ideal. The ultrasound beam does not penetrate the rumen well, but the right kidney (and sometimes the left) and the liver can be visualized from the right side if fiber is clipped or copious 70% isopropyl alcohol is applied. The liver can be imaged caudal to the costal arch, on a line between the point of the right elbow and the wing of the ilium. The gallbladder is typically distended in anorectic animals. The abomasum may be greatly distended in sheep with abomasal emptying defect or in goats with a foreign body (often plastic or cloth) obstructing the stomach. Note that small ruminants almost never develop a displaced abomasum as seen in cattle.



Figure 1-19 Ballottement of the abdomen to detect a retained fetus immediately after parturition.

Motility and distention of the small intestine can be evaluated. An intussusception will lead to fluid accumulation proximal to the obstruction. The affected animal can live for many days, but its abdomen does not become gaunt even though it is not eating. Bloody mucus may be present in the rectum of an animal with intussusception, whereas an unobstructed animal that is eating poorly will have smaller than normal fecal pellets. Enlarged intestinal lymph nodes can be recognized by ultrasonography in small ruminants with paratuberculosis. If much free fluid is present in the abdomen but the urinary bladder is not distended, intestinal adenocarcinoma and cardiac failure (from endocarditis) are possible causes. Migrating immature liver flukes can also cause increased fluid and fibrin tags in the peritoneal cavity.

Evaluation of the Urinary Tract

Any male or castrated male (wether) sheep or goat that is off feed or depressed, straining, or acting constipated should be presumed to have a urinary obstruction until observed to urinate freely. It may be possible to feel pulsation of the urethra at the brim of the pelvis in the obstructed animal. Ultrasonography will demonstrate bladder distention and often free fluid in the abdomen subsequent to bladder leakage, both common sequelae of urethral obstruction. Hydronephrosis may be visible. It is also important to examine the urethral process at the end of the penis for the presence of a stone or sand. Rams can be set vertically, on their rumps, to aid in the extrusion of the penis (Figure 1-20), but goats object to being in this position and may need

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Figure 1-20 Positioning the animal on its rump with the body slightly forward of vertical will aid in extrusion of the penis.

to be tranquilized with diazepam (perhaps 0.1-0.2 mg/kg IV). If the animal is obese, and especially if it was castrated before puberty, it will be very difficult or even impossible to extrude the penis. A blood sample should be obtained for creatinine determination and then the animal released. The sheep or goat that has been stressed by the attempted examination and blood collection will often urinate when released if the urethra is patent. Serum urea nitrogen will not rise as rapidly as creatinine, as excess urea can be excreted via saliva and passed to the rumen where microbial action will metabolize it for some hours after obstruction.

Examination of the Udder and Scrotum

An acute mastitis, often due to *Staphylococcus aureus*, can rapidly kill a sheep or goat but may present as unilateral hind-limb lameness. One side of the udder may be swollen and firm or cold and blue with gangrene. Chronic mastitis, typically presenting as abscesses in the parenchyma of the udder, usually warrants culling in a commercial flock. Thus the presence of udder abscesses may limit the allowable expense of veterinary treatment to something less than the meat value of the animal. For a pet, udder amputation would be a reasonable treatment for udder abscesses, as it is for massive enlargement of the udder of a goat that has never been bred (inappropriate lactation syndrome).

At parturition, the teats of the dam should always be checked for patency and milk availability. Previous bacterial mastitis, interstitial retrovirus mastitis (caprine arthritis-encephalitis or OPP) or scar tissue induced at the base of the teat by excessive nursing efforts by hungry offspring during the previous lactation will result in starvation or failure of passive protection in the neonate.

Although a CMT can be easily performed to check for elevated somatic cell count in the milk of small ruminants, it must be remembered that recent parturition, late lactation, or a systemic illness limiting milk production can markedly elevate the somatic cell count. The milk from a healthy goat udder can easily give a +1 on a CMT without mastitis, and a marked difference between the CMT results from the two udder halves is more meaningful than a bilaterally increased CMT reaction.

The scrotum of a breeding male should be examined for the presence of two firm, resilient, freely movable testes. Both cryptorchidism (usually unilateral) and herniation of intestines into the scrotum are relatively common hereditary conditions and should result in removal of the male from the breeding population. Trauma and accumulation of free urine in a male with urolithiasis are additional reasons for swelling of the scrotum. An ultrasound examination will facilitate the diagnosis of these problems, including location of a cryptorchid testis. Bacterial (lamb) epididymitis in ram lambs around the time of puberty and enlargement of the tail of the epididymis in mature rams that have contracted ram epididymitis due to *Brucella ovis* can often be detected by palpation and warrant culling. Skin infections or frostbite of the scrotum may lead to temporary infertility. When males are castrated by application of a rubber castration band, a testis occasionally slips out of the scrotum and will be found tight to the abdomen of the wether after the scrotal sac has sloughed.

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EXAMINATION OF THE SURGICAL PATIENT (PIG)

Robert J. Callan

GENERAL CONSIDERATIONS

Pigs present unique challenges when it comes to obtaining a complete physical examination, whether for evaluation of a medical or a surgical condition. In general, both commercial and pet pigs do not quietly accept restraint and excessive handling. This presents a problem because a complete physical examination requires close contact and manipulation of the pig. However, a complete physical examination is a critical tool to evaluate the potential surgical condition and evaluate the patient for additional problems that could complicate a surgical procedure, increase the risk of sedation or anesthesia, or increase the risk of surgical or medical complications.

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Obtaining an accurate and thorough signalment, presenting complaint, and history provides important context to the clinical evaluation. If this is done while present with the patient, the time can also be used to evaluate the environment, the animal's interaction with the surroundings, and the general attitude of the patient. Particular observations to note will be described under the specific organ system here. It is most important to be calm, quiet, and patient when attempting to examine the pig. Working with the pig rather than applying excessive restraint will often result in a more effective and useful physical examination.

Safety, Handling, and Restraint

Minimal restraint with gentle guidance often provides better results than close physical restraint for both pet and commercial pigs. Commercial pigs should be approached quietly and calmly in a nonthreatening manner. Adult commercial pigs, particularly sows with piglets, can become protective and aggressive and bite. Examining an adult pig at feeding time or providing feed during the examination may distract the pig and allow the examination to be performed. Some pigs will allow you to examine them freely in an enclosed pen using the side as a barrier. Gentle scratching at the base of the neck or along the top back line may help keep some pigs calm. Restraint in a pig crate that prevents the pig from turning around can be helpful. Alternatively, pigs can be restrained between a wall and a pig board or a gate and wall (Figure 1-21). Younger pigs can also be restrained by sitting them up. The clinician stands just behind the pig and grasps the front limbs and shoulders and sits the pig up on its rear, similar to sheep. This will allow examination of the head, ears, eyes, and front feet. After this, the pig can be let down on its back and braced between the examiner's legs. Many pigs will struggle less while lying on their back. This will allow further options for examination.

Commercial pigs will often respond well to a snout snare. The snare is applied over the maxilla and behind the incisors (Figure 1-22). Once applied the pig will generally pull back against the snare but allow examination, palpation, and manipulation of the body. Vocalization during restraint may make auscultation of the thorax and abdomen impractical. Young commercial pigs are often caught by grabbing a front or hind leg. Small pigs, once caught, can be restrained by suspending from both hind legs while cradling the pig between the restrainer's legs, or firmly supporting it laterally against the restrainer's trunk. Holding pigs by their trunks is rarely effective for commercial pigs and often results in considerable vocalization. Placing in a smaller crate or suspending in a sling may work better for young pigs.

In general, pet pigs are more easily restrained and handled for a physical examination than commercial pigs. Most procedures of a general physical examination, including the collection of vital signs, thoracic and abdominal auscultation, general palpation, and even ultrasound examination can be done with minimal restraint for pet pigs. Depending on the pet pig, this might be best done in an open-topped travel crate or box, on an examination table, free on the ground with treats, backed into a corner, or with someone holding the pig (Figure 1-23). Some pet pigs respond well to being wrapped in a towel or blanket; however, many times they may also vocalize more with this restraint. Covering the eyes with one's hand while firmly supporting the pig's body against the restrainer will soothe many small commercial or pet pigs. Some pigs may restrain well by kneeling and placing them between the examiner's legs and either holding up their noses or even sitting them up on their hindquarters like sheep. Gentle scratching with your fingers or a table fork on the back, rump, or belly may calm a pet pig, making the examination easier. Suspending the pig in a sling with holes cut for the legs can also work well. It may be necessary to try several different approaches to find the one that works best for what you are trying to accomplish.

Some methods typically used for restraint in commercial pigs would not be acceptable to owners of pet animals and can result in injury. Pet pigs should not be caught and restrained by grabbing their legs. There is increased risk of limb, pelvic, or back trauma with these methods. Also, pig snout snares are generally not accepted by pet pig owners. However, a pig board or gate can sometimes be helpful and well accepted for a larger pet pig.



Figure 1-22 Use of a snout snare for restraint to perform procedures.



Figure 1-21 Using a board to restrain a pig in a confined space.



Figure 1-23 Use of a board to manipulate pigs in a confined space.

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Figure 1-24 Mask used for induction of anesthesia in a pig.

Chemical sedation can be extremely helpful in performing a physical examination and other procedures such as blood collection. Refer to Chapter 5 for additional information on drugs that are effective for sedation or anesthesia in pigs. Midazolam (0.2-0.3 mg/kg) and butorphanol (0.2-0.3 mg/kg) given together intramuscularly provide consistent mild sedation for most commercial and pet pigs. Acepromazine (0.03-0.1 mg/kg intramuscularly) can also be used for general mild sedation. The response to xylazine is variable and often requires high dosages.

Masking a pig with inhaled isoflurane works very well for pet potbellied pigs and smaller commercial swine (Figure 1-24). It also has the advantage of a very rapid and smooth recovery. Masking with isoflurane alone or in combination with the sedation protocols mentioned here is suitable for short diagnostic or surgical procedures. Initially, concentrations of 4% to 5% isoflurane should be used until the pig is recumbent and then the concentration is reduced to 2% to 3% for the duration of the procedure. General anesthesia can be induced with sedation followed by masking with isoflurane. In the author's experience, endotracheal intubation is easier when chemical sedation precedes masking with isoflurane and intubation. Endotracheal intubation in swine has been recently reviewed (see recommended reading). Knowledge of the anatomic challenges and utilization of an appropriate size endotracheal tube greatly increases the success of this procedure.

Vital Signs

General vital signs can often be obtained from a pig without excessive restraint or sedation. Respiration rate is best obtained before handling the pig and can be obtained while observing the pig from a short distance. Normal respiration rate in a healthy nonstressed pig ranges from 15 to 50 breaths per minute. Normal rectal temperature ranges from 101.6 to 103.6 °F. Peripheral pulses are difficult to identify in pigs so heart rate is generally determined by thoracic auscultation. Normal resting heart rate ranges from 70 to 120 beats per minute.

Peripheral tissue perfusion can be assessed in multiple ways. Examination of oral mucous membranes is not always possible in nonsedated pigs. Caution should be exercised with any pigs because they may bite. The vulva of female pigs provides a convenient way to assess perfusion at a mucous membrane surface and obtain a capillary refill time. Ocular conjunctiva can also be evaluated. Evaluation of the surface temperature of distal extremities including the ears, feet, and legs can help assess peripheral perfusion and shock. Noting how far the coldness extends up the limb can provide objective criteria to this assessment and help evaluate response to treatment. The sclera should be examined for evidence of injected blood vessels, suggesting systemic sepsis.

There is no established best method for evaluating hydration status in pigs. The clinician should evaluate multiple criteria including mucous membrane moisture, eyeball recession, and skin tent. Skin tent is best evaluated over the thin skin of the ventral abdomen. The skin can be pinched between the thumb and finger, twisted 90 degrees, and then let go to evaluate the number of seconds to return to normal. Normal skin tent in pigs, as in other animals, is less than 2 seconds. Dehydration can be estimated with the following formula:

Estimated % Dehydration = (Skin Tent (seconds) × 2) – 4

General Appearance

Taking some time to evaluate the general appearance of the pig will also help focus a more specific examination. The normal pig should stand and walk with a fairly straight or slight dorsal curve to the back. Excessive hunching or dorsiflexion suggests lameness or skeletal or abdominal pain. Many potbellied pigs normally demonstrate a tightrope gait in the rear limbs that may be confused for weakness or ataxia. If observed, additional evaluation should be performed to rule out possible musculoskeletal, neurologic, or abdominal disease. The ears should be held erect and pointed. The pig should respond to sounds in the area. A normal pig will use its nose to investigate the environment by sniffing. The respiratory pattern should be even and without effort. The abdomen should appear full but not distended, gaunt, or tucked up. A gaunt tucked-up belly may indicate an animal that is not eating. The pig should appear symmetric through all major muscle groups. The body contours should be smooth with no evidence of bumps or masses. The perineum should be clean and not stained from feces or vaginal discharge.

Skin

The skin should be visually inspected as well as palpated for any bumps or irregularities. It should feel warm and, in unpigmented pigs, have a pink color. A yellow discoloration of the ears or unpigmented areas may indicate jaundice. The skin surface should be examined for bite marks, other wounds, and lice. Mites should be considered if the pig is pruritic, and these pigs will often have areas of erythema, thickened and possibly crusty skin. Erysipelas is characterized by raised red diamond-shaped lesions and is a potential zoonotic disease. Ringworm lesions often present as raised tan or brown lesions with hair loss. Many pigs have dry crusty skin. This can be an indication of nutritional deficiencies such as vitamin E or zinc. Dietary supplementation, seborrheic shampoos, topical vitamin A and E, or skin conditioners may improve this in pet pigs. Any light-color pig is susceptible to sunburn. This can result in a wide range of clinical signs including redness of the skin, hypersensitivity, irritability, and even behavior that looks like colic or seizures.

Head, Eyes, Ears, Nose, Mouth, Throat, and Neck

The head should be held in a natural position and is symmetric. The eyes should appear alert without excessive discharge. Pale conjunctiva may be a sign of anemia or shock. A pen light should be used to evaluate the cornea, surrounding ocular structures, and pupillary light reflex. The eye

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should be centered in the orbit with normal ocular movement. Enophthalmos may be seen with emaciation or dehydration. Exophthalmos may indicate retrobulbar abscess or neoplasia. Nystagmus is suggestive of central neurologic disease, such as meningitis, salt toxicity, or trauma. Potbellied pigs, particularly overweight pigs, are prone to entropion, and the eyes should be carefully examined for this condition.

The animal should be checked for any evidence of a drooped ear, discharge, bleeding, or bite marks. A drooped ear may be an indication of ear infection or possible neurologic disease. The nose should be moist, and the pig will interact with the environment by sniffing. Excessive serous discharge, purulent discharge, bleeding, or nasal deviation is abnormal. The mouth should be symmetric and aligned. The animal should not drop food when eating. There should not be excessive drooling. Examination of the oral mucous membranes and oral cavity is often difficult without sedation. When possible, a capillary refill time can be performed and is normally 2 seconds or less. Pale mucous membranes may be a sign of systemic shock or anemia. The mandible and maxilla should be palpated for any signs of irregularities or masses that could indicate tooth-root infections, abscesses, or oral neoplasia.

The intermandibular and retropharyngeal regions are examined for masses that could be abscesses or enlarged lymph nodes. Lymphosarcoma can occur in young as well as old pigs. The larynx and trachea are palpated with an attempt to induce a cough. The neck is evaluated for any asymmetry, masses, or sensitivity.

Cardiovascular

If the patient is calm and approachable, cardiac auscultation can often be performed without sedation. The heart rate is assessed by auscultation, and both the first and second heart sounds should be audible just in front of the point of the elbow. The cardiac rhythm should be a normal sinus rhythm. Auscultate both the left and right sides for abnormal cardiac sounds including cardiac murmurs. Valvular endocarditis in pigs is most commonly found at the right atrioventricular valve and the murmur if present will be loudest at the right-heart base. Congenital cardiac anomalies can also result in cardiac murmurs. Muffled or washing-machine–type sounds suggest possible pericarditis or pleuritis. A peripheral pulse may be palpable in the auricular artery or the femoral artery but is generally difficult to identify in most pigs.

Respiratory

The breathing character with the animal resting should be noted while watching and listening for a cough or sneeze. Thoracic auscultation of breath sounds can be performed in many pigs with limited restraint. Normal pigs may have very quiet breath sounds. Increased loudness of breath sounds ventrally is suggestive of bronchopneumonia. Breath sounds heard dorsally with decreased breath sounds ventrally suggest possible pleural effusion. Crackles or wheezes are always considered abnormal and should be investigated further. An occasional spontaneous cough may be normal, but consistent coughing or sneezing is abnormal. The larynx and trachea should be palpated as well and pinched to attempt to produce an inducible cough.

Some pigs, particularly pet pigs, may allow further auscultation of breath sounds using a rebreathing bag. A plastic bag or rectal sleeve is placed over the nose and mouth and the pig is allowed to breathe normally. As the pig begins to show distress, the bag is removed and breath sounds are auscultated immediately. This procedure induces deep breaths that may accentuate abnormal breath sounds.

Thoracic ultrasound examination has become a much more common procedure for evaluation of lower respiratory disease in farm animals with the wider availability of ultrasound equipment. The techniques and findings of thoracic ultrasound examination described in cattle are applicable to pigs.

Gastrointestinal

The feces should be examined for color and consistency. Normal pig feces are formed and often clumped. Firmly clumped dark feces are often a sign of dehydration. Dark black feces may also indicate melena. Watery feces are typically a sign of infectious enteritis or colitis. If no feces are present, the perineum should be examined for fecal staining. A digital rectal examination can be performed to obtain feces if present. Scant feces, or the lack of feces, may indicate intestinal obstruction. Constipation is a common sequela in ill, anorexic pigs. Congenital atresia ani is observed in pigs, and it is important to confirm patency of the anus in a sick neonate, especially if it has a distended abdomen. Rectal prolapse also occurs in pigs, often secondary to other gastrointestinal or respiratory diseases that cause abdominal straining. Rectal palpation is rarely done in pigs but can be performed in some adult sows and boars for evaluation of abdominal organs.

If tolerated, the abdomen should be palpated for fill, internal masses, and response to abdominal pain. The body wall, umbilicus, and inguinal region should be examined for possible herniation. The abdomen can be auscultated for the presence of borborygmi. If the abdomen is distended, it can be gently balloted during auscultation, listening for the sound of fluid and gas within the stomach or intestine. This may be a sign of obstruction, entrapment, volvulus, or gastroenteritis. Ultrasound is extremely helpful to evaluate the abdominal cavity and will be discussed under ancillary diagnostics.

Mammary

The mammary glands should be symmetrically located on both sides of the ventral midline. Sows should have at least 6 glands per side (range, 3 to 16). The mammary glands should be soft and pliable. Enlarged, red, hot, or painful mammary glands are a sign of mastitis. In lactating sows, milk can be expressed from the teats and examined grossly or submitted for bacterial culture if there is evidence of mastitis. Firm nodular mammary glands may be a sign of neoplasia.

Musculoskeletal

When standing, all four feet of the pig should be placed evenly on the ground, with no evidence of lameness when walking or trotting. Some pigs will allow more detailed palpation and examination of the limb with mild physical restraint. Another alternative is to sit the pig up on its hindquarters or lay it on its back. About 50% of lameness in pigs is in the feet, and the remaining 50% is in the limb itself. All four limbs should be examined for any swelling, erosions, or bleeding. The feet should be examined for any evidence of erosion or damage to the hoof including the sole. Pinching the claw may elicit a pain response indicating abscess, infection, or trauma. The hoof wall is checked for cracks or defects. The coronary band is examined for evidence of inflammation or vesicles that could be caused by irritants or viral vesicular diseases.

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Figure 1-25 Pig weak in the hind end.

All joints should move easily and have no evidence of swelling. Septic arthritis is common in commercial pigs. Osteoarthritis is common in older pet pigs. Fractured legs and joint luxation may also occur. Both of these conditions are generally very painful and often result in a non-weight-bearing lameness. The major muscle groups should also be palpated for signs of swelling, hardness, or pain. Muscle trauma or nutritional myopathy can result in lameness.

Nervous

Nervous system evaluation is similar to that in other species. Abnormal mentation may be a sign of a cerebral central nervous system disorder, such as trauma, salt toxicity, viral encephalitis, or bacterial encephalitis or meningitis. Nystagmus is a common sign observed with cerebellar diseases. A basic cranial nerve examination can also be performed in most pigs without much difficulty. Ambulation should be assessed, noting any signs of weakness, ataxia, or conscious proprioceptive deficits (Figure 1-25). If a peripheral nerve abnormality is suspected, limb reflexes may be attempted in cooperative patients. Withdrawal reflex and pain response should be assessed in any recumbent or paralyzed patient.

Reproductive

In the sow, the vulva should be examined for symmetry, swelling, or abnormal discharge. The vulvar mucous membranes should be pink and have a capillary refill time of 2 seconds or less. Vulvar hematoma or cellulitis can occur following parturition and is noted by swelling. Hemorrhagic, purulent, or necrotic vaginal discharge in a pregnant gilt or sow suggests abortion or dystocia. Following parturition, abnormal discharge may indicate retained placenta, metritis, or retained fetus. Vaginal prolapse can occur in pigs. Uterine prolapse can also occur during or following parturition.

In the boar, the scrotum, testes, and epididymis should be evaluated visually and by palpation. The scrotum and testes should be symmetric, located in the ventral perineum. The testes are firm but not hard or nodular. Asymmetry or softening of the testes may indicate testicular degeneration. The prepuce is palpated for any abnormal masses or swelling. The paired preputial diverticula are located at the distal aspect of the prepuce and form two swellings on either side. The preputial diverticulum normally contains a malodorous fluid that can be manually expressed from the prepuce. However, if this fluid is purulent or hemorrhagic, or if the diverticulum is firm and painful, it may indicate infection or abscessation. In pet pigs, owners may request surgical resection of the preputial diverticulum for esthetic reasons. The penis can be palpated within the prepuce. Hemorrhagic discharge from the prepuce is abnormal and should be investigated further.

Urinary

When indicated, based on the presenting complaint, the patient should be evaluated for normal urination. Evidence of dysuria (pain during urination), stranguria (difficulty in urination), or pollakiuria (abnormally frequent urination) are all signs of possible urinary disease. These signs could indicate possible urinary infection, bladder stones, or urethral obstruction. Collection of urine with urinalysis is recommended if signs of urinary-tract disease are observed. A digital examination can be performed to evaluate muscular contraction and pulsation of the pelvic penis that is supportive of urethral obstruction. Urolithiasis is the most common cause of urethral obstruction in pigs. Further diagnostic evaluation of the urinary tract including the kidneys, ureters, urinary bladder, and urethra by ultrasound or radiography may be indicated.

Hemolymphatic

Peripheral lymph nodes are not generally palpable in the normal pig. Occasionally you can palpate a prescapular or prefemoral lymph node in a normal pig. Thus the presence of palpable lymph nodes is most commonly associated with an abnormal medical condition such as infection or lymphosarcoma. The intermandibular, retropharyngeal, axillary, prescapular, prefemoral, inguinal, and popliteal regions should be assessed for the presence of lymph-node enlargement.

The hemolymphatic system can be further evaluated by a complete blood count (CBC). Blood collection is more challenging in pigs than it is in most other domestic species because peripheral blood vessels suitable for venipuncture are not as easily identified. In commercial pigs, blood can be obtained from the auricular veins. However, these veins collapse easily and may not allow the clinician to acquire a sufficient volume of blood. Blood collection from the ear veins can be accomplished using a rubber band at the base of the ear as a tourniquet and a 22- to 19-gauge butterfly catheter for venipuncture. If all that is needed is a small volume to perform a PCV and total protein, then a needle can be inserted directly into the vein and hematocrit tubes filled directly from the hub of the needle. Small volumes (generally <1 mL) of blood can also be obtained from the base of the tail. The tail veins in pigs lie more superficially than in cattle.

Larger volumes of blood can be collected from the right brachiocephalic vein or the right external jugular vein in the neck. Neither of these veins is superficially apparent in the neck, and a blind stick is generally performed based on anatomic landmarks. The right side is recommended to minimize potential trauma to the phrenic nerve, thoracic duct, vagosympathetic trunk, recurrent laryngeal nerve, or esophagus because they are more vulnerable on the left side. Venipuncture of the brachiocephalic vein or the right jugular vein can be performed with the animal in a sitting or sternal position with the head and neck extended, particularly in larger adult commercial pigs. A snout snare can be used for restraint in commercial pigs. In smaller pigs, including potbellied pigs, the animal may be positioned in a sitting or sternal position, or in left lateral or dorsal recumbency. Additional assistance restraining the pig will be necessary. Alternatively, the pig can be masked down with isoflurane to allow safe collection of an adequate sample.

Brachiocephalic venipuncture is performed at the base of the neck just rostral and lateral to the manubrium in a notch

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formed by the manubrium and the shoulder. A $1\frac{1}{2}$-inch (pigs <100 kg) or 2-inch (pigs >100 kg) 16- to 20-gauge needle is used, depending on the size of the pig. In very small pigs (<10 kg) a 1-inch needle may be long enough. The needle is inserted at this site and steadily directed toward the dorsal border of the left scapula. Negative pressure is maintained on the syringe or the vacuum tube is inserted on the vacuum tube needle. Once blood is obtained, the syringe or tube is filled and the needle withdrawn. If blood is not obtained, the needle is slowly withdrawn through the skin and then reinserted in either a more medial or lateral direction.

Jugular venipuncture is performed in the mid- to distal third of the right jugular furrow. A $1\frac{1}{2}$-inch needle is inserted perpendicular to the skin. If no blood is obtained on first insertion, then the needle is pulled back out to the skin and redirected medially and then laterally until blood is successfully obtained. Ultrasound can be a helpful tool to identify the brachiocephalic and jugular veins when learning to perform this procedure (Figure 1-26).

In pet pigs, venipuncture of the cephalic vein or the lateral saphenous vein can be attempted. These veins are not generally visible due to the thickness of the skin. A blind stick is performed based on knowledge of the normal anatomy. Ultrasound with a standoff probe can help locate these veins and direct the needle for venipuncture.



Figure 1-26 Ultrasound-guided percutaneous catheterization of vasculature.

Ancillary Diagnostics

The CBC, serum chemistry, and urinalysis are the most useful ancillary diagnostic tests used in the evaluation of swine. These procedures are less commonly performed for commercial swine but may be commonly requested by pet pig owners. Normal values are available in some of the references listed at the end of this section. Reference values can also be obtained using the online Merck Veterinary Manual (www.merckvetmanual.com).

Radiography can be helpful in assessing several different organ systems including the thorax, abdomen, and skeletal structures. Ultrasound is also an extremely helpful diagnostic tool that is becoming more commonly used for field and hospital diagnostic evaluation in all food animal species. Specific reviews of diagnostic ultrasound evaluation of swine are not currently available. However, the principles are consistent across species. Several excellent references for diagnostic ultrasound in cattle are listed at the end of this section.

Intravenous Catheterization

Intravenous catheterization in commercial pigs can often be performed in one of the auricular veins. Auricular-vein catheters are suitable for general IV fluid and medication administration. However, in potbellied pigs, these veins are rarely sufficiently visible and accessible for catheterization. The cephalic vein has been used by some clinicians in potbellied pigs; however, success is variable due to the difficulty in identifying the vein and inserting the catheter. Ultrasound-guided percutaneous IV catheterization has also been described (Figure 1-26) (see Recommended Readings).

The lateral saphenous vein, located on the lateral aspect of the rear limb, just proximal to the hock, provides excellent access for a surgically placed catheter (Figure 1-27). With the animal heavily sedated or under general anesthesia, the described area of the hock is clipped and prepared for aseptic access. The lateral saphenous vein runs proximally from the hock in the tissue between the calcaneus and tibia. A 3- to 4-cm incision is made over the lateral saphenous vein (Figure 1-28*A*). The subcutaneous tissues are separated by sharp and blunt dissection until the vein is isolated (Figure 1-28*B*). Once isolated, a catheter can be placed in the vein. The



Figure 1-27 Anatomic figure depicting location of lateral saphenous vein.

author prefers a flexible Mila over the wire catheter for this procedure (Mila International; Erlanger, KY).[2] With this catheter, the insertion needle is placed into the vein and the wire is threaded up the vein (Figure 1-28*C* and *D*). Alternatively, the vein can be held with a thumb forceps and the needle used to make a nick into the vein. The wire is then threaded through the nick into the vein without the guidance of the needle. Once the wire is in place, the catheter can be inserted and sutured in place.

[2]Mila International, Erlanger, KY 41018, USA, *https://www.milainternational.com/*.

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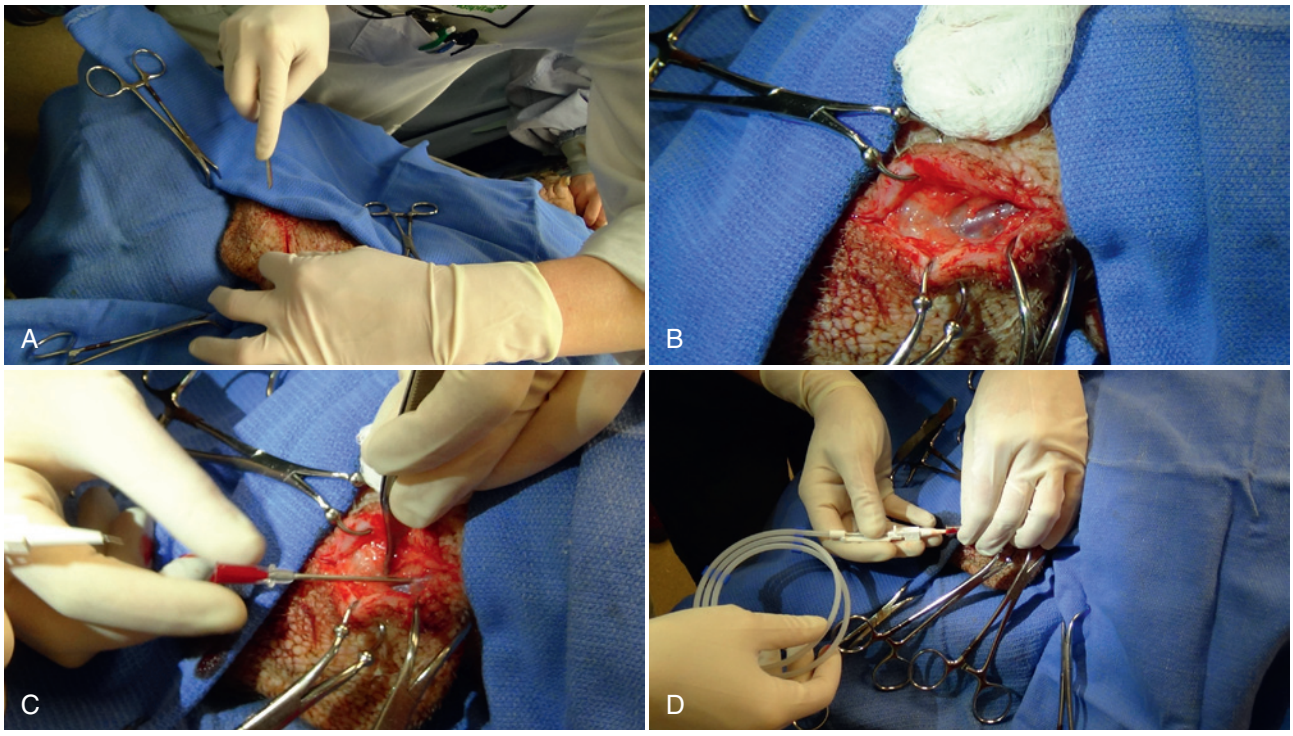


Figure 1-28 *A*, Small incision is made through the skin over the lateral saphenous vein. *B*, The lateral saphenous vein is isolated. C, A Mila stylet catheter is introduced into the lateral saphenous vein. *D*, The catheter is advanced into the lateral saphenous vein through the stylet.

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CHAPTER 2

Diagnostic Imaging

Anthony Pease
(The editors wish to acknowledge and thank prior authors Drs. Stephanie Nykamp and Amy Yeager)

Diagnostic imaging, such as radiographs and ultrasound examination, is an invaluable and underused tool for the farm animal practitioner. Other infrequently used modalities include nuclear medicine, computed tomography (CT), scintigraphy, and magnetic resonance imaging (MRI). Because of the variety of available imaging modalities, the proper imaging study must be selected to maximize the chances of detecting lesions while minimizing time and cost to the client and staying in compliance with respective regulatory offices. This section will provide an outline for general techniques and indications of when to use various imaging modalities in the food animal.

RADIOGRAPHY

Survey radiography, including digital and computed radiography, is considered the mainstay of diagnostic imaging. The various views that can be acquired have been described in detail in other publications (Bargai et al, 1989c; Pharr and Bargai, 1997). A table has been provided to illustrate a general guide—a starting point—for techniques to acquire different radiographic studies in various species using standard radiographic cassettes or computed radiography. Without digital radiography, the nature of ambulatory work does not allow practitioners the luxury of developing the film, evaluating the radiograph, adjusting the technique, and retaking radiographs if the exposure is unsatisfactory. The expansion and availability of digital radiography and even more portable computed radiography equipment are beginning to eliminate this limitation, especially for larger farms or institutions able to afford the technology. All recommendations on exposure assume an average-sized animal and a film-to-tube focal distance of no greater than 40 inches (or as close as possible in regard to thorax and abdomen). If the patient appears thin or obese, decreasing or increasing the kilovolt peak by no less than 15% adjusts the technique. Alternatively, the milliamps per second can be changed by no less than 50%, depending on the radiographic study required.

In general, increasing the kilovolt peak will provide greater penetration of the x-ray photons and give an overall gray appearance, which is desirable for thoracic radiographs. In contrast, increasing the exposure time (milliamps per second) will increase the contrast of a film, thus making it more black and white. This technique provides good bone detail that is desirable when radiographs of the extremities are obtained. With computed and digital radiography, technique becomes less about controlling subject contrast, because this is done with the computer, and more about making sure you penetrate the patient. Therefore higher kilovolt peak and lower milliamps per second are used to minimize patient motion.

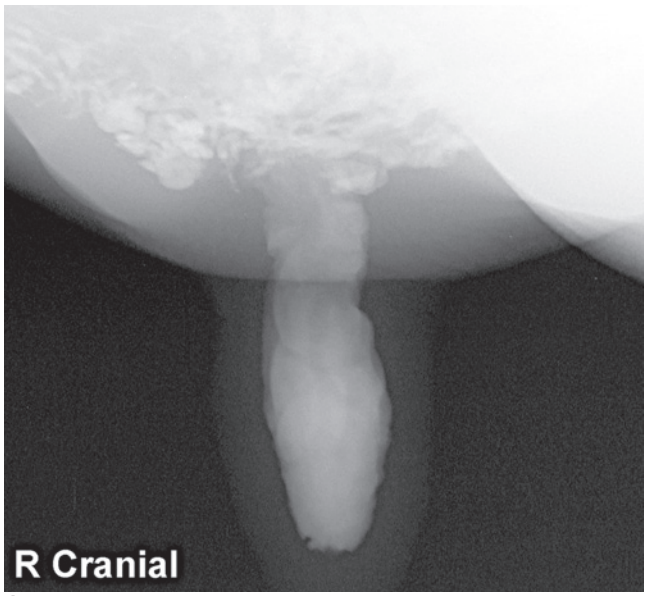
Proper technique will aid in providing a quality film; however, appropriate measures must be taken to provide adequate radiation safety to the practitioner, patient, and technicians. The basic principle of ALARA—an acronym for ***a***s ***l***ow ***a***s ***r***easonably ***a***chievable—should always be used. This means using a cassette holder, lead gloves, and lead aprons when exposing a film. The minimum exposure time should be used, and all personnel should be kept as far from the primary beam as possible. It should always be remembered that the cassette, lead gloves, and lead apron do not stop the primary x-ray beam. Therefore people or body parts in line with the primary beam receive a radiation dose similar to that of the structure being imaged.

In addition to survey radiographs, contrast radiography can also be performed to provide additional information about soft tissue structures. Contrast procedures that examine the esophagus, digits, mammary gland, and urinary bladder have been described. Positive contrast mammography can be performed on the mammary gland and teat; however, to the author's knowledge, no milk withdrawal times for iodinated contrast media have been published. In addition, intravenous sodium iodine is not for use in the lactating dairy cow; thus no inferred withdrawal time can be made. Therefore if iodinated contrast media is used in the lactating cow, the recommendation is to strip the teat thoroughly and observe a withdrawal time of approximately 5 days. In the United States this withdrawal time is only a suggestion, and the authors recommend contacting the local state regulatory commission before performing the procedure. To perform positive-contrast mammography, a small volume (10-30 mL) of iodinated contrast media (Hypaque-76[1]) is infused into the affected and a nonaffected teat via a teat cannula. Lateral radiographic projections are then acquired of each mammary gland separately. Structural lesions of the papillary duct and lactiferous sinus can be detected (Figure 2-1*A* and *B*).

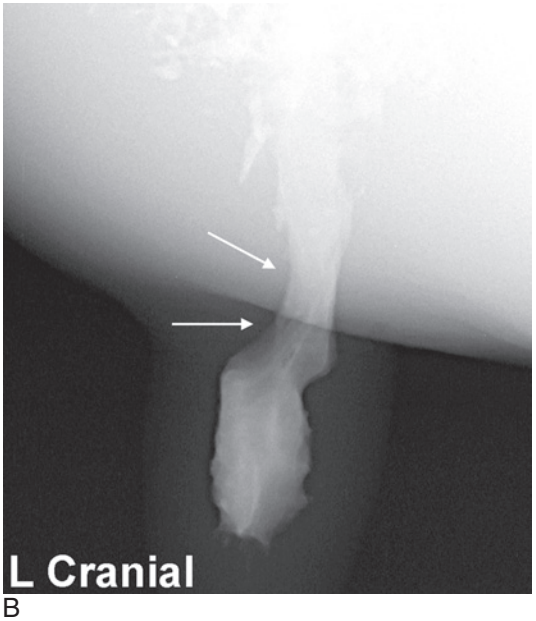
Positive-contrast urethrography is difficult to perform in goats because of the urethral process. In the pig, it is also difficult to pass a urinary catheter in a retrograde fashion because of the spiral nature of the penis. For this reason, positive-contrast normograde urethrography via a tube cystotomy is recommended. This procedure entails placing a percutaneous (or surgical) cystotomy tube and approximately 50 to 200 mL of iodinated contrast medium (e.g., Hypaque-76) into the urinary bladder. The bladder is filled with sterile saline until the urine overflows into the urethra or the urinary bladder is palpable. A liter of saline may be required before urination occurs and the urethra is opacified. Gentle pressure can be placed on the urinary bladder to promote emptying. This procedure provides a positive-contrast cystogram and a positive-contrast urethrogram. If

[1]Diatrizoate Meglumine and Diatrizoate Sodium, Nycomed Inc., Princeton, NJ, USA.

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A



B

Figure 2-1 Contrast lateral radiographs of the unaffected right-cranial quarter (*A*) and the left-cranial quarter (*B*) in an adult cow. Note the filling defect *(arrows)* in the lactiferous sinus of the left cranial quarter (*B*).

available, fluoroscopy greatly aids in evaluating the urinary bladder and urethra during this procedure (Figure 2-2).

Thoracic and abdominal radiography, especially in large food animals, requires specialized equipment generally found only in teaching or referral hospitals. The reticulum can be imaged with a portable unit if the cow is first placed in dorsal recumbency. This moves the contents of the reticulum and abomasum toward the back of the animal, and the air rises to outline the ventral position of the reticulum (see Figure 14-49). Alternate imaging modalities, such as ultrasonography, should be considered for evaluating the thorax and abdomen.

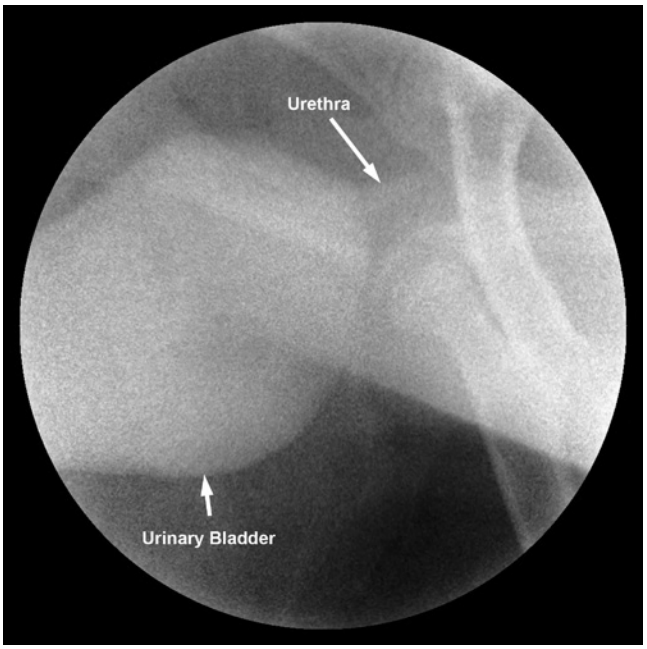


Figure 2-2 Fluoroscopic, contrast cystogram of a goat. A catheter was placed percutaneously into the urinary bladder, and contrast medium was administered. Pressure was placed on the urinary bladder to put contrast medium into the urethra. This is useful to help identify urinary calculi within the urethra. Generally, there is too much contrast medium in the urinary bladder at this point to be able to see calculi within the urinary bladder itself, and therefore a small volume of contrast medium is administered first to provide a contrast cystogram.

ULTRASOUND

For ultrasound examination of the thorax or abdomen of a large animal, the major requirement is a low-frequency (MHz) probe. This is because the lower the frequency of the sound waves emitted, the deeper the penetration of the probe. However, the depth of penetration is inversely proportional to resolution, which means the deeper the structure being imaged, the less clear it will appear.

Ultrasound works by sending high-frequency sound waves into the structure being imaged. The sound waves are then attenuated, absorbed, scattered, or reflected back to the transducer. The transducer detects the sound waves reflected back and determines the depth of the sound wave based on the time that passes from the initial pulse. This assumes that the structure imaged is soft tissue, which conducts sound at 1540 m/s. The intensity of the reflected sound wave is converted to a grayscale. Based on the time and intensity of the sound waves returned to the transducer, images are produced. The images are then described based on the echogenicity, margin, and size. Echogenicity is a relative term and is usually described based on the surrounding parenchyma or another structure (e.g., spleen is hyperechoic in comparison to the liver and kidney is hypoechoic to spleen).

The convention to display images is to have the patient's left side on the right side of the video screen or print (much like viewing a radiograph). In addition, dorsal or cranial is displayed on the left of the video monitor and ventral or caudal is on the right. Images are described based on the plane on which they were acquired. Generally this involves

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transverse (cross-section), longitudinal (long-axis), or oblique image planes. These planes can be related either to the patient as a whole (transverse sonogram of the cranial abdomen) or to the organ or structure being imaged (longitudinal image of the abomasum).

In a standard large-animal (bovine) abdomen, a 5- to 2-MHz probe generally is used. The sonographer can use any approach as long as it is systematic and thorough. The general abdominal ultrasound examination begins at the paralumbar fossa of either the right or left side, progresses cranially between intercostal spaces, and continues to the level of the thoracic cavity (lungs and heart). Then the opposite side is imaged. The technique described can be used for any farm animal but is different from the organ system approach used in small animals. For the left-abdominal window of the bovine, the rumen and reticulum are the most notable structures. The liver and spleen can also be evaluated. In the right-abdominal window, the right and left kidneys (Figure 2-3), omasum, liver (Figure 2-4), gallbladder (Figure 2-5), and intestines can be seen. In the ventral abdomen, the intestines, abomasum, and reticulum can be seen. During transrectal ultrasound examination, evaluation of the reproductive tract and potentially of the urinary bladder and left kidney can be performed.

No established technique has been reported for evaluating the thorax. In the authors' hospital, thoracic ultrasonography generally begins cranially and progresses caudally while using the intercostal spaces. This is done until the lung is no longer detected. Because the lung is relatively superficial, a higher frequency probe (8 to 5 MHz) can be used for a normal lung. A low-frequency probe is required to evaluate the heart, large pleural-fluid accumulations, and large pulmonary or mediastinal lesions. During thoracic ultrasonography, only the surface of the aerated lung (Figure 2-6) can be seen because the air interface reflects 99% of the sound waves back toward the transducer. In doing so, the air interface prevents detection of deeper structures. Pulmonary lesions must extend to the surface of the lung to be detected. Thoracic ultrasound is most useful for detecting pleural fluid, pleural masses, and body wall lesions (Figures 2-7 and 2-8*A* and *B*). Ultrasound-guided fine-needle

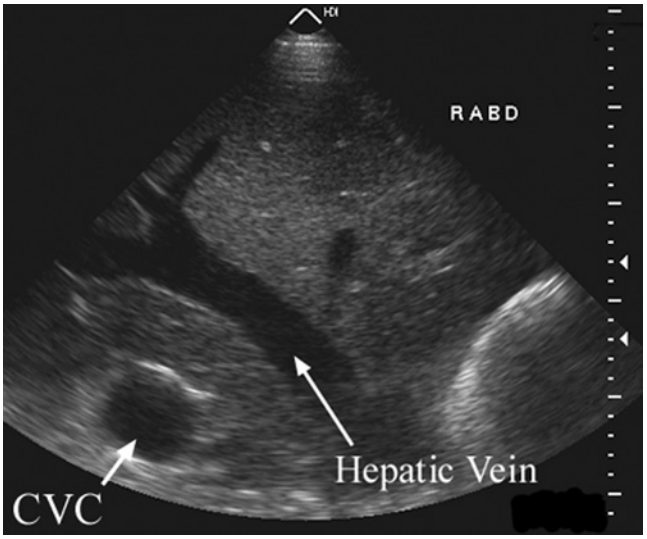


Figure 2-4 Oblique sonogram of the liver using a 3- to 2-MHz phased array sector probe in an adult Holstein cow with a history of anorexia and diarrhea for 7 days. Note the large hepatic vein and caudal vena cava (CVC). The patient had right-sided heart failure with secondary passive congestion of the liver and gallbladder.

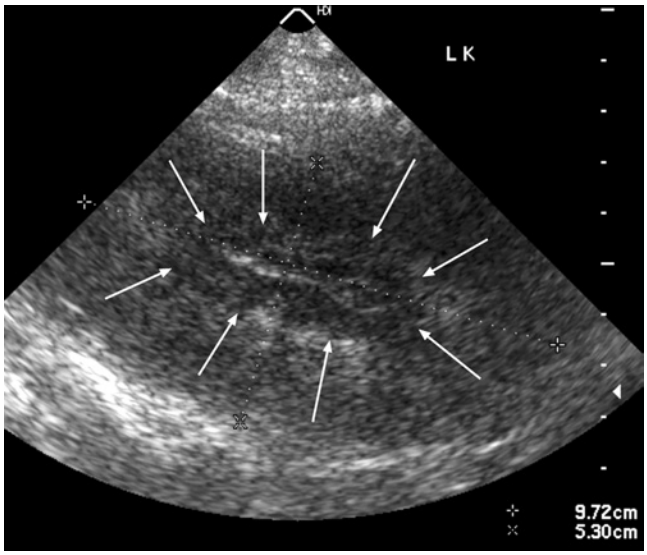


Figure 2-3 Transverse sonogram of the left kidney with a 5- to 3-MHz phased array sector probe in an adult Rambouillet sheep with a history of weight loss. Note the hypoechoic medulla of the kidney *(arrows)* in comparison to the cortex. This patient was diagnosed with immune-mediated glomerulonephritis secondary to chronic *Corynebacterium pseudotuberculosis* infection.

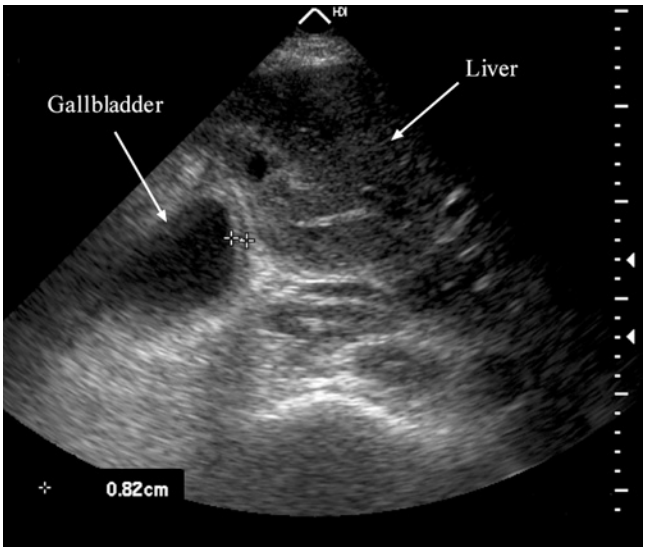


Figure 2-5 Oblique sonogram of the liver with a 3- to 2-MHz phased array sector probe in an adult Holstein cow with a history of anorexia and diarrhea for 7 days. Note the thick wall of the gallbladder (8 mm), attributed to edema. The patient had right-sided heart failure with secondary passive congestion of the liver and gallbladder.

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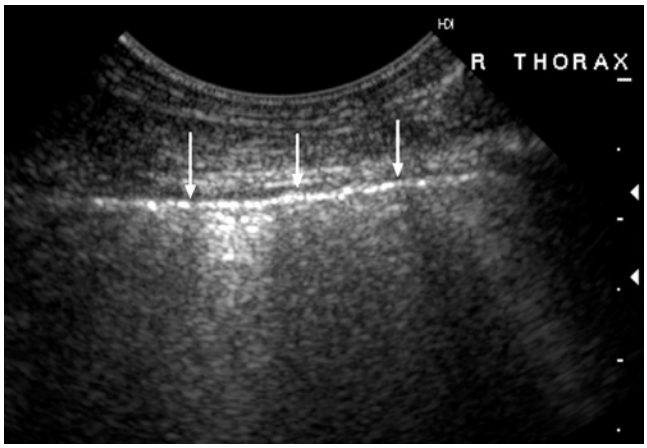


Figure 2-6 Transverse sonogram of the right thorax using an 8- to 5-MHz curved array probe in an 8-month-old pigmy goat with postanesthetic hypoxia. Note the bright hyperechoic line *(arrow)* with no returning echoes deep to the structure. This line should move with respiration and represents the interface of lung and pleural space. No abnormality is detected.

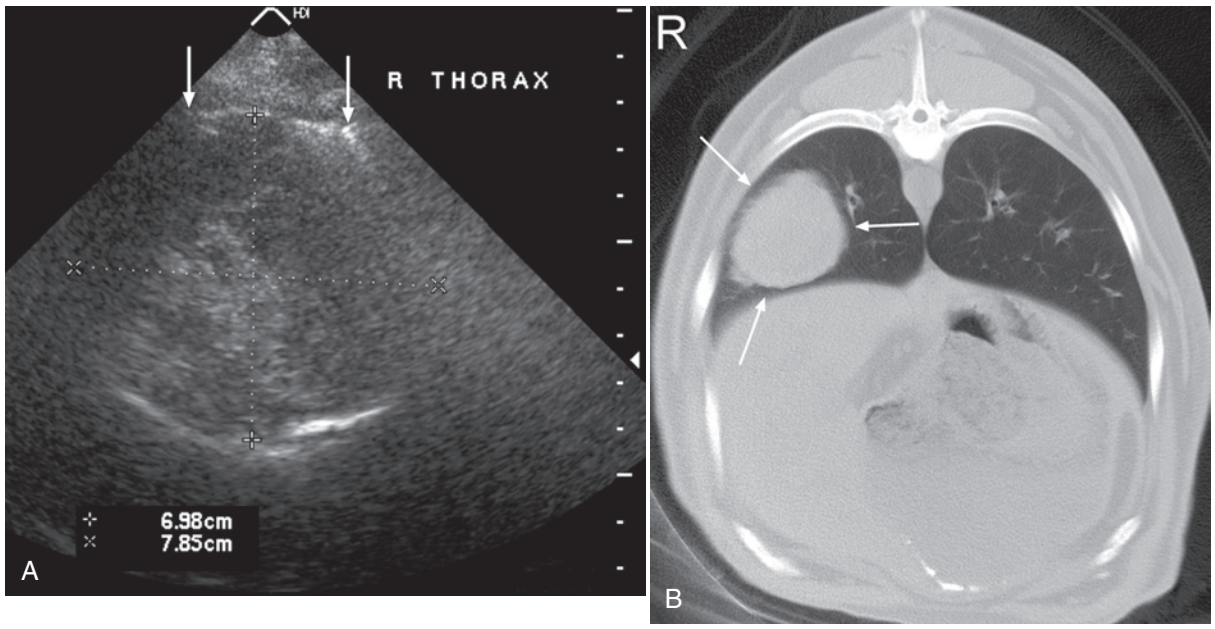


Figure 2-7 Longitudinal sonogram using a 5- to 3-MHz phased array sector probe (*A*) and transverse computed tomography (CT) (*B*) of the right thorax in an adult Rambouillet sheep with a history of weight loss. In the sonogram, note the large, hyperechoic mass in the right caudal lung lobe. The ribs (*arrows*) cast acoustic shadows that obscure the cranial and caudal aspects of the mass. On CT (*B*), note the large, soft tissue dense mass within the right caudal lung lobe (*arrows*). This mass was a pulmonary abscess that cultured positive for *Corynebacterium pseudotuberculosis*.

aspirates for cytology and culture can be obtained to aid in making a diagnosis.

Ultrasound of specific locations—including the neck, umbilicus, mammary glands, subcutaneous tissues, joints, limbs, and perineum—can be performed. These sites are generally used to evaluate lymph nodes, foreign bodies, masses, abscesses, or urinary calculi.

The use of ultrasound examination to evaluate fractures of the shoulder, proximal thoracic and pelvic limbs, or the pelvis has also been suggested. This is because, as described previously, the techniques required for radiography of these structures are generally beyond the capabilities of the ambulatory practitioner. In addition, ultrasonography gives real-time images in a method that is anatomically intuitive and

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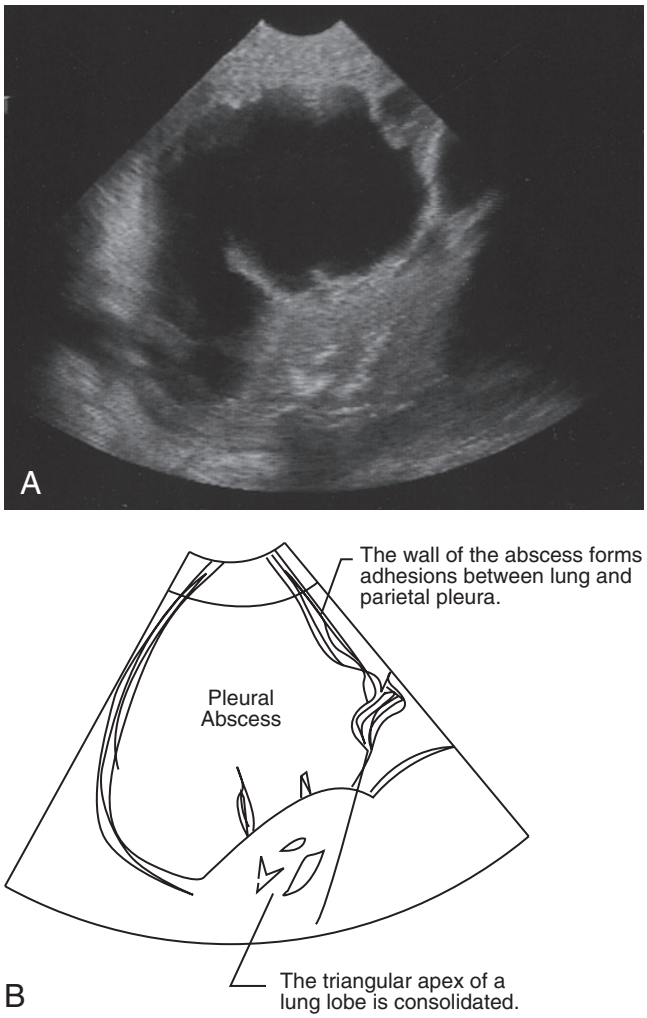


Figure 2-8 *A*, Transverse sonogram of left thorax using an 8- to 5-MHz convex linear probe in a 6-year-old Suffolk ewe with a pleural abscess. The right side of the sonogram is ventral. *B*, Schematic representation of sonogram.

can be a means to acquire a diagnosis using fine-needle aspirates or biopsies.

NUCLEAR MEDICINE, CT, AND MRI

Other imaging modalities infrequently used in farm animal practice include nuclear medicine, CT, and MRI. Nuclear medicine is not recommended in farm animals in the United States. The United States Nuclear Regulatory Committee states that no radiopharmaceuticals are approved for use in animals intended for the human food supply. However, the use of technetium methylene diphosphonate for bone scintigraphy can be useful for diagnosing lameness or other skeletal abnormalities (Figure 2-9). Use of radiopharmaceuticals is off-label in the food animal; therefore consultation with the Food and Drug Administration is recommended if the procedure is attempted. CT and MRI have been used in a very limited fashion in farm animals. Unless targeting a calf, sheep, goat, or pig, the size of the animal (i.e., adult bovine) limits evaluations to the head (including brain and sinuses) and distal extremities (Figure 2-10). CT has also been used as an anatomic guide in calves, but there are limited reports and uses in farm animals due to the cost of the animals. The requirement for general anesthesia and specialized equipment make these modalities unlikely to become universally used or recommended for the farm animal.

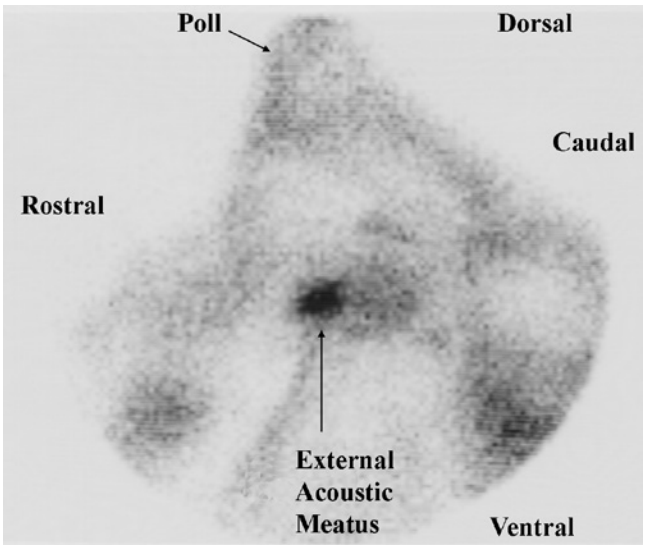


Figure 2-9 Left-lateral bone scintigraphy of the head in a 1-year-old Holstein cow with cervical pain. Technetium methylene diphosphonate—110 mCi—was administered intravenously, and images were acquired 2 hours after injection. No abnormality is detected. Note the high activity detected in the petrous temporal bone. This is considered a normal finding because of superimposition of dense bone; therefore a large amount of activity is present in that area.

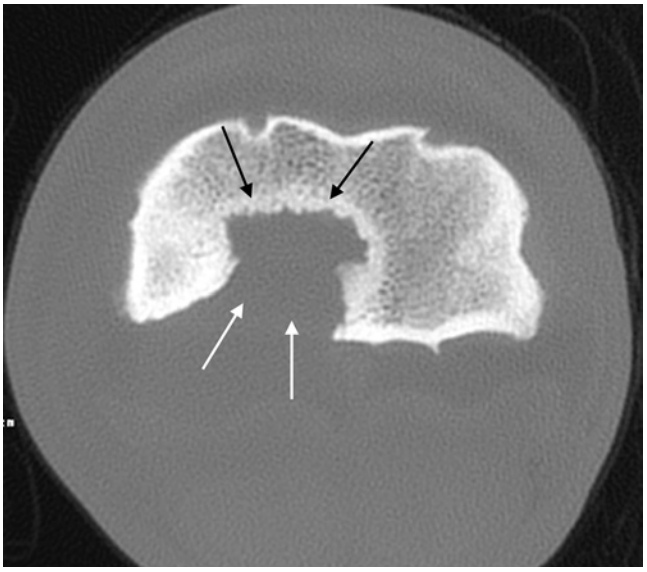


Figure 2-10 Transverse CT of the left thoracic limb in a 3-year-old bull with left-thoracic-limb lameness. In the distal metaphysis of the left third metatarsal bone, there is a focal area of bone lysis *(arrows)*. The bull was euthanized, and the necropsy disclosed a bone abscess at this site.

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CHAPTER 3

Presurgical Considerations

Ava M. Trent, Richard Wheeler, André Desrochers, Gilles Fecteau, Gillian A. Perkins and Emily A. Barrell

PREOPERATIVE PREPARATION

Ava M. Trent

EVALUATION OF THE PATIENT

All animals that are surgical candidates should have a complete physical examination, including auscultation of the heart and lungs and an assessment of the surgical problem. For simple elective surgical procedures in young healthy animals, preoperative laboratory work is probably not necessary. Laboratory screening is of value for animals that undergo general anesthesia, those with a more complicated disorder, and animals with significant potential hemodynamic complications associated with surgery (such as blood loss). Packed cell volume and total protein are screening tests easily performed that may influence preanesthesia preparation and intraoperative response to blood loss. For cattle with complicated gastrointestinal disturbances, such as an abomasal volvulus, plasma electrolyte concentrations help determine appropriate replacement fluid therapy (see Chapter 4). A complete blood count would help identify animals affected with serious infectious processes and may influence preparation and the timing of surgery. If other systemic concerns about a farm animal exist, such as fatty-liver syndrome in a cow, specific tests such as a serum γ-glutamyl-transferase can be run, or if finances permit, a large-animal biochemical panel may be more appropriate.

Cattle that undergo elective surgical procedures under general anesthesia in lateral or dorsal recumbency should be fasted 24 to 48 hours before surgery to decrease the ruminal content, ruminal distention, and risk of aspiration pneumonia. Furthermore, in ruminants subjected to general anesthesia, fasting is essential to improve venous return and ventilatory capacity (see Chapter 5).

DECISION MAKING

The cost of surgery and perioperative care for farm animals usually requires that it make economic sense. This financial reality dictates good judgment in selecting preoperative preparation. If the surgical procedure is beyond the capabilities of the clinician or the available facilities, a referral should be considered. If this is impractical because of time, distance, or financial constraints, and if the client understands the risk, it may be appropriate to attempt an unfamiliar procedure. Much can be gained through familiarity with the anatomy and through envisioning the operation step by step so that appropriate plans can be made. With farm animals, withdrawal times for meat and milk must be taken into consideration in the choice of pharmaceuticals.

With experience, clinicians develop a sense about which animals require intervention and what the likely outcomes will be. This experience dictates recommendations to owners, choice of surgical approach, and procedures to be performed. However, one is inevitably humbled by finding the unexpected or a cow with a different disease than anticipated. If a problem arises or something does not work correctly during surgery, changing an aspect of the procedure (such as extending the incision, trying a different approach, performing an enterotomy, or asking for help from someone more experienced) rather than struggling for a long period of time is ultimately best for that patient and the practitioner.

PATIENT POSITIONING

Determining the appropriate incision site is half the battle in gastrointestinal surgery in dairy cattle. Fortunately, the placid nature of the dairy cow permits many procedures to be done on a standing animal using a local anesthetic. For a more fractious animal, it may be possible to use small amounts of sedation, but this should be used with caution because it increases the risk that the animal will become recumbent. Lateral recumbency can be used for flank and inguinal approaches. Dorsal recumbency may be used for teat surgery, access to the cranial abdomen, and cesarean sections. Padding of bony prominences is indicated in recumbent procedures. For animals placed in left-lateral recumbency, placing an inner tube or other pads under the shoulder and hip of a cow has been suggested as useful in making a so-called sling for the rumen (Figure 3-1). Rarely have we had to place animals in sternal recumbency, either for nasal or cervical surgery (Figure 3-2). Other acceptable padding includes air mattresses, water beds, foam pads, and inflatable surgery tables (Snell tables[1]).

PREPARATION OF THE SURGERY SITE

Once the decision is made for the surgical approach, dirt and manure should be removed. Hair should be clipped and a generous area left free of hair and debris. Some advocate shaving the actual site of the skin incision, but this may increase chances of infection if the skin is inadvertently nicked. As a rule of thumb, a 25-cm hairless margin around the surgical site is recommended.

In thick-skinned animals, an initial prep with a clean, stiff brush may be helpful. This should be followed by repeated scrubs with a disinfectant solution. Scrub solutions typically contain povidone (polyvinylpyrrolidone)-iodine, 4% chlorhexidine gluconate, or 2% chlorhexidine diacetate. Povidone-iodine and chlorhexidine products have a broad antimicrobial spectrum, including most bacteria, some fungi, and many viruses. Scrub solutions can be rinsed with water, saline, or 70% isopropyl alcohol. For long procedures (longer than 90 minutes), povidone-iodine with an alcohol rinse or chlorhexidine with a water or saline rinse is

[1]Snell Veterinary Systems, Sherborne, Dorset DT9 4LJ, United Kingdom, http://www.snell2000.com/vet/index.htm.

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Figure 3-1 Cow in lateral recumbency under general anesthesia. Placing appropriate pads under the cow's shoulder and hip creates a cavity to support the distended rumen. (Reproduced with permission from Smith DF: Bovine intestinal surgery: Part 1, *Mod Vet Pract* 65: 853–857, 1984, p 854, Figure 1).

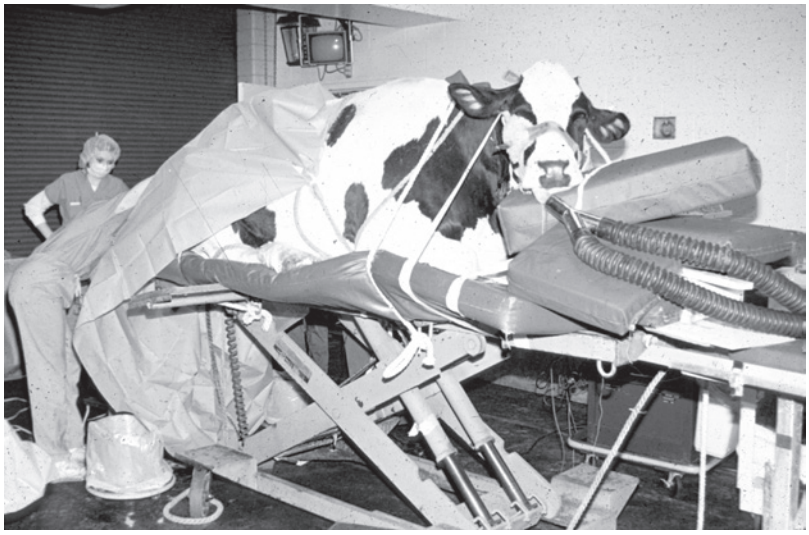


Figure 3-2 Cow in sternal recumbency under general anesthesia.

recommended. To aseptically prepare a skin incision, the planned incision site should be cleaned and followed by a circular motion moving from the center to the periphery. This should be repeated at least three times. Depending on the gross contamination of the skin, more cleansing may be indicated; the gauze should be checked for cleanliness at the completion of the scrub. Some clinicians don a sterile glove and use sterile gauze for the final preparation. The incision site should be draped if at all possible. Impervious drapes can be placed over cloth or paper drapes to help keep the incision dry and free of infection. If the surgery becomes contaminated (e.g., if an enterotomy is performed), the area should be isolated with drapes or towels, and the surgeons should reglove after the procedure.

PREPARATION OF THE SURGEON

In a hospital setting, clean, comfortable cotton or cotton-blend clothing with use restricted to the operating room is ideal and helps reduce the number of environmental contaminants. Some type of clean head covering that confines hair has also been shown to reduce the incidence of surgical infections. Caps, hoods, and bouffant-style coverings are some options. Facial coverings other than masks protect the wound from droplets of saliva and nasal exudates but are not effective bacterial filters. When properly fitted, facemasks direct airflow away from the surgical wound, which—theoretically—should cut down on wound infection. Studies have not supported this finding, but masks are still recommended. Shoe covers are fairly impractical in most farm animal surgery, although waterproof shoes add to the surgeon's comfort.

Surgical gowns are used for most lengthy procedures in a hospital environment. Lint-free gowns that are impervious to water and bacteria are most effective. Reusable gowns made of muslin or, more recently, of 270-count pima cotton are somewhat resistant to water but not bacteria. Gowns treated with Quarpel, a fluorochemical finish, combined with phenazopyridine hydrochloride or melamine hydrophobe, have a better barrier to water and bacteria and a pore size reduced to 10 µm. Gore-Tex fabric makes an even more durable bacteria-resistant gown.

Disposable gowns are made from olefin, which is regenerated cellulose, a petroleum byproduct. Some gowns have extra layers of water-repellent material in the sleeves to prevent constant dampness and subsequent capillary migration of skin flora, which lead to increased bacterial counts of surgical wounds. Advantages of disposable products are ease of handling and storage and reduced bacterial contamination

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in the surgical environment compared with nondisposables. However, purchasing and disposing of disposable items are more expensive. Nondisposable gowns are more comfortable and less expensive but do need to be laundered and replaced on a regular basis.

Gloves should be worn for all surgical procedures. This helps avoid contamination from the residual flora on the surgeon's hands. Gloves also protect the surgeon from any allergens or contact dermatitis. Most gloves are made of latex and come in a single-use package in a wide variety of sizes. Hypoallergenic vinyl gloves are available for those with latex sensitivity. Magnesium silicate powder is preapplied to most gloves to make them easier to don; therefore gloves should be rinsed before handling tissues. Gloves commonly develop holes and should be checked often for defects. Double gloving is used if extensive draping is required or contamination of the surgeon's hands by sharp objects such as bony fragments and orthopedic implants is likely. Gloves can be applied with a closed- or open-gloving technique. Closed-gloving techniques are preferred because the surgeon's skin will not make contact with the outside of the gown cuff. An open gloving is recommended to replace a glove during a procedure. Otherwise, the cuff of the gown that has been exposed to skin and perspiration will be pulled over clean hands. Cuffs of the surgeon's gown should be covered completely by gloves because the cuff material is not impervious to water penetration. Water often finds its way to the surgeon's hands regardless of the material chosen; therefore plastic safety sleeves and double gloving are often helpful during procedures in which the surgeon's hands and arms may be submerged. Although a gown is sterile when first applied, it should be remembered that only the front, above the waist, is considered sterile during the procedure.

DRAPING THE SURGICAL FIELD

The purpose of drapes is to create and maintain a sterile field around the operative site. In stationary, recumbent animals, the surgical field is usually surrounded first by sterile towels held in place with penetrating towel clamps. Large cloth or disposable drapes are placed next. Impervious drapes are ideal if a lot of fluid or blood is expected or exteriorization of viscera is necessary.

If long enough, the tails of adult cows should be tied—usually to one hind leg—for standing procedures. Large disposable laparotomy cloths or disposable drapes are available.[2] They may be fenestrated, or an appropriate-sized hole can be made by the surgeon. They are usually used alone and secured in place with penetrating towel clamps. Although they are relatively expensive, they are a great help in allowing the surgeon to focus on the procedure without worrying about contamination from dirt, fecal material, or body fluids.

PREVENTION OF PERITONITIS AND SURGICAL INFECTION

The surgeon must always be aware of the potential to promote or prevent peritonitis or other infections of the surgical site during surgery in the cow. It is often possible is to reduce the risk of infection before contamination ever occurs or to intervene between the time contaminants are first introduced into the abdomen and the development of infection.

[2]http://www.vetsurgicalresources.com, Darling, MD 21034.

Precontamination

The optimum time to intervene in the development of a surgical infection is before a known or anticipated episode of contamination. Careful planning of the procedure will minimize the period of contamination, ensure adequate restraint, and minimize the use of potential adjuvants to reduce the risk of infection. Prophylactic antibiotics should be considered in planning any clean-contaminated or contaminated procedure and clean procedures in patients with identified risk factors. Common patient risk factors include preexisting nonbacterial inflammatory peritonitis, malnutrition, circulatory shock, and remote or systemic infection. In the latter case, elective procedures should be delayed until the preexisting infection can be treated and resolved. Similar steps should be considered when facilities, the animal's behavior, or its condition increase the risk of contamination. Field conditions often involve less than optimal restraint facilities, fractious animals, limited control of external sources of contamination, and conditions that might predispose to unexpected recumbency during standing procedures (hypocalcemia, exhaustion, extreme peritoneal tension), all of which increase morbidity.

Antibiotics should be administered just far enough before surgery to maintain high serum levels throughout the period of contamination. Intravenous (IV) administration of a single dose 15 minutes before surgery or intramuscular (IM) administration 60 minutes before surgery achieves this goal for most antibiotics. Parenteral, subcutaneous (SQ), and intraperitoneal routes are not recommended for prophylaxis because the time to peak levels is longer and less predictable and because peak levels are lower in comparison to IV and IM routes of administration. If intraoperative sample collection for culture is planned, some prophylactic effect can still be obtained by intravenously administering an appropriate antibiotic immediately after sample collection.

Prophylactic antibiotics should be selected with as specific a spectrum as possible, based on probable contaminants. This can be based on knowledge of common contaminants from planned surgical sites (e.g., anaerobes for rumenotomy), culture results from potential sites of leakage or preexisting infection (e.g., culture results from an umbilical abscess), or predicting other common infectious agents. The ability of antibiotics to penetrate fibrin or function in the presence of necrotic debris or altered pH should not be a major concern in antibiotic selection during the precontamination or contamination stages. Antibiotic options are provided in Appendix 1.

Contamination

Preventive measures are similar to those described for the precontamination stage, with a few additions. Prophylactic antibiotics can still be of some benefit, but they should be given intravenously to achieve high serum and tissue levels as soon as possible. If a source of contamination first develops intraoperatively, rapid steps to minimize the amount and distribution of contamination are indicated. For example, in gastrointestinal surgery, gross contamination should be localized whenever possible by exteriorizing the site of leakage or isolating it with laparotomy sponges, physically removing all accessible contaminants, and avoiding palpation unless absolutely necessary so that contaminants are not physically transported from the site of leakage to other sites in the abdomen. If the site can be adequately exteriorized to allow external drainage, localized lavage with a sterile isotonic fluid can help remove contaminants. However, generalized lavage is more likely to distribute high concentrations of organisms to potentially clean areas and is only recommended if the site cannot be exteriorized or dissemination has already occurred. Adding antibiotics to the lavage fluid

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Figure 3-3 Floating tank.

may be indicated even if appropriate systemic antibiotics have been administered.

Other important considerations in the aftercare of the surgical farm animal are supplying adequate hydration (see Chapter 4), keeping neonates warm, and providing adequate nutrition and oral electrolytes.

Down cattle need excellent footing that keeps them from slipping. They need to be supported by having food and water where they can be reached. Good padding in a heavily bedded stall or on soft dirt is ideal. If cattle remain down for prolonged periods of time it may be necessary to try to get them up with well-padded hip lifts. Alternatively, cattle can be "floated" in a commercial tub ("Aqua cow"[3]) (Figure 3-3). "Floated" in this instance means placing the cow in the apparatus—which can require considerable manpower—and then filling the chamber with water to create what is essential a wading pool to support the bulk of the cow's weight. This apparatus requires a fair amount of time, patience, and manpower. Regardless, it has been successful in the right hands for recumbent cows that are amenable to therapy.

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SURGICAL CONSIDERATIONS

PERIOPERATIVE ANTIMICROBIALS AND ANALGESICS

Thomas Divers and Emily Barrell

The extralabel use of antimicrobials and analgesics is regulated under the Animal Medicinal Drug Use and Clarification Act of 1994 (AMDUCA) by the FDA Center for Veterinary Medicine. Penicillin and/or ceftiofur are the most commonly used perioperative antibiotics for cattle that undergo surgery without enterotomy. Each drug has its advantages and disadvantages: penicillin is more effective than ceftiofur against *Trueperella pyogenes* and other bovine anaerobic pathogens. It should be used (alone or in combination with another compatible bacteriocidal drug) when surgery is done on anatomic locations that normally harbor anaerobic organisms (e.g., mouth, gastrointestinal tract, reproductive tract). Unfortunately, penicillin is not very effective against most gram-negative organisms, and the duration of withdrawal time for milk or meat is a disadvantage. As an example, in lactating dairy cattle at an extralabel dosage of 24,000 U/kg IM (10,900 U/lb, a 45-mL dose for a 1250-lb animal), the suggested withdrawal time for milk is 5 days and for meat is 12 days, whereas for the generally clinically ineffective label dose of 6600 U/kg (3000 U/lb), the respective withdrawal times are 2 and 10 days. It should be noted that when penicillin is given SQ, at larger doses, or in volumes of more than 10 mL per injection site, withdrawal times may be markedly prolonged. Ceftiofur sodium (Naxcel), when used in dairy cattle at the label dosage, has the advantage of no withdrawal time for milk and only a 4-day meat withhold. Ceftiofur hydrochloride (Excenel) has only a 3-day meat withdrawal and no milk withdrawal time.

If an enterotomy is performed, broad-spectrum coverage may be required. A therapy that combines penicillin (at two to three times label dosage) and ceftiofur is often used. In a hospital setting, IV penicillin salts (22,000 U/kg) are sometimes substituted for procaine penicillin to achieve higher tissue concentrations, but more frequent administration (every 6 hours) is required. Although the water-soluble form of ceftiofur used IV achieves high plasma and tissue levels of the parent drug, in the United States it is now illegal to use cephalosporin-class antibiotics in major species (cattle, swine, and poultry) at an extralabel dose, treatment duration, frequency, or administration route. Thus, ceftiofur use in the above case would be limited to the SQ or IM route. The SQ administration route has the advantage of preserving beef quality because less muscle irritation occurs compared with that associated with an IM injection. Another option is oxytetracycline, a broad-spectrum antibiotic that is moderately effective against gram-positive and gram-negative aerobic and anaerobic organisms. It is occasionally used at an extralabel frequency (every 12 hours) to maintain higher tissue levels. Tetracycline is more lipid-soluble than either penicillin or ceftiofur; therefore higher tissue concentrations would be expected. Tetracycline disadvantages are its bacteriostatic activity and potential for causing renal failure when administered at high daily dosages and/or to dehydrated animals. At present, only aqueous solutions of oxytetracycline with concentrations of 200 mg/mL (Liquamycin LA-200, Maxim 200, Bio-Mycin 200, etc.) are labeled for use in lactating dairy cattle. Used at the label dose (6.6 to 11 mg/kg [3-5 mg/lb] IV, SQ, or IM every 24 hours), the drug has a 28-day meat withdrawal and 4-day milk withdrawal.

All perioperative antibiotics should be administered only 1 to 2 hours before surgery so that the highest concentration of drugs is present when tissue is being incised and handled and when clots/fibrin are forming. If the surgery is uncomplicated (e.g., a routine laparotomy), many surgeons do not use antibiotics. If antibiotics are used, it is imprudent to use them for a shorter duration than the label recommendation. Most cattle antibiotics are labeled for 3 days' minimum use. More complicated surgeries (e.g., enterotomy, internal fixation) require continuous treatment for at least 5 days. If infection is discovered at the time of or after surgery, treatment should be continued for longer periods. When bacterial infection is suspected before surgery, the decision

[3]Vet. Surgical Resources, Inc., PO Box 368, Darlington, MD 21034, USA, http://www.vetsurgicalresources.com.

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to withhold preoperative antibiotics until a culture sample can be obtained should be based upon the location and predicted benefit of culturing the infected site. For most abdominal surgeries with preexisting infection (e.g., reticular or umbilical abscess), preoperative antibiotics are recommended because offending organisms are predictable, cultures are generally not taken, and some risk of spreading the infection at the time of surgery exists. Conversely, antibiotics are generally withheld for orthopedic surgery that involves presumably infected bone until a culture sample can be obtained. If an offending organism's sensitivity is known from samples obtained before surgery, antimicrobial selection should be based upon the organism's sensitivity, predicted drug(s) tissue levels, confidence in drug safety and cost, and FDA approval of extralabel use.

Florfenicol (nonlactating cows), enrofloxacin (beef cattle with respiratory disease only), and tetracyclines are occasionally used as perioperative antibiotics. Aminoglycosides combined with penicillin, ampicillin, or ticarcillin/clavulanate are rarely used in calves, and then only with strict adherence to extralabel use. Antibiotics prohibited under all circumstances in food animals and more information are available from http://www.nationaldairyfarm.com.

PERIOPERATIVE ANALGESICS

Perioperative analgesics and antiinflammatories are indicated in most surgical procedures to temper the initial inflammatory response and decrease swelling and to improve the appetite and general well-being of the patient. In cattle with routine, relatively nontraumatic surgery (e.g., omentopexy), perioperative analgesics commonly are not used simply because of cost and loss of product value as a result of milk withholding. This is particularly true if lactating cattle are being treated perioperatively with ceftiofur, which has no milk withholding time. The most commonly used antiinflammatory drug is flunixin meglumine. Flunixin is a cyclooxygenase inhibitor that provides excellent analgesia, including visceral analgesia, and is the only FDA-approved nonsteroidal antiinflammatory (pyrexia, endotoxemia, inflammation) drug for cattle. It may be indicated during the time of routine (one or more dosages) bovine surgery and in the immediate postoperative period when withholding times for milk and meat are not a major issue. When used only perioperatively at the label dosage (1.1 to 2.2 mg/kg IV), it incurs 4 days of meat withholding and 36 hours of milk withholding. At present, there are no drugs specifically approved for analgesia in any livestock species.

Phenylbutazone and aspirin are other antiinflammatory analgesics that historically have been used in food animals. Phenylbutazone is known to induce blood dyscrasias in humans and is therefore illegal for use in female dairy cattle 20 months of age or older. However, given the potential adverse reactions in human consumers, the Food Animal Residue Avoidance Databank (FARAD) strongly discourages phenylbutazone use in any food animal, and a veterinarian would need to provide justification as to why flunixin meglumine was not effective in the animal being treated to legally use the drug. FARAD further discourages aspirin use in food animals for the following reasons: 1) there is no FDA approval for use in food animals; 2) flunixin is an available alternative; and 3) it has questionable efficacy (administered orally, the drug reaches baseline serum concentrations in 12 to 24 hours).

Additional analgesics that may be used are lidocaine, alpha agonists, and butorphanol. Lidocaine is mostly used either for epidural administration to provide analgesia to the pelvic area during and after perineal or rectal surgery or as IV anesthesia (with a tourniquet) during surgery on a distal limb (15 to 30 mL lidocaine). Lidocaine is most commonly used as a local analgesic for cutting skin to prevent an animal from becoming fractious.

Xylazine epidurals (0.05 mg/kg) or medetomidine 5 to 15 µg/kg may provide slightly better analgesic effects than lidocaine. Xylazine 0.03 mg/kg can be combined with lidocaine (0.2 mg/kg) for both fast-acting and long-lasting (4 to 5 hours) analgesia. Butorphanol may also be used IM or IV (0.1 mg/kg) for severe pain that cannot be adequately diminished with nonsteroidal antiinflammatory drug (NSAID) therapy. For information regarding the use of nonapproved antibiotics and analgesics, the reader is encouraged to consult FARAD at www.farad.org.

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FACILITIES AND RESTRAINING DEVICES

Richard Wheeler

INTRODUCTION

When working with livestock, there are inherent safety risks to both the animal and handler. Bovines by their sheer size are a threat to humans. Both fear and aggression on the part of the animal can increase this danger. Bulls should always be considered dangerous and unpredictable. Dairy bulls, because of their extensive human contact, lack a natural fear of humans and may display increased aggression. Beef bulls generally react out of fear toward humans.

Cows do not guarantee safety either. The protective, maternal instinct of a cow with a calf makes her significantly more dangerous than a single cow. Because beef cows usually are not intensively handled, they are more dangerous than dairy cows. It has been suggested that the position of the hair whorl between a cow's eyes correlates with the degree of agitation the cow will demonstrate under restraint. Animals with whorls located high on the forehead, above the

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level of the eyes, were found to be more aggressive under restraint (high whorls, hot-headed) (Grandin, 1995) than cows with lower whorls.

Although small ruminants (sheep, goats, and calves) can inflict injury to their handlers, they are more likely to injure themselves when struggling against restraining devices or overly aggressive handlers. Sheep and goats have a strong herd instinct and become stressed when separated from herdmates. Stress adversely affects wound healing and general health, growth, and production. In pigs, stress has been associated with sudden death.

ANIMAL BEHAVIOR

Consideration of the animals' natural instincts enables a handler to humanely and safely move and restrain livestock. Large and small ruminant livestock are prey animals whose primary defense mechanism is sight and flight. They have evolved wide-set eyes that afford them extensive peripheral vision in surveillance of predators. With an angle of vision approaching 300 degrees, their only blind spot is directly behind them. To avoid startling an animal when approaching it, the handler should remain within its line of sight. Startling an animal can elicit struggling, provoke the animal to kick, or incite a stampede.

Panoramic vision provides prey animals a wide angle of vision but sacrifices depth perception. This is why cattle commonly balk at shadows, are reluctant to step across different colored floors, and closely inspect objects in their paths. Handlers should be patient. They should allow the animal to assess the danger of a situation or novel object before forcing it to enter a foreign environment or head gate.

Animals naturally maintain a safe distance between themselves and potential predators. This distance is the flight zone. If the flight zone is invaded, the animal will move away from the invader to reestablish an adequate safe distance. In relation to people, this distance is influenced by the amount of contact the animal has had with humans. Dairy cattle, which are handled daily, may have practically no flight zone and can be readily approached. Alternatively, beef cattle often have greater fear because of limited human contact and may require several meters of space. Sheep and goats commonly move as a herd, and the comfort level of the first animal establishes the flight zone for the herd.

KNOTS

Ropes are invaluable assets in animal restraint. However, a rope is only as good as the knot that is tied. There is a unique knot, with a particular advantage, for practically any situation imaginable. At the very least, every animal handler should be proficient with the three knots covered in the following discussion.

Square Knot

The square knot joins two rope ends. Joining the ends of a single rope forms a loop that allows the rope to be tied to a fixed object. Alternatively, the ends of two separate ropes can be joined to form one long rope. Once tightened, a properly tied square knot will not slip under tension. A common error is to tie a granny knot that slips when tension is applied (Figure 3-4).

Quick-Release Slip Knot

The quick-release slip knot and its modifications (see the Tail Ties section) secure a rope in a way that allows it to be easily untied at the end of a procedure or in case emergency release

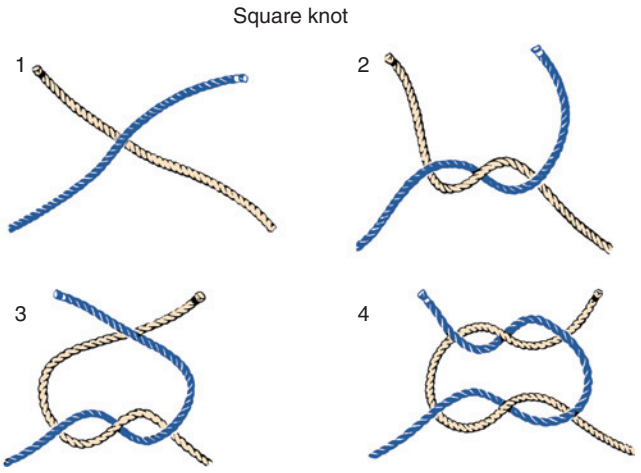


Figure 3-4 Square knot. (Adapted from Leahy JR, Barrow P: Restraint of animals, ed 2, Ithaca, NY, 1953, self-published.)

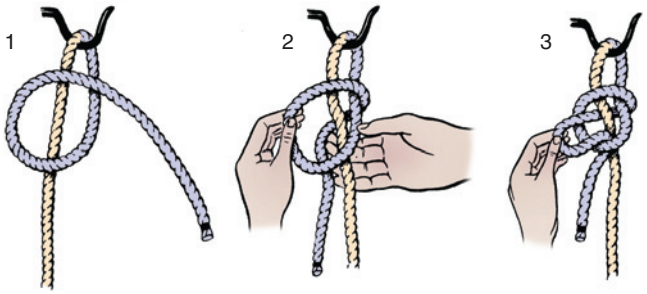


Figure 3-5 Quick-release knot. (Adapted from Leahy JR, Barrow P: Restraint of animals, ed 2, Ithaca, NY 1953, self-published.)

is required. Most commonly, the free end of a halter will be tied to a post to restrain an animal's head. When properly tied, the bow end of the knot is entirely surrounded by rope; if the bow lies against the object to which it is tied, it is not secure and will loosen as the animal struggles. Because it is a slipknot, there will always be a little play in the rope as it slips down to its anchor; tying the knot as close to the anchor as possible is important (Figure 3-5).

Bowline Knot

The bowline knot creates a permanent loop that will not tighten. It is useful to place around an animal's body, neck, or limb because it will not cinch down and compromise respiration or circulation (Figure 3-6).

RESTRAINT OF CATTLE

Moving Cattle

One should take advantage of ruminants' flight instinct when moving a single animal or a herd. The spatial relationship between the handler and the animal's body dictates the direction the animal will move when approached. The animal's shoulder is the point of balance. If approached caudal to the shoulder, the animal will move forward; if approached cranial to the shoulder, the animal will generally move backward.

The flight zone should be entered slowly, steadily, and silently so the animal is not spooked. The rate at which the animal moves depends on how deeply and rapidly the flight

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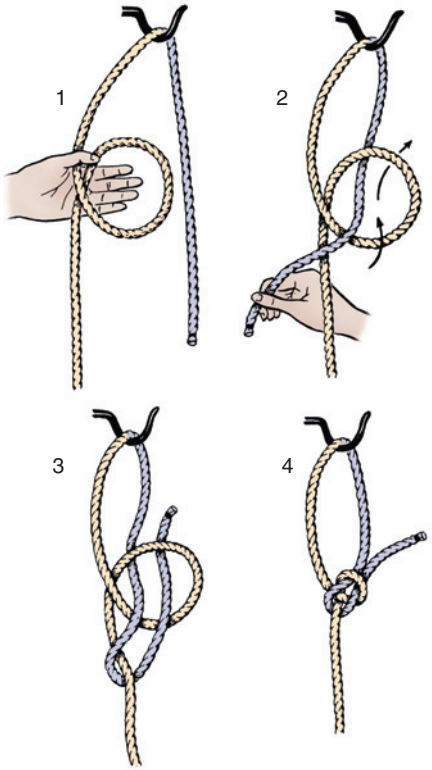


Figure 3-6 Bowline knot. (Adapted from Leahy JR, Barrow P: Restraint of animals, ed 2, Ithaca, NY 1953, self-published.)

zone is penetrated. If an animal gets too anxious or moves too quickly, the handler should back away and allow the animal to relax. Excited cattle are more difficult to control and are more likely to be injured or injure a person. Cattle should be moved no faster than a walk. An animal can also be transported in portable stocks (Figure 3-7). These are also convenient for restraint during standing surgical procedures.

Getting a Cow to Stand

Most recumbent animals will stand as the handler enters the flight zone. However, dairy cows are so intensively managed they may require physical contact to incite them to rise. Before a recumbent animal is prompted to stand, the handler should evaluate the animal to ascertain it is physically capable of standing. A gentle nudge on the caudal thigh with the inside of one's foot is often sufficient to encourage an animal to stand. If more substantial prompting is necessary, one may use a pen, key, or other blunt object to tap on the animal's spine or caudal thigh. If the animal remains recumbent, the operator should stand at the animal's back, buckle his or her knees into the animal's ribs, and simultaneously slap the animal's chest on the contralateral side. If the animal still won't stand, and efforts have been made to ensure that the animal is physically able to stand, then an electric cattle prod may be used as a last resort. Occasionally the animal can be intimidated to stand without being shocked. The humming noise made by activating the prod or touching the uncharged nodes of the prod to the animal may prompt it to rise.

For weak cattle it may be helpful to use hip lifters (Figures 3-8 and 3-9). These should be applied tightly to the tuber coxae and then attached to a hoist. Once the cow stands the hip lifters should be removed immediately because they can cause pressure necrosis and they can be dangerous if the cow swings toward a person. If an animal is unable to stand at all, it can be floated in a water tank (see Figure 3-3). It can be quite labor intensive to get the cow into the tank and keep her floating with the head above water, but the results can be very favorable.



Figure 3-7 Portable stocks.



Figure 3-8 Hip lifters.

Moving Animals by Halter

A halter-broken cow may follow the handler when the lead is pulled. However, an animal unfamiliar with haltering will resist being pulled. Often the animal will move forward more willingly if the handler steps to the animal's side, caudal to the shoulder and behind the point of balance, while maintaining control of the lead. The animal's natural tendency is to move forward. The drawback is that the handler's position is deep in the animal's flight zone; therefore the

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Figure 3-9 Hip clamps applied on each tuber coxae.

animal may charge forward because it perceives no hindrance in its forward flight path. To maintain control, the handler must keep the lead rope short and pull the animal's head caudally toward its shoulder, impeding the animal's ability to proceed forward. If the animal gets out of control, the rope should be released. Safety should not be compromised in an attempt to halt a stampeding animal.

If an animal is reluctant to proceed, the handler should make sure advancement is not impeded and no one is standing in the animal's path or line of vision. When encouragement is required, the handler should again start with the least noxious prodding necessary to stimulate the animal to move forward—a slap on the rump or a prod along the backbone with a blunt object. Although the discomfort from a tail twist is often effective, there is a risk of breaking coccygeal vertebrae. The electric prod should be used only as a last resort. Shouting increases confusion, stress levels, and impatience and should be avoided.

Moving Animals through Chutes

Using flight zones works well to move a single animal or group of animals through a chute. The handler walks alongside the chute in the opposite direction the cattle should move. Because the flight zone is deeply penetrated, the animals will move forward as the handler passes their points of balance. As the line of animals begins to move, the handler walks outside the flight zone back to the lead animal and penetrates the zone again to walk alongside the animals. Repeating this pattern causes the cow or group of cows to keep moving forward.

When moving cattle, the handler should eliminate as many distractions as possible. Chutes should be constructed without corners to facilitate uninterrupted forward movement. Cows are leery of abrupt turns. The chute should terminate in a well-lit space as animals are reluctant to enter dark spaces. Solid-sided chutes limit the animals' distraction, so they will move forward more readily. People should stay out of sight as much as possible. Objects that could distract or frighten the animals should not be left in or on the chutes.

Head Restraint

Halters

Properly used, halters provide excellent control of an animal's head. The halter should be placed with the nosepiece over the top of the animal's nose halfway between the eyes and nostrils to prevent airway obstruction or trauma to the eyes. The lead rope should run below the jaw. Putting the halter on upside down with the lead rope running behind the ears or over the nose is a common mistake. An improperly fitted halter severely compromises control of the animal's head and is prone to slip off.

Nose Tongs

A nose tong is a pincer-type device with blunt bulbous ends that are inserted into each nostril to apply pressure to the nasal septum. The discomfort deters movement. Nose tongs should only be used in conjunction with another form of head restraint such as a halter or head gate. Tension must be maintained on the nose tongs, but they should never be tied to a fixed object. If nose tongs are not available, the nasal septum can be grasped between the thumb and middle finger.

A nose ring is a variation of the nose tong that is permanently inserted through the nasal septum in bulls. Again, a halter should always be use in addition to the bull's nose ring to prevent excessive pressure from tearing the cartilage of the nasal septum.

Head Gates

Head gates are a necessity in working with large animals. Even the smallest cattle operation should be equipped with some type of head gate to provide ease in handling, restraint, and safety. The manufacture and design of head gates can range from homemade vertical wooden plank devices, dairy stanchions, and self-locking feeders to custom-made catches and devices. Head gates constructed with convex curved bars reduce vertical head and neck movement but may increase asphyxiation potential from a blocked trachea or the carotid arteries if the animal lies down or is oversedated. Straight bars are less likely to result in asphyxiation, but they do not restrict vertical head movement.

Single-file chutes provide ease in directing an animal into the head gate and restrict sideways movement of the animal. Squeeze chutes are commercially manufactured with the added advantage of having compressible side walls that apply pressure against the animal, providing greater control, creating a calming effect, and supporting the animal if it attempts to lie down. Chutes are an invaluable asset for controlling livestock, but they do limit access to the animal as well as create a potential for operator injuries between the animal and chute. Also, spring-loaded levers and moving parts can cause severe injury to handlers.

Kicking

A major consideration for personal safety is the animal's ability to kick. Cows are very deft kickers and are notorious for kicking to the side—"cow kicking." They also kick forward surprisingly well and can extend the leg as far cranial and dorsal as the shoulder. Cows are also very proficient at kicking straight backward. They may even "mule kick" with both hind feet at the same time. The safest place to stand when working at the hind end of a cow is immediately adjacent to the animal's body, so that the cow pushes the handler away rather than delivering a harmful blow with the snap of the kick. When working cranial to the hind legs, the operator should stay out of reach of a forward kick by standing level with the animal's shoulder at arm's length.

Hobbles

Hobbles may be used to tie the hind feet together to deter cattle from kicking. Commercial hobbles are available, but effective restraints can easily be fashioned out of rope.

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Flanking

A manual method to deter an animal from kicking is called "flanking." The fold of skin in the flank is lifted, and the handler's thigh is placed against the animal's stifle. This provides mechanical resistance that interferes with the animal's ability to kick. A commercially available device working under the same premise lifts the flank and attaches over the animal's back beneath the transverse lumbar vertebral processes. A flank rope can also deter kicking; it is placed around the cow's midsection cranial to the udder and cinched up cranial to the tuber coxae (hooks).

Tailing

Tailing discourages kicking by causing discomfort and distracting the animal's attention. To tail an animal, the tail's base is grasped and lifted directly over the animal's back. Care should be taken with this technique, because coccygeal vertebrae may fracture if too much force is exerted.

Tail Ties

A swishing tail may contaminate a previously cleaned site, catch the handler in the eye, or otherwise be an annoyance. Tying the animal's tail out of the way is imperative for many surgical techniques as well as handler safety when he or she works near the back of the animal.

A secure tail tie can be made using baling twine, rolled gauze, bandaging tape, or a light rope. One end of the rope is placed over the animal's tail below the last coccygeal vertebra. The switch (long hair at the end of the tail) is folded over the rope. The short end of the rope is run completely around the tail, made into a bow, and tucked underneath the loop that encircles the tail. This modified quick-release knot is tightened by pulling on the long end of the rope, which is then tied to a leg or around the neck. The tail should not be tied to a fixed object in case the animal escapes or falls down.

A proper tail tie will not loosen as the tail moves. Incorporating the switch into the tie prevents the rope from sliding off the end of the tail. If the tail has been docked or the switch cut short, the tail tie must be modified. A modified quick-release knot is tied at the tail's base with two or three half-hitches made distally, creating, in effect, a "Chinese finger trap" that prevents the rope from slipping off the bobbed tail. The free end of the rope is secured to the leg or neck as previously described.

Alternatively, the tail can be securely taped dorsal to the hock on the leg contralateral to the planned procedure. Care must be taken not to restrict blood flow to the distal tail.

Surgical Position

Surgical Tables

Surgical or tilt tables are convenient and effective for positioning animals for surgery or other procedures that require maximal restraint. Numerous variations are available, but commonly belly bands or squeeze panels and leg wraps are used to secure the animal to the table. The table is then mechanically or hydraulically tilted until the animal is in lateral or dorsal recumbency. Tilt tables are convenient and offer excellent restraint but may be financially unfeasible unless a large number of surgeries are done to compensate for the expense.

Casting

An animal may very effectively be maintained in lateral or dorsal recumbency by casting and rope restraint if no surgery table is available. The major disadvantage is that surgical procedures must be done at or near ground level, which may be inconvenient, uncomfortable, and exhausting to the surgeon, as well as making aseptic technique more difficult to maintain.

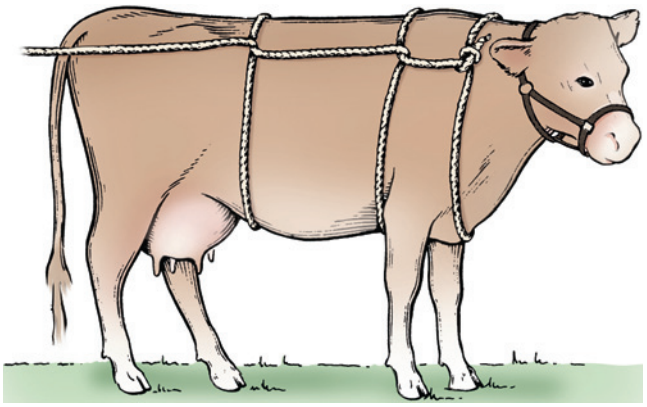


Figure 3-10 Position of the rope for casting a cow. (From Leahy JR, Barrow P: Restraint of animals, ed 2, Ithaca, NY 1953, self-published.)

Casting is a technique used to force an animal to lie down (Figure 3-10). A loop of rope is placed around the animal's neck with a bowline knot or a quick-release Honda. Some people prefer to run the loop over the neck and between the front legs to prevent undue pressure on the trachea. Two half-hitches are placed over the back so that the knots lie against the animal's spine when tightened. The first half-hitch is behind the shoulder, and the second is in the flank, cranial to the udder or caudal to the penis. With the head secured, the rope is pulled with steady pressure until the animal lies down. The rope is tied with a quick-release knot cranial to the second half-hitch to maintain rope pressure and keep the animal recumbent. The front and hind legs are bound together with hobbles or ropes. The legs are extended and tied to sturdy supports to secure the animal. Alternatively, for a quick procedure, the hind legs can be tucked under the second half-hitch. The animal can be balanced against a wall, between bales of straw, or supported manually if dorsal recumbency is required.

Foot Restraint

Hind Feet

Hind feet commonly are raised to treat infected or injured hooves or claws, manage leg wounds, or increase exposure to the udder and teats. The method described here is versatile and practical (Figure 3-11). One end of a rope is secured around the hind leg, dorsal to the hock, with a noose or quick-release Honda. The free end of the rope is passed through a beam hook suspended from the ceiling. Coming from behind the cow, the rope is passed between the udder and hock, around the lateral aspect of the hock, and back through the beam hook. Pulling down on the free end of the rope, the pulley system created will elevate the hind leg as it bends at the stifle and hock. The free end of the rope is fastened by tying a quick-release knot around the rope itself close to the beam hook or by tying to the stanchion or another fixed object.

Front Feet

Raising the front feet is physically more difficult than raising the back feet. The forelimb of an amenable cow can be raised manually. The handler's shoulder is placed at the crux of the cow's elbow. The dewclaws are grasped with one hand and the dorsum of the foot with the other. The handler applies lateral pressure to the cow's shoulder to displace its weight

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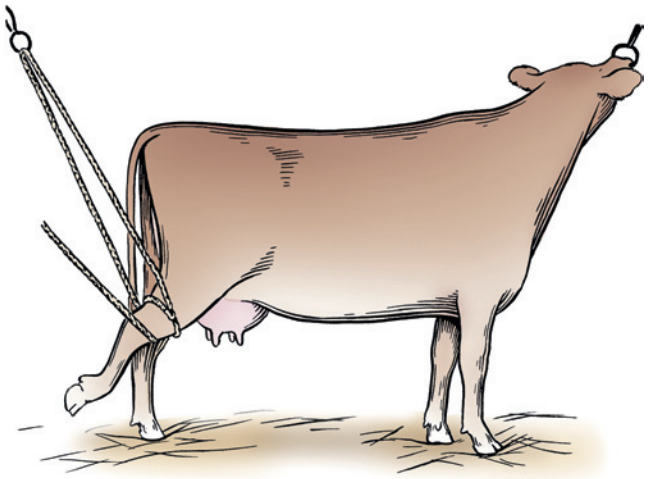


Figure 3-11 Position of a rope and beam hook used to lift a hind foot. (Adapted from Leahy JR, Barrow P: Restraint of animals, ed 2, Ithaca, NY 1953, self-published.)

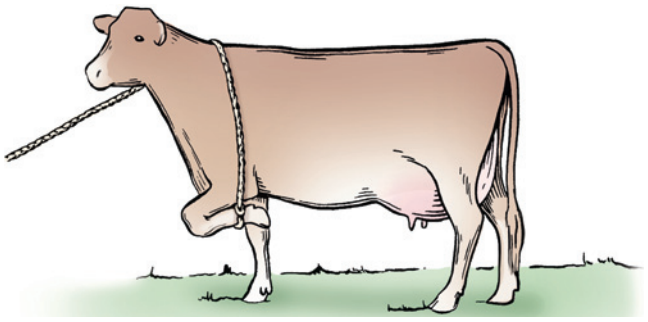


Figure 3-12 Position of a rope used to lift a front foot. (From Leahy JR, Barrow P: Restraint of animals, ed 2, Ithaca, NY 1953, self-published.)

onto the contralateral foot and simultaneously lifts the dewclaws and hoof, thus forcing the leg to bend at the carpus. Once flexed, the carpus and lower leg can be rested on a straw bale while the foot work is done.

Alternatively, a rope technique can be used to elevate the front feet. A rope is placed around the leg, dorsal to the fetlock and passed over a ceiling beam hook. The foot is raised and bent at the carpus. A second rope can be used to pull the foot laterally away from the animal's body to facilitate access to the foot. Both ropes should be secured with quick-release knots for ease in untying.

A third option uses one rope tied above the fetlock, run over the back of the animal, and secured (Figure 3-12).

RESTRAINT OF SMALL RUMINANTS

Moving Small Ruminants

When moving small ruminants (sheep, goats, or calves), the handler should use the same approach as for moving cattle, taking advantage of natural flight instincts and points of balance. Sheep and goats are very flock oriented; thus, whenever possible, the animals should remain together. If a single animal must be removed, it may be necessary to forcibly move the animal. Pulling or pushing risks injury to the animal. Undue force on the cervical vertebrae, strain on the leg joints, or excessive wear on the hooves are potential problems with forcing an animal to move. Carrying the animal may be necessary. If the animal is too large or unruly to carry, it should be loaded onto a cart or wagon. Prudent use of sedation is advisable (see Chapter 5). Hand-raised animals may be coerced with small amounts of sweet feed or their favorite treats.

To catch an elusive small ruminant, one should first attempt to move the herd or group of the animals into a smaller catch pen. The desired animal can then be cornered against a wall or fence. The animal is restrained by holding it around the neck and behind the rump or by reaching across its back and grasping the fold of skin in the flank. Horns serve as a convenient handhold but should be used with caution to avoid breaking them. Grabbing the wool is discouraged as it can damage the fleece of a production animal and may cause trauma to the integument. Restraining the animal by a leg is also inadvisable because the ensuing struggle could injure the animal or handler.

Head Restraint

As with cattle, control of the head is essential in controlling the small ruminant. Ironically, horns, which evolved for sexual prowess and defense, serve as a convenient handhold for restraint. If the animal lacks horns, a halter is necessary. For many procedures, including jugular venipuncture, ophthalmologic examination, or early dehorning, sufficient head restraint can be maintained by straddling the animal's neck. The animal's head should be turned caudally around the handler's leg and held between the handler's elbow and thigh.

Surgical Positioning

The appropriate use of chemical and rope restraint allows small ruminants to be securely maintained in proper surgical position. With the exception of some approaches to the head, few procedures are done with the animal standing. Sheep are generally amenable to minor operations without sedation or general anesthesia if appropriate local or regional anesthesia is used. Sheep generally tolerate being restrained on their rumps or in dorsal recumbency. To force a sheep onto its rump, the handler stands alongside the animal with one hand under its jaw and the other over its back. With one swift movement, the sheep's head is turned toward its back, away from the handler, so that it faces its rump. Simultaneously, the animal's rump is pivoted around the handler's leg or lifted by the fold of skin in the flank. Once the animal is sitting, it can be held in this position, propped against the handler's legs or reclining in a sheep cradle. Alternatively, the animal can be lowered into lateral recumbency and held down along the length of its torso. Sheep placed in dorsal recumbency are quite content to lie in a V-shaped trough.

Unfortunately, calves and goats are not so willing to be constrained. To place a goat or calf in lateral recumbency, the handler reaches over the animal's back; one hand grasps the intended dependent foreleg, and the other hand grasps the fold of skin in the contralateral flank. The flank is lifted while the front leg is pulled out from underneath and the animal is lowered to the ground. If sufficient assistance is available, animals can be adequately held in lateral recumbency for minor procedures. To do so, one person kneels along the dorsal aspect of the animal, places a knee on the animal's neck, and flexes and maintains upward control of the animal's dependent front leg while a second person extends the animal's exposed back leg and maintains pressure against the caudal thigh of the dependent leg. (Often the second person is seated on the

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ground directly behind the animal). Appropriate sedation is recommended for procedures of longer duration or if the animal is struggling excessively.

RESTRAINT OF SWINE

Moving Swine

Hand-raised animals may voluntarily follow a handler offering food treats. Otherwise, the pig may be driven from behind to the intended destination. When driving unpredictable or aggressive animals, a portable, solid barrier (hard plastic, slab of wood, or a door) is used to provide a safe partition between the pig and handler (Figure 3-13).

When working with individual swine, the handler stands at the animal's shoulder. Aggressive or frightened animals may attempt to bite. However, their bulk and short necks make it impossible for them to turn their heads backward without also turning their bodies, thus making the handler safe if positioned by the shoulder.





Figure 3-13 *A,* Hard plastic partition used to move pigs. *B,* Adult pig being "guided" safely using plastic partition.

Head Restraint—Snare

A snare can be fashioned from a rope or wire noose. The loop is passed over the upper jaw and behind the tusks. When the snare is tightened, the pig will pull backward to resist. A metal pipe threaded over the standing end of the noose will provide additional control of the head and prevent the animal from moving forward. The pig can be held in place for minor procedures or as chemical restraint is administered.

Surgical Positioning

Body Restraint

Pigs are very vocal and will loudly protest any kind of restraint. Very small or well-socialized pigs may be managed with body restraint. Suspending a neonate by its back legs with its head downward sufficiently immobilizes it for early castration, ear docking, and clipping needle teeth. For more extensive procedures anesthesia is recommended.

Crates or Chutes

Sows, and occasionally boars, in intensively managed herds are permanently housed in crates. Such confinement is often very conducive to veterinary examination and certain surgical procedures. Animals housed at large need to be moved into narrow chutes that restrict lateral movement and prevent them from turning around to facilitate veterinary procedures and examinations.

Barrier

Swine housed in pens individually, or in small groups, can be pinned against the pen wall with a slab of wood. If the animal is still be able to move forward or backward, additional assistance may be necessary to keep the animal confined.

RECOMMENDED READINGS

Grandin T: Behavioral principles of handling cattle and other grazing animals under extensive conditions. In Grandin T, editor: *Livestock handling and transport*, ed 2, New York, 2000, CABI Pub.

Grandin T, et al: Cattle with hair whorl patterns above the eyes are more behaviorally agitated during restraint, *App An Behav Sci* 46:117–123, 1995.

Leahy JR, Barrow P: *Restraint of animals*, ed 2, Ithaca, NY 1953, Cornell Campus Store, Inc.

DOWNER COWS: CASE MANAGEMENT AND APPROPRIATE USE OF A FLOATING TANK

André Desrochers and Gilles Fecteau

OCCURRENCE AND ETIOLOGY

Down cows have been a challenge for both veterinarians and owners for many years considering the lack of resources available on a farm to make an accurate diagnosis and establish optimal therapy. Recurrent hypocalcemia is still incriminated as the primary cause of downer cows but there are many other reasons for persistent recumbency: trauma, acute mastitis, lymphoma, and hypokalemia, among others. Public concern for animal welfare has increased awareness

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of appropriate handling of nonambulatory cattle. In many countries, down animals are not allowed to be transported alive. Prompt and thorough examination is therefore essential to decide if the animal has a fatal condition, can be treated conservatively, or would benefit from a floating tank. Inadequate handling of downer cows will create further damage and worsen the prognosis, which could have been good otherwise.

DEFINITION OF A DOWNER COW

A downer cow is often defined as a cow unable to stand after two consecutive treatments of hypocalcemia. It is a very narrow definition, limited to one category, although it may be the most common. The list of conditions possibly causing an adult cow to become recumbent can be summarized in a few broad categories: electrolyte imbalance (calcium, potassium, magnesium, and phosphorus), musculoskeletal injuries (coxofemoral luxation, gastrocnemius rupture), systemic inflammatory illness (acute metritis and mastitis), and nerve paresis (sciatic, obturator, or central origin (that is, lymphoma).

Several terms have been used to define a cow not able to rise and stand: *down cow, downer cow, alert downer, nonambulatory cow,* etc. As a referral center we generally use *down cow* to describe a cow that cannot walk out of the trailer upon arrival at the hospital. Once examined, nonambulatory cows are then subdivided into two categories: 1) those in which a primary cause has been identified and is considered reversible (e.g., hypocalcemia) and 2) those in which there is no obvious explanation for the inability to stand.

PATHOPHYSIOLOGY OF A DOWNER COW

Regardless of the primary cause, complications will develop over time from inappropriate handling, awkward movement of the animal, or unsuccessful attempts to stand or simply because of excessive pressure and inactivity.

In 1969, Fenwick showed that the incidence of problems related to recumbency following milk fever increased with time elapsed between onset of recumbency and treatment with calcium. For recumbency lasting under 6 hours before the first treatment, the rate of down cows is negligible; for 7 to 12 hours, he estimated the rate of complications to be 26%; for 12 to 18 hours, it is 32%; and for more than 18 hours, it reaches 38%.

In 1982, Cox et al. investigated the consequences of compression in down-cow syndrome. Fifteen adult cows were kept in sternal recumbency on a rubber mat for 6, 9, or 12 hours with the right hind limb under the body. Afterward, half of the cows were able to stand up but eight remained down. Among the latter, the right limb was stiff and swollen. During necropsy, the most obvious anomaly was the sciatic nerve in the caudal region of the proximal femur. The nerve was discolored and surrounded by a deposit of collagenous tissue. Muscle damage was limited to the same caudoproximal region of the thigh: the semitendinosus was the most affected (very pale and necrotic) as well as the gluteal muscle on the greater trochanter. Regular measurements of creatinine kinase for all animals showed values within normal limits 3 and 6 hours after anesthesia and similar levels for all the animals after 12 hours. Significant differences between the two groups (the cows able to stand or not) appeared 24 hours after anesthesia. The levels of creatinine kinase in the animals that stood peaked at 24 hours and began to drop, whereas the levels from downer animals continued to increase and peaked at 48 hours. Six days later, both groups found comparable levels of creatinine kinase. The comparable levels during the first day show that the two groups of animals had similar muscle injuries, indicating that only the sciatic nerve lesions found during autopsies could explain the trend toward prolonged recumbency in some cows. He also revealed how a pathologic condition in human medicine, also recognized in horses, afflicts downer cows: limb-pressure necrosis due to prolonged recumbency (Figure 3-14*A* and *B*). With an increase of pressure on the external soft tissue, vascular permeability increases, producing an extracellular accumulation of fluid and therefore swelling. If the fascia that surrounds the muscle prevents distention, the internal pressure will increase dramatically, even beyond the external pressure that initiated the problem. Tissue anoxia leads to cell damage and inflammation, which in turn induces an increase in pressure within the tissue.

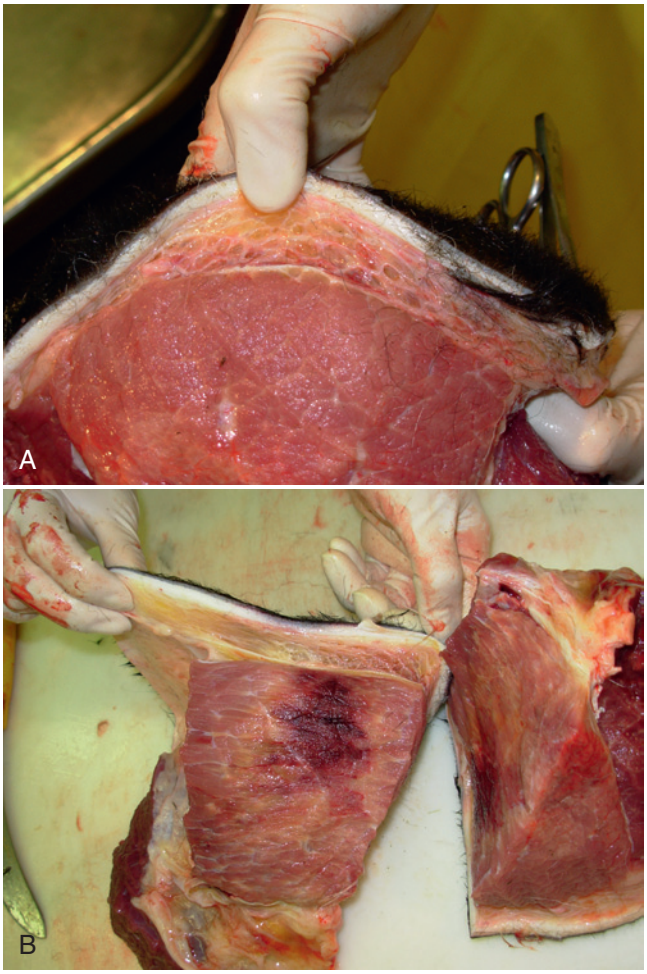


Figure 3-14 Pictures taken from a downer cow at necropsy. *A,* Although the skin is intact, the subcutaneous tissue is edematous. *B,* Muscular lesions are compatible with pressure necrosis.

ASSESSMENT OF A DOWNER COW

History

The cow's history is of paramount importance in the diagnostic process.

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Figure 3-15 Fetlock injury following continuous effort to rise with both hind limbs hyperextended.



Figure 3-16 The animal is restrained in lateral recumbency while the right hind limb is examined.

Age of the Animal

Cows older than 5 years are more likely to suffer from hypocalcemia and lymphoma in endemic countries. Primary trauma rather than metabolic origin must be suspected in younger cattle or in the dry-cow group.

Calving

Dystocia and forced extraction lead to inflammation of the soft tissue surrounding the pelvic canal. The most common peripheral nerve problems involve the obturator and the sciatic with subsequent paralysis or paresis.

Trauma

Trauma should be suspected as a primary cause if the animal is recumbent outside the postpartum period. However, self-inflicted trauma from unsuccessful attempts to stand (muscle tear, luxation) are also frequent. Traumas of the upper limb or vertebral column are difficult to diagnose.

Behavior While Being Recumbent

Specific questions on position and comfort of the recumbent animal should be assessed. Some cows will favor lying on one limb or side. While standing, was there any weakness, abnormal position or specific area of swelling that was noticed? A detailed description of any attempt to rise can be helpful in completing a problem list to establish a specific diagnosis (Figure 3-15).

Treatment History and Response

A detailed list of administered drugs, their posology (dose, frequency, and routes of administration), and response to treatment should be obtained.

Physical Examination

Physical examination of a downer cow is difficult but essential. The animal is often cornered in a small place, limiting manipulation. Nonetheless, time and energy should be directed toward this first and important task. The physical examination is performed methodically, keeping in mind four common causes of recumbency: acute systemic inflammatory conditions, musculoskeletal problems, neurologic injuries and electrolyte imbalance.

In large animals, it is common practice to perform the physical examination by side, right and left. The same principle applies to downer cows. However, it should be divided in sternal and lateral recumbency for each side. The animal must be in lateral recumbency for the musculoskeletal examination and to evaluate the mammary gland. The examination will start with whichever side the cow is lying on with sternal and lateral recumbency. Then the animal will be switched to the other side to repeat the same process. Auscultation and percussion or ballottement as well as abdominal palpation per rectum can be inconclusive on a recumbent cow. We often repeat them with the animal standing in the floating tank.

Table • 3-1

Musculoskeletal Conditions Frequently Affecting Downer Cattle

Pelvic limb	Gastrocnemius rupture
	Myositis
	Peroneus tertius rupture
	Ventral coxofemoral luxation and pelvic fracture
	Nerve injury (sciatic, obturator)
	Abductor muscle injury
	Femoral fracture (head and shaft)
	Collateral ligament rupture
Thoracic limb	Nerve injury (brachial plexus or specific nerve)
	Myopathy
	Ruptured triceps
Others	Vertebral column fracture or luxation
	Oblique muscle injury from excessive use of hip lifter.
	Acute laminitis

Musculoskeletal Examination and Conditions

As stated before, musculoskeletal injuries can be the primary reason for recumbency, or they can be secondary to injuries during manipulation or prolonged recumbency. The examination is performed with the animal in lateral recumbency. Bedding must be soft, or if available, padding or a mattress can be used to prevent further injuries during the manipulation (Figure 3-16). The examination is performed only on the uppermost limbs. The common conditions affecting the limbs are summarized in Table 3-1.

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Figure 3-17 With the animal in lateral recumbency and the leg slightly elevated, a Frick speculum is used to evaluate the patellar reflex.



Figure 3-18 An adult Hereford cow with a ruptured gastrocnemius muscle. The diagnosis is confirmed by flexing the tarsus while the stifle is maintained in extension.



Figure 3-19 An extended tarsus with a flexed stifle is compatible with a ruptured peroneus tertius (that is, fibularis tertius).

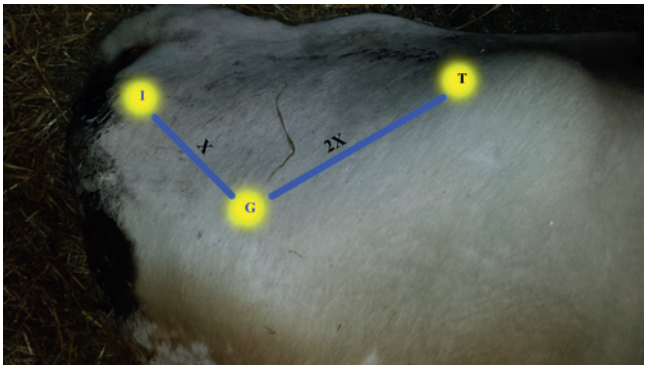


Figure 3-20 The normal triangle configuration of the tuber coxae (T), tuber ischia (I), and the greater trochanter (G) of the femur.

Pelvic Limb

The thigh and gluteal muscles are palpated for fibrosis, swelling, hardness, and pain. Skin sensitivity is evaluated with a hemostatic forceps by pinching the skin starting from the coronary band up to the stifle. With the limb slightly elevated, the patellar reflex is evaluated by knocking on ligament insertion on the tibial crest with a tool (e.g., a Frick cattle mouth speculum instead of a reflex hammer) (Figure 3-17). Then the limb is palpated and manipulated from the claws to the hip. Although many lesions can be found, the primary goal of this examination is to find the cause of recumbency. Digital dermatitis, tarsal bursitis, or mild joint distention cannot prevent a cow from standing up. Each joint and bone is stressed to elicit pain; the joints are flexed and extended, and long bones are firmly palpated.

The integrity of the gastrocnemius and the peroneus tertius is evaluated by flexing or extending the tarsus and stifle. Being part of the reciprocal apparatus, the stifle and the tarsus are flexing or extending in harmony. With a ruptured gastrocnemius, the hock can be flexed while the stifle is partially extended (Figure 3-18). With a ruptured peroneus tertius, the hock is extended while the stifle is partially flexed (Figure 3-19).

The stifle and the hock are evaluated for articular fracture and collateral ligament rupture. Lateral and medial movement of the joint will help to determine joint instability and abnormal craniocaudal limb angulation. Although cruciate ligament injury is possible, it is the authors' opinion that it will not prevent a cow from standing. Cruciate ligament injury physical evaluation will be more likely inconclusive with the animal in lateral recumbency. Condylar or supracondylar femoral fractures are not uncommon in adult cattle. It is diagnosed by abducting and adducting the distal limb. Crepitation can be felt at the stifle level, and the limb can be abnormally abducted.

The coxofemoral joint is first assessed by the relative position of the greater trochanter to that of the tuber coxae and the tuber ischii. The normal position of the greater trochanter is ventral to both of these bony prominences, and imaginary lines drawn between them will create a "triangle" with a shorter side between the greater trochanter and the tuber ischia (Figure 3-20). Positioning of the greater trochanter in line with the tuber coxae and tuber ischii suggests dorsal luxation of the coxofemoral joint. If a ventral luxation is present, the greater trochanter cannot be seen or palpated as usual because of its abnormal medial positioning. The limb is usually slightly abducted. The hip is further manipulated by forcefully abducting and adducting it. A subluxated hip can be ventrally luxated by excessive abduction, which is diagnostic. A normal abducted uppermost leg can form an angle of approximately 45 degree with the down leg. If the angle is 90 degrees, hip luxation must be suspected and/or trauma of the adductor muscles (Figure 3-21*A* and *B*). To

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Figure 3-21 A down cow with a ventrally luxated hip. **A,** The right hind limb is excessively abducted on presentation. **B,** With the cow in lateral recumbency, the limb is abducted with an abnormal angle of 90°.

complete the physical examination of the hip, the hands of the clinician are placed over the greater trochanter while an assistant is abducting, adducting, and circumducting, making a circle with the leg. Fracture of the physis of the head of the femur (capital physeal fracture) should elicit crepitation of the hip that can be felt and occasionally heard. Coxofemoral joint luxation should elicit more crepitation, excessive movement of the greater trochanter, and ease of abduction if the luxation is cranioventral. Palpation and location of the femoral head per rectum can also be performed if limb manipulation is inconclusive.

Thoracic Limb

With the cow in lateral recumbency as previously stated, the larger muscles are palpated for fibrosis, swelling, and pain.



Figure 3-22 Skin necrosis over the tuber coxae from excessive use of hip lifter.

Skin sensitivity is evaluated from the coronary band up to the elbow. Triceps reflex is assessed with the Frick speculum hitting the tendon at its insertion on the olecranon. Then each joint and bone is stressed to elicit pain with pressure, flexion, and extension.

Vertebral Column

Trauma to the vertebral column is suspected if there is bilateral paresis or paralysis of the limbs or if the animal is in pain for an unknown reason. Needless to say, the vertebral column is difficult to evaluate on a down cow. The lateral aspect of the cervical vertebra can be palpated. The neck is carefully flexed in different directions to elicit a reaction from the animal. An S-shaped neck is often observed on hypokalemic animals from muscle weakness. The spinous process and epaxial muscles of the thoracic and lumbar vertebrae are palpated for abnormal deviation, swelling, or pain. Crepitation can be felt over luxate or fractured areas. This is an extremely painful condition, and the animal must be immediately euthanized.

Other Areas of Concern

The use of a cow lift or hip lifter is still indicated in relatively small cows but must be discouraged in large cows. Inadequate use of them can seriously damage the oblique and other surrounding muscles of the tuber coxae (tensor of fascia lata, gluteal muscles), leading to massive irreversible muscle damage, keeping the cow down even if the primary problem was successfully treated (Figure 3-22). It must be clear that the cow lift is a rising system and not used to suspend the animal.

Ribs can be fractured from a fall or during careless manipulation of the downer cow. The affected animals will be in pain, tachypneic with a very superficial respiratory pattern. Ribs are individually palpated and pain reaction observed. An ultrasound examination can be used to confirm a fracture in the affected area. We have seen lung trauma from fractured ribs.

The tail is often neglected when manipulating or moving the animal. The sensitivity, motility, and color are evaluated upon admission of the animal. A necrotic tail can be at the origin of ascending neurologic infection. It is not unusual that the tail becomes damaged while the animal is recumbent and unable to move freely on her own (Figure 3-23).

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Figure 3-23 Necrosis of the tail secondary to a trauma from being down.



Figure 3-24 An adult Holstein cow with a radial nerve paresis. The upper limb is swollen from prolonged recumbency.

NONFATAL MUSCULOSKELETAL CONDITIONS ON A DOWNER COW

Muscular Damage

Muscular damage is of two origins: a specific torn muscle or myopathy or muscle degeneration and necrosis from prolonged recumbency. Previous studies have clearly shown the muscle damage secondary to prolonged recumbency on a concrete floor. All downer cows have some degree of muscle necrosis. However, greater than 25,000 U/L of creatinine kinase and 1000 U/L of aspartate aminotransferase, we found that the recovery rate is significantly reduced and the total cost if the animal survives significantly higher. Specific torn muscles can be the cause of the recumbency or secondary to unsuccessful attempts to get up. It is difficult to give a prognosis based on the location of the affected muscles. Usually the prognosis is based on the treatment's response. The affected animals must be on a deep bedding, their inflammation and pain controlled with NSAIDs, with judicious use of the floating tank. Although difficult to objectively assess, acute muscle degeneration and necrosis preclude the animal's ability to stand in the tank. It is suffering and it is the authors' opinion that these animals will benefit from simply resting in a well-bedded stall than trying to stand in the tank.

Peroneus Tertius (That Is, Fibularis Tertius) Rupture (See Chapter 15)

The peroneus tertius in cattle has muscle fibers that compare with those of the horse. It originates from the extensor fossa of the distal femur along with the digital extensor and inserts in the area of the tarsometatarsal joint. It will rupture after a hyperextension of the tarsus although the stifle remains flexed. This situation is often encountered when the animal slides with the limb backward. Its rupture renders hock flexion more difficult and the animal might fumble, having difficulty clearing the ground with its foot. Based on ultrasound findings, the rupture is more a muscle tear than a straight tendinous rupture, precluding any surgical attempt to suture it. It should not prevent the animal from standing or walking. Other than stall rest for weeks, there is no specific treatment for this condition.

Brachial, Radial Nerve Paralysis

While attempting to get up and stand, the cow might slip and overabduct a thoracic limb. The more dramatic consequence is radial nerve damage. Prolonged lateral decubitus on a hard surface can also be at the origin of the damage. Typically the elbow will drop and the carpus remains partially flexed (Figure 3-24). Animals with ruptured triceps or humeral or olecranon fracture will show a similar posture. Affected animals have difficulty getting up and standing, lacking the strength to keep their balance. Physical examination rules out fracture. Skin pricking or pinching and triceps reflex confirm the diagnosis of radial nerve paralysis. Splinting at the caudal aspect of the forelimb, from the foot up to the elbow, might help the animal to stand. If there is a neurapraxia, strength will come back in less than 3 weeks. If paresis is still present after that, nerve damage is significant and a prognosis is difficult to establish.

FATAL MUSCULOSKELETAL CONDITIONS ON A DOWNER ADULT COW

The pain and weakness engendered by some conditions will prevent the cow from getting up even in a floating tank. Even if repair of a luxation or fracture is surgically successful, the chance of survival is slim in a downer animal. The amount of pressure or stress on the repair is tremendous on a debilitated cow trying to rise and stand. Postoperatively, these animals will have to be floated; otherwise prolonged decubitus will worsen the prognosis. Floating a cow in a tank with a cast, a splint, or simply a fresh surgical wound seems feasible with appropriate measures (sticky surgical drape on incisions, plastic bag over a cast) but is often unrewarding. Although it is feasible, a grave prognosis

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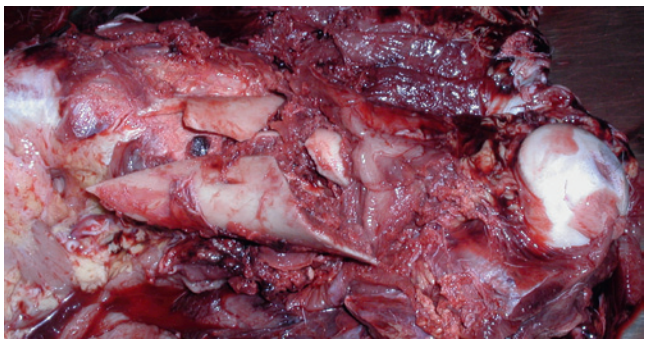


Figure 3-25 A necropsy specimen from an adult down cow with a severely comminuted femoral fracture.

with thorough explanation of the situation must be given to the owner.

Ventral Coxofemoral Luxation

As reported in the literature, most cows affected with ventral luxation are presented down (68% to 83%) compared with dorsal luxation (6% to 43%). The origin of this ventral luxation is most likely secondary to an extreme abduction because of a slippery floor or obturator nerve paresis or paralysis. Although clinical examination is often diagnostic, a ventrodorsal radiographic image of the pelvis will confirm the luxation but not its exact direction. Acetabular, femoral head fractures will worsen an already grave prognosis. Therefore downer cows with ventral luxation are most often immediately euthanized. If reduction should be attempted, it must be within 48 hours. Close reduction of a ventral luxation is extremely difficult compared with a dorsal luxation. An open approach is possible but also extremely difficult. The cartilage, capsular, and adjacent muscles are extensively damaged, preventing efficient surgical stabilization and increasing postoperative relapse. Recovering animals should be kept in a small stall with deep bedding on a nonslippery floor for 2 months. Hobbles are used to prevent excessive abduction and recurrence of the luxation after reduction. According to one study, the prognosis factors for successful outcome were standing at admission (this is very rare with a ventral luxation), age less than 3 years, body weight less than 400 kg, and duration of less than 12 hours. Those criteria are rarely met in downer cows.

Ruptured Gastrocnemius

As described in Chapter 15, the rupture is usually at the tendinous-muscular junction. To keep a cow down, the rupture must be complete (see Figure 3-18). The condition and the repair carry a grave prognosis and the animal is rapidly euthanized.

Femoral Fracture

This is a fatal condition in adult cows because of the severity of the fracture. On a down cow, the femoral fracture is generally comminuted and condylar, with extensive soft tissue damage. The cow is unable to stand because of the pain and the lack of support from the shattered femur (Figure 3-25). Abnormal angulation and crepitation upon manipulation of the limb will confirm the diagnosis.

Vertebral Trauma and Lymphoma

Vertebral trauma often results in spinal cord injury. Affected animals are in pain, and limbs can be paralyzed depending of the level of the trauma. The vertebral column is palpated, and the clinician should look for abnormal tumefaction, pain, deviation of the spinous process, and panniculus reflex. Careful examination of the skin sensitivity and reflexes of the limbs might help localize the affected area. Special attention must be in the thoracolumbar region. Lateral radiographic views of the vertebral column can be performed to confirm the diagnosis. Cerebrospinal fluid tap at the level of the lumbosacral area can confirm the diagnosis of trauma or lymphoma, depending of the severity and the location of the disease.

Acute Systemic Inflammatory Conditions

With the physical examination the clinician should be able to rule out the frequent inflammatory conditions that can occur during the puerperal period: acute metritis and mastitis (check all four quarters, even those difficult to reach because they are under the cow).

Neurologic Deficit

As stated in the previous section on musculoskeletal examination, skin sensitivity and reflexes may be useful in locating the nerves involved when the cow is recumbent. If the animal is standing in a floating tank or with the help of straps, it is easier to pinpoint the location of the damage. Remember that in most cases several nerve branches can be affected, complicating the clinical aspect of a problem. For example, the sciatic and obturator nerves are often injured during difficult parturition. It is difficult to be precise in determining the extent of nerve damage and its prognosis. We rely on clinical evaluation. Electromyography could be used, but we don't have experience with this procedure.

Electrolyte Imbalance

Calcium, magnesium phosphorus, and potassium are the primary cause of recumbency in many cases. Clinical signs associated with electrolyte imbalance should be evaluated carefully. Laboratory tests are often necessary to state with certainty that the electrolyte concentrations are within normal range. Often previous treatments will mask the clinical signs of classic milk fever, and marginal residual hypocalcemia cannot be identified without a laboratory analysis.

Treatment and Management of a Down Cow

Moving the cow to a larger stall or trailer or directly to a floating tank must be undertaken with caution. We have seen many animals traumatized in the process of moving them, from simple abrasions to a broken tail and torn muscles. Direct traction on the animal is totally unacceptable. The pelvic limbs should be tied together (hobbled) to prevent abductions that can result in severe muscle tears and even dislocated hips.

The primary problem must be treated first and fatal conditions eliminated before investing time and effort on a down animal. Before attempting to help the animal to rise and stand, we must assure that the animal is comfortable.

Stall and Stall Surface

The consequences of recumbency must be prevented at all costs by moving the affected animal to a floor other than concrete and keeping it in a normal anatomic position. Ideally, the cow should have a large stall, where she can turn around and move without difficulty, with a dirt floor covered with a thick layer of straw. Thirty centimeters of sand with a gentle slope for good drainage is an excellent alternative. Sand has the added benefit of not retaining

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Figure 3-26 An adult Ayrshire with skin necrosis from prolonged recumbency. **A,** The skin is black with a leather aspect. It is just distal and caudal to the greater trochanter, a common pressure point. **B,** A pressure ulcer on the olecranon.

water or urine, which prevents skin maceration. Another advantage is that it molds to the cow's body and provides better weight distribution. If she is unable to change sides herself, the cow has to be rolled over regularly (ideally every 4-6 hours) to minimize the pressure on the skin, muscles, and nerve structures (Figure 3-26*A* and *B*). After she moves, pay special attention to the down limb(s). Make sure the limb bearing most of the weight of the animal is in a normal sleeping position and not stretched under her. Care must be taken to maintain renal perfusion by keeping the animal hydrated. Regularly offering water is important. A cow's digestive system slows when recumbent, so it is helpful to maintain appetite by ensuring the palatability of food and its close proximity.

Fluid-Replacement Therapy

A recumbent animal is often dehydrated, and fluid replacement should be considered. Oral or intravenous fluid therapy will help restore basic functions. The fluid should contain calcium and potassium unless blood results show that these electrolytes are within normal range. Many dairy cows in the immediate postpartum period are challenged by some degree of lipid mobilization. The presence of ketones should be measured and dextrose added to the fluid therapy if necessary.

Pain Control and Antiinflammatory Drugs

The administration of an analgesic improves the comfort of the animal and helps maintain appetite. Whether it is to reduce inflammation around the nerve structures or to decrease the acute inflammatory response associated with endotoxemia, the use of NSAIDs in the treatment of recumbent cows is no longer controversial. However, there are no guidelines for the selection of a specific NSAID or steroidals. Steroidals are usually used when nerve structures are involved and NSAIDs when acute inflammatory response is diagnosed.

Stress caused by the recumbency and/or by a primary condition is often significant enough to explain the high incidence of abomasal ulcer. In addition, the effect of antiinflammatory treatments on the mucosal defense mechanisms in the stomach can result in an ulcer. As abomasal ulcer is difficult to treat in ruminants; it is better to prevent it. It is difficult to decide if the animal would benefit more from NSAIDs for the muscular damage or be better off without them to prevent abomasal ulcer.

Antibiotic Therapy

This will be indicated if an infectious process is identified by clinical or laboratory examination. Be aware that many recumbent cows develop clinical signs of pneumonia (fever, tachypnea, increased respiratory sounds, and sometimes a cough). The majority of cases appear to benefit from antibiotic treatment.

LIFTING A COW

Many systems have been designed to lift cows, but very few do a good job. Most of the systems were designed many years ago when the average cow's weight was 500 kg. This is not the case anymore. The following is an evaluation of the advantages and disadvantages of the different assistive technologies available to lift down cows with emphasis on the floating tank. All of them are rising systems. They are not made to make cows stand for hours. If the cow does not help herself, she must be let down and rested until later in the day or the day after. It is our opinion that insisting on lifting uncooperative animals is useless.

Physical Assistance

You can best help a cow get up by supporting the base of the tail, which acts as an anchor. Take the time to properly position the limbs beforehand. It is also a good idea to change the side a cow is on just before giving her a boost in case the limb on which she spent the night is a bit weak.

Lifting Straps

Several models exist and each offers its own advantage, but they all have a major drawback: the animal squeezed in a strap is just not comfortable (Figure 3-27*A* and *B*). In addition, if the cow is unable to stand, the pressure in some areas quickly leads to complications (wounds, swelling). We have seen abdominal muscles torn because the animal was left hanging in straps.

Hip Clamps

Hip clamps are still widely used, even though the clamps cause significant muscle damage for large cows. If used on small cows by someone with experience, they can be useful;

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Figure 3-27 **A-B**: Different strap systems used.

however, we believe that this technique is outdated, and we strongly discourage its use (see Figure 3-9).

Inflatable Ball

The deflated ball is slid under the cow and inflated with a special pump. The animal is strapped to the ball. Although the principle is interesting, it is very difficult to keep a cow in balance on that system.

Flotation Tanks/Aqua Cow

The advantage of this system is that it facilitates standing without abdominal compression (e.g., straps) or muscle compression (e.g., hip clamps). Once the animal is standing, it is easy to examine the pelvis and limb position and to note any swelling or deformities of the proximal limbs and if the cow is putting weight equally on all four legs. Another advantage of this technique is that it avoids ischemia compression associated with recumbency. Flotation tanks are limited by the fact that they require access to a large amount of water (ideally warm). Flotation tanks in no way replace the necessity of examining an animal carefully, but given their superior performance in helping lift down cows, it improves the prognosis compared with other devices.

Although often called flotation tanks, the cow does not float. It is still a rising system where the animals have to bear weight and stand by themselves (see Figure 3-3). Briefly, here is the sequence of events to put a cow in a tank:

1. Physical examination of the animal with emphasis on the musculoskeletal system.
2. The cow is put on a rubber mat with hobbles on the hind limbs and pulled into the tank with a halter on (Figure 3-28*A*).
3. After the front and back doors of the tank are secured, lukewarm water fills up the tank as fast as possible (Figure 3-28*B*).
4. Forcefully restrain the animal down by keeping the head on her side until there is enough water to help her stand (Figure 3-28C).
5. While standing, the head is secured to the front of the tank and a specially designed feed bunk is installed (Figure 3-28*D*).
6. If the cow is unable to stand and simply float, we usually leave her for 5 to 10 minutes, pushing her side-to-side until she stands by herself. If unsuccessful, the water is drained out of the tank and the cow moved back to her stall.

After floating 1000 cows in 20 years, we know certain facts. The overall prognosis is at least 50% with the tank without considering diagnosis. If fatal conditions are not included, the prognosis reaches 60%. Alert and eating down cows have a better general prognosis. It takes an average of 3 days to make a down cow stand with a floating tank. If she does not stand by then, her prognosis is guarded and a discussion with the owner should take place to consider euthanasia, taking into account the actual value of the animal. We have successfully floated animals for 2 weeks before they were able to stand by themselves. It is costly and is reserved for elite animals.

The animal will be discharged from the hospital when she can stand by herself without help for at least 2 days in a row. She'll be leaving with the hobbles on, with strict instructions to keep them on for a few more days at the farm (Figure 3-29).

COMPLICATIONS

There are many complications on downer cows. They can further injure themselves by sliding while getting up. Mastitis is a serious concern, especially if the animal is on sawdust (*Klebsiella* sp.), or the facilities do not allow adequate milking. Anorexic peripartum cows are susceptible to displaced abomasum, ketosis, and ulcers. Some of these cows will run a fever for an unknown reason.

Down cows that have gradually stopped eating or that have suddenly developed complete anorexia should be reexamined carefully. A significant and life-threatening complication could have developed (acute mastitis, stomach ulcer, gastrointestinal accident) that could seriously reduce the chances of success.

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Figure 3-28 **A,** The cow is on a rubber mat ready to be moved into the floating tank. **B,** The back and front doors are locked in place. **C,** The cow is forcefully kept still until there is enough water to stand easily, avoiding injuries. **D,** The cow is now standing, bearing weight on all limbs.

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Figure 3-29 An adult Holstein cow ready to go home. She still has hobbles and will keep them during hauling and convalescence on the farm.

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BIOSECURITY

Gillian A. Perkins

The term *biosecurity* is referring to the prevention of zoonotic diseases that could cause disease in veterinary colleagues, employees, and clients, along with the prevention of inhospital transmission of various infectious diseases to farm animal patients. This chapter focuses on an infection prevention program for haul-in facilities for doing day surgeries. These typically involve a facility with a few stalls and an area for performing surgery. Many cow-calf beef operations will use a haul-in facility for cesarean sections and neonatal calf management, whereas in the dairy areas, many practices may choose to perform LDA surgeries in a haul-in facility. Alternatively, large dairy farms develop a treatment area for on-site surgeries. A mixed practice may also choose to treat calf scours and urinary obstruction in small ruminants. Biosecurity for veterinary teaching hospitals (VTH) are described in more detail, and reviewers are referred to the recommended readings at the end of the chapters. These are valuable resources when planning and implementing a biosecurity program for a private practice.

The most important aspects of a biosecurity program with the previously mentioned goals for a surgical facility start with basic hygiene practices that are listed here:

- Promoting personal hygiene habits among veterinarians and staff to include excellent hand hygiene, professional attire, and routine cleaning of personal items such as cell phones, stethoscopes, and pen lights
- Minimizing the time the animals spend in the facility, with outpatient management being preferred
- Routine cleaning and disinfection of all areas of the hospital to include stalls; surgical, diagnostic, and treatment areas; reception area; pharmacy
- Timely and appropriate manure removal and waste management
- Routine cleaning and disinfection of medical equipment (ultrasound machine, surgical lamps, etc.)
- Controlling the flow of human and animal traffic to go from clean, to clean-contaminated, to contaminated, and out
- Limiting entrance of patients with infectious diseases of concern and providing a separate area for treatment of animals with infectious diseases, such as calf scours

The most routine surgeries in dairy and beef cattle, small ruminants, and pigs are not infectious in nature. However, the animal may be subclinically infected and shed infectious diseases of concern for your facility during hospitalization and surgery. The most common agent, and one that has caused problems for many VTHs, is *Salmonella* spp. This agent can persist in the environment despite adequate cleaning and disinfection protocols and can cause mild to severe disease if contracted in a hospital. Johne's disease, or *Mycobacterium paratuberculosis*, although a major concern on a farm, is not considered as much of a concern for a veterinary practice due to the manure management and low environmental load accompanied by short hospital stays. It is important to define the infectious diseases of concern for your practice (hazard identification). These agents may differ among geographic regions and may be affected by client perception, likelihood, and severity of disease induced by the agent. There are certainly many infectious agents that are a nuisance to the veterinarian, the veterinary care providers, and the client—for example, external parasites, such as lice. But they are unlikely to present a major expense to control or to disrupt your ability to see other patients. In general, diseases of fecal-oral transmission (*Salmonella* spp., *Cryptosporidium parvum*) or indirect contact (multidrug-resistant *Enterobacter* spp. or methicillin-resistant *Staphylococcus aureus*) are of most concern. If animals are seen concurrently from different farms then respiratory (bovine respiratory syncytial virus, bovine viral diarrhea, and other) and fomite transmission of pathogens also becomes a concern.

Dystocia management and cesarean sections are routinely fetal malposition or mismatch size but also carry the risk of being abortions due to infectious conditions such as brucellosis, leptospirosis, and Q-fever, all of which are zoonotic.

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Every effort should be made to be as clean as possible during obstetric manipulations, donning rectal sleeves, a new set of coveralls, and/or water-resistant overwear. After the dystocia, the veterinarian and staff should change and wash hands, and the area should be cleaned and disinfected. If any infectious condition is suspected, showering on site before handling other patients may be necessary. Any fetal or aborted tissues should be contained and placed in a medical waste bag or container and disposed of appropriately or sent to a diagnostic laboratory for further testing.

Prevent entrance of infectious diseases into your facility. Outpatient surgical procedures done at a haul-in facility minimize the time the patient spends at the facility and thus reduce contamination of the environment by the patient as well as the risk of contracting other disease agents of hospital origin or from animals from other farms. For the most part, if an animal has an infectious disease of concern to your hospital or treating facility, then the animal should be either treated or managed on the farm or brought into the facility with appropriate precautions and isolation to prevent spread. This could include a designated area away from the surgical outpatients that has its own supplies (feed tubs, shovels, water buckets, etc.) or supplies that can be designated to that patient and area until the animal is discharged. Personal protective equipment (PPE), such as one-time-use disposable suits,[4] plastic boots, and examination gloves, could be used when handling the patient.

In general, your practice should clean and disinfect the environment on a regular basis to minimize the infectious disease burden and, hence, the chance that another hospitalized animal will become clinically ill. That said, having a building with appropriate walls and floors that can be disinfected is very important. For example dirt floors or unfinished wood boards cannot be disinfected and are not the substrate of choice for the hospital setting. There are many products available for this purpose, and a good review of disinfectants can be found at the Center for Food Security and Public Health at Iowa State University (http://www.cfsph.iastate.edu/Disinfection/index.php). The proper selection takes into account the effectiveness of the disinfectant against various disease-causing organisms balanced with the safety (for both humans and animals), effect on the environment, and cost. When cleaning and disinfecting the hospital environment, it is always important to remove organic debris, such as feces, urine, shavings, etc., and then use soap and a scrub brush to clean the area followed by the disinfectant of your choice. Adhering to the appropriate dilutions and contact time is essential for any disinfectant to be efficacious.

When returning home to the farm, if possible, the animals should be separated from the rest of the herd for 3 days or more and their temperature taken once or twice daily. This is especially important if they have come into contact with animals from other farms. Providing information to the client in the discharge instructions regarding biosecurity issues is important, and they should contact you immediately if the animal has any medical problems postoperatively. Should a patient develop a fever upon return to the farm, then an infection associated with the surgical procedure or a nosocomial infection may have occurred. Surgical complications include a surgical site infection, pneumonia secondary to inhalant anesthesia or aspiration during recumbency, and catheter site infections. Alternatively, the patient may have acquired an infectious disease in the hospital, and now the animal is clinical. Performing a physical examination, determining the cause of the fever, and knowing the previous history of the veterinary practice will help guide the diagnostic and treatment plan for these patients.

[4]For DuPont™ Tyvek® Coveralls, see http://www.dupont.com/products-and-services/personal-protective-equipment/chemical-protective-garments/brands/tyvek-protective-apparel/products/tyvek-coveralls.html.

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SPECIAL CONSIDERATIONS WHEN WORKING WITH RESCUE ORGANIZATIONS

Emily A. Barrell

An ever-increasing population of farm animals seen in veterinary practices and universities includes those from rescue organizations and sanctuaries. Numerous groups exist throughout the United States that provide care for all species of farm animals, including cattle, swine, sheep, goats, and poultry. From small, privately owned rescue groups to large, nonprofit sanctuaries, these organizations often have far different financial considerations, treatment goals, and management capabilities than those of traditional livestock production operations. The unique nature of these animals as food-producing species in a nonproduction setting poses an interesting challenge to the practitioner when contemplating drug usage, implications on herd health, and ultimate long-term outcomes for these animals. This chapter will highlight several of the special considerations associated with treating farm animals from rescue organizations.

The prescription of medications is an important and regular part of any veterinarian's job, and medicating livestock from animal rescue organizations is no exception. Although these animals have been taken in with the intention that they will never enter the food chain, they continue to be regulated by the same rules as their food-producing counterparts. The Food Animal Residue Avoidance Database (FARAD) is a national, USDA-sponsored cooperative project, with a primary mission to prevent or mitigate illegal residues of drugs, pesticides, and other chemicals in foods of animal origin, with no consideration given to whether an animal or its products are intended for use in the food chain or not. As per FARAD representatives, the Food and Drug Administration (FDA) has mandated that regardless of whether an animal is a pet or in a rescue organization, if it is a member of a food-producing species, it is considered a food animal (personal communication). As such, both major (cattle, poultry, and swine including pot-bellied pigs) and minor (goats, sheep) species housed in sanctuaries, acquired

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by rescue organizations, or kept as companions are subject to the same restrictions and regulations that guide the use of drugs in all livestock species.

Therefore it is imperative that veterinarians working with and treating this unique group of livestock be familiar with all regulations that apply to food animal species. *On-label drug use* refers to the use of an antimicrobial, anesthetic, analgesic, or other drug in the manner specifically detailed on the product label and approved by the FDA. However, due to the limited number of medications approved for use in livestock species, use of drugs in an extralabel fashion became legal in 1994 under provisions of the American Medicinal Drug Use Clarification Act (AMDUCA). Extralabel drug use (ELDU) is permitted only under the direct supervision of a veterinarian with an established veterinary-client-patient relationship (VCPR), and only drugs approved for use in humans and animals may be utilized. Use of drugs in an extralabel fashion by a rescue organization without a valid VCPR (for example, a drug prescribed for one animal and used in another animal without examination of that animal by a veterinarian) or use of drugs that are not FDA approved (for example, compounded medications) remains illegal. Furthermore, ELDU is legal only in cases in which an animal's health is suffering or threatened and may not be used for enhancement of production.

Although AMDUCA provides a route for the use of medications in an extralabel fashion, it also mandates that the FDA can prohibit use of an entire class of drugs in selected animal species if the FDA determines that (I) an acceptable analytical method needs to be established and such a method has not or cannot be established or (II) the extralabel use of the drug or drug class presents a public health risk. The FDA can also limit the prohibition on extralabel use to specific species, indications, dosage forms, routes of administration, or a combination of these. Multiple drugs are regulated under AMDUCA and are categorized as those without approved label uses and therefore prohibited or those with restricted ELDU. Group I drugs are those without any allowance for extralabel use in any food-producing species, including cattle, swine, poultry, sheep, and goats (Box 3-1). With the exception of fluoroquinolone-class antibiotics, which must be used strictly according to label recommendations, none of these agents carry label recommendations for livestock species, making their use in these animals illegal. Group II drugs are those with restricted extralabel uses in food-producing species. These agents carry restrictions that may or may not apply to all food-producing species (Table 3-2). For example, cephalosporin antibiotics, such as ceftiofur sodium, may be used in cattle and swine for conditions other than those as specified on the label, but use must be limited to the same dose, route, frequency, and duration as those on the label. In contrast, extralabel use of cephalosporins is not restricted when used in the minor food animals (for example, sheep and goats).

Another notable example of ELDU in rescue animals is the use of medications specifically to manage pain and provide palliative care for animals. Animal welfare and prevention or alleviation of pain and suffering are important topics for all veterinarians, including those who work in traditional production settings. There are currently no medications approved by the FDA in the United States solely for the purpose of analgesia; therefore the use of any drug for such purpose is considered extralabel (Smith 2013). Regardless, for rescues and sanctuaries, animal welfare may be the most important governing philosophy, so practitioners working with these groups are tasked with providing the best pain management possible while still working within the confines of what is legal and allowable. Examples of conditions that might require pain management in a rescue setting include chronic osteoarthritis, developmental orthopedic disease, chronic neurologic disease, or neoplasia. Analgesics and NSAIDs that have been used in our clinic in the treatment of such conditions include aspirin, carprofen, firocoxib, flunixin, gabapentin, ketoprofen, meloxicam, phenylbutazone, pregabalin, doxycycline, and tramadol. Tramadol and pregabalin are classified by the Drug Enforcement Agency as schedule IV and V drugs, respectively, whereas all others listed are readily available to most veterinarians. Because NSAIDs and steroids carry the risk of gastrointestinal ulceration and renal medullary crest necrosis in all species, careful monitoring of patients receiving these drugs is necessary.

Local therapies for chronic joint disease have been used with some success in our clinic to supplement systemic

Box • 3-1

Drugs without Allowable Extralabel Uses in Any Food-Producing Animal

Chloramphenicol
Clenbuterol
Diethylstilbestrol (DES)
Fluoroquinolone-class antibiotics
Glycopeptides, including vancomycin
Medicated feeds
Nitroimidazoles, including metronidazole
Nitrofurans, including nitrofurazone

Table • 3-2

Drugs with Restricted Extralabel Uses in Food-Producing Animals

DRUG	RESTRICTION
Adamantane and neuraminidase inhibitors	ELDU prohibited in all poultry
Cephalosporin-class antibiotics (except cephapirin)	ELDU restricted in cattle, swine, chickens, turkeys No ELDU for disease prevention No ELDU at unapproved dose, route, frequency, or duration Agent must be approved for that species and production class ELDU restrictions do not apply to minor species
Gentian violet	ELDU prohibited in all food-producing species
Indexed drugs	ELDU prohibited in all major species (exceptions for minor species)
Phenylbutazone	ELDU prohibited in female cattle older than 20 months
Sulfonamide-class antibiotics (except approved uses of sulfadimethoxine, sulfabromethazine, sulfamethoxypyridazine)	ELDU prohibited in lactating dairy cattle

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treatment. For example, methylprednisolone acetate has been used intraarticularly in the affected carpus and coxofemoral joint (the latter with ultrasound guidance) of a 2-year-old Nubian doe with progressive arthritis secondary to caprine arthritis encephalitis (CAE) virus, providing additional analgesia in combination with a regimen of meloxicam and gabapentin. In a 6-year-old Hampshire hog with severe, bilateral stifle osteoarthrosis, intraarticular injection of methylprednisolone acetate, silicone oil, and morphine was used to supplement ongoing treatment with firocoxib. In addition to intraarticular injections, topical diclofenac cream has been used locally for analgesia over a joint.

To complement the aforementioned therapies, alternative and ancillary therapies such as physical therapy, acupuncture, and nutritional supplements can be considered in those patients with chronic pain. Intramuscular polysulfated glycosaminoglycans (Adequan) could be considered in cases of joint disease. In the hog described in the previous paragraph, glucosamine/chondroitin/avocado soybean unsaponifiables (Cosequin ASU) were added to the multimodal pain management plan and provided additional relief from pain associated with chronic arthritis.

It must be reiterated to the reader that all of the examples mentioned represent off-label use of analgesic medications. Often, there have been no studies or drug trials in the species of interest on which to base recommendations for withdrawal intervals when using medications in an off-label fashion in livestock. Therefore direct inquiries to FARAD regarding the use of analgesics can and should be made on a case-by-case basis. It is ultimately the responsibility of the supervising veterinarian to remain current on all regulations that apply to food animals, including those in a rescue or sanctuary setting, and to ensure that the organizations responsible for these animals be aware of the implications and consequences of improper use of these drugs. To view updates to the list of drugs prohibited for ELDU in food animals, visit www.fda.gov/cvm. For more information on FARAD-recommended withdrawal intervals for extralabel use of approved food animal drugs or to search for required withdrawal times for approved food animal drugs, visit www.farad.org.

Because it is the mission of most rescue organizations to provide indefinite shelter and care for their animals, culling an animal afflicted with a chronic, serious, or contagious disease is often not a viable course of action. Thus not only is care of the affected patient a primary goal, but also biosecurity and screening for infectious diseases within the herd become of paramount importance for veterinarians working with animal sanctuaries or rescues. Notable examples of diseases encountered in a rescue setting that have implications for herd health include small ruminant lentiviruses such as CAE and ovine progressive pneumonia (OPP), caseous lymphadenitis, parasitism, Johne's disease, and reportable diseases such as pseudorabies and brucellosis in swine and, rarely, prion diseases such scrapie in sheep and goats. It is important that each organization identify diseases that are both new to and endemic within their herds and have screening guidelines in place for new additions. Discussion of the ideal method of detection of diseases and timing of testing is an excellent way for the veterinarian to establish a routine, working relationship with the rescue or sanctuary.

CAE and OPP in small ruminants serve as excellent examples of the need for long-term management of a disease in a rescue or sanctuary rather than eradication through culling, as may occur in a production setting. Although CAE can cause clinical signs that include leukoencephalomyelitis, pneumonia, and mastitis, the most common manifestation of disease that we see in our population of hospitalized, rescued small ruminants is progressive polysynovitis and arthritis. Affected goats have ranged in age from juvenile to aged animals, and most present after therapies with NSAIDs and other pain medications such as gabapentin or tramadol have failed to provide relief or halt progression of the disease process.

The most common method of transmission of CAE and OPP involves passage of the virus in colostrum and milk from an infected dam to a susceptible neonate. However, horizontal transmission through direct contact is also possible. Therefore to prevent the spread of disease, offspring of affected dams should be separated and fed an alternate source of colostrum and milk. New additions to a rescue should be tested for these lentiviruses, as well as any animals in contact with a resident animal that tests positive. All positive animals should be housed separately from their seronegative cohorts. Furthermore, although CAE tends to affect goats and OPP more commonly affects sheep, both species can be infected by both viruses, and so it is recommended that sheep and goats be housed separately. These recommendations are frequently difficult to implement in a rescue organization. Space and housing are often limited, so segregation of positive and negative animals is logistically difficult. In particular, caregivers often find the idea of separating dams from their offspring to be more ideologically unpleasant than the actual disease transmission. Thus the disease has remained a challenge to eliminate from rescue herds in our experience.

As a case example, a 6-year-old mixed breed ewe was presented to our clinic for weight loss of 6 months' duration despite a good appetite, labored breathing, and a cough that was not responsive to treatment with antimicrobials. When the ewe had been acquired as a member of a group of rescued lambs, one herdmate had tested positive for OPP and succumbed to disease. Although the ewe had previously been tested for OPP and was negative on AGID, her clinical signs and history of comingling with an affected herdmate dictated repeat testing. PCR and ELISA confirmed a positive test result. The ewe had been comingled with 12 other sheep at the rescue facility in the 6 years after her rescue. Therefore the organization elected not to segregate the sheep as exposure to the herdmates had likely already occurred. Palliative care included provision of a high-fat, high-protein pelleted feed to supplement her diet, as well as steroid therapy. Despite treatment, the ewe continued to lose weight and was humanely euthanized 6 months after diagnosis. This case highlights the fact that subclinical infections can be present within a herd, as well as the need for testing of exposed animals, perhaps with multiple tests if there is strong suspicion of infection in a group.

Perhaps the most common diagnosis made in our population of hospitalized rescue animals is parasitism. Whether the infestation is detected secondary to routine fecal flotation in a surgery patient or if it results in the primary presenting complaint of anemia, neurologic disease, or diarrhea, infection with parasites affects all species of livestock. Animals housed in rescues or sanctuaries are often housed in heavily stocked areas, may have access to pasture, and frequently harbor parasites that are resistant to many, if not all, classes of anthelmintics subsequent to repeated deworming, all in stark contrast to current recommendations for management of parasites in groups of animals (Fleming, 2006). All of these factors combine to result in animals that are chronically affected by parasites, become quickly reinfected after deworming, and serve as reservoirs for the spread of parasites to the remainder of the animals at the rescue. When resistance has developed, herd management becomes increasingly important to decrease parasite burdens. In a production setting, it is recommended that animals with heavy worm burdens be culled, as they are

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likely to always be less productive then their less heavily parasitized herd-mates. Furthermore, they serve as sources of infection to other animals. However, in a rescue setting, culling is not a viable option, and therefore identification and segregation of animals with high worm loads are essential.

Currently, the American College of Veterinary Internal Medicine (ACVIM) recommends that new additions to an organization be isolated in a dry lot and simultaneously dewormed with triple-class anthelmintic therapy (for example, moxidectin, levamisole, and albendazole), with feces collected before and 14 days after deworming for fecal egg count reduction testing (FECRT). After this regime, the animal should be moved to a "dirty" pasture or pen, as any remaining parasites would be considered resistant to all three classes of dewormers and a high risk to the remainder of the herd. For those animals already present in a rescue setting, routine fecal flotation should be performed by a qualified laboratory and a targeted deworming plan formulated based on these results and in combination with FAMACHA scoring of adult animals. New approaches to the traditional FAMACHA scheme involve the consideration of the resistance level of the herd and careful balance of the use of more effective compounds versus the development of resistance with overuse. To document the occurrence of resistance in a population of small ruminants, fecal egg count reduction testing (FECRT), egg hatch assays, or larval developmental testing should be performed. Stocking rates for animal enclosures are also an important consideration when trying to limit parasite contamination, and, in general, it is recommended that there be no more than five to seven small ruminants per acre.

Rotating pastures every 2 to 3 months in tropical and subtropical climates may reduce pasture worm burdens, but in milder climates, 8 to 12 months may be necessary to reduce infectivity on contaminated pastures. This long duration is often not practical or possible for many rescue organizations, and so other housing strategies must be considered. Dirt paddocks are preferable to pasture to facilitate frequent removal of feces and prevent contamination of pastures. If pasture housing is necessary, keeping the grass length short can promote UV irradiation of larvae and reduce the burden in the field. If the anthelmintic resistance status of the farm is known, pastures may be rotated after deworming. It has also been recommended that dewormed animals be kept off pasture for 24 hours after anthelmintic administration to reduce the eggs excreted onto a pasture. Because most parasites, especially *Haemonchus contortus*, seem to be specific to a single species (that is, the *H. contortus* of small ruminants does not survive well in cattle and vice versa), one viable biosecurity tool is to recommend cograzing of species (cattle with small ruminants, simultaneously or in tandem) in an organization that houses multiple species. If both groups are being dewormed appropriately, this strategy can result in each species consuming the other's specific parasites, thus reducing the amount of larvae available for infection of the target species.

Importantly, animals identified as heavily parasitized or those without appropriately reduced burdens after deworming should be viewed as a risk to other animals on the property. Although culling these animals would reduce the overall worm burden on a property, this is usually not an option and goes against the governing philosophy for most sanctuaries and rescues. The organization should be made aware of the fact that heavily parasitized animals are often chronically debilitated and remain susceptible to parasitism and secondary disease. They should be housed separately or grouped with other animals of similar loads, both of which can be difficult to accomplish in rescue organizations in which space is often limited and animal numbers frequently high. Although these recommendations are all based on sound reason, they can be difficult to implement when space is a limitation, as it is with many rescue and sanctuary organizations. Further recommendations regarding anthelmintic resistance as it pertains to small ruminants can be found in the ACVIM consensus statement.

Johne's disease, caused by *Mycobacterium avium* spp. *paratuberculosis*, can be found in rescue settings as well in production herds. Examples in our clinic include a 5-year-old mixed breed ewe and a 10-year-old Toggenburg doe, both of whom had clinical signs of anorexia, diarrhea, and weight loss. Testing revealed heavy growth on Johne's-specific fecal culture and positive AGID and ELISA results in the ewe, and light growth on fecal culture and positive PCR and ELISA results in the doe. In both cases, infection had likely occurred at a young age and shedding of the organism into the environment before detection was probable, based on the pathophysiology of the disease. This example highlights another instance in which testing is necessary not only for individual patient management but also to protect the remainder of the herd and implement biosecurity measures within the rescue. Specific recommendations regarding clinical signs, diagnosis, and management of Johne's disease in individual animals, as well as in a herd, can be found in an ACVIM consensus statement.

Although rare in any setting, be it production or sanctuary, reportable diseases can occur and should be diligently monitored for by veterinarians working with livestock, regardless of their intended use. Examples of these conditions include brucellosis, transmissible spongiform encephalopathies (TSE) such as bovine spongiform encephalopathy (BSE) in cattle and scrapie in sheep and goats, and malignant catarrhal fever (MCF). Although testing for MCF and brucellosis is relatively straightforward, TSE testing in live animals is unusual in a production setting. The long incubation period of most TSEs means that disease can be contracted early, perhaps before an animal is acquired by a rescue organization, and it can be many years before overt signs develop. Alternatively, atypical BSE may arise spontaneously with no history of previous feeding of BSE-infected animal products in animals of advanced age. Scrapie in small ruminants can be transmitted either from dam to offspring in colostrum or via direct contact between animals. Clinical signs include pruritus, behavioral changes, weight loss, lack of coordination, or gait abnormalities. Other differentials to consider include external parasites, toxins, or aberrant parasite migration, namely *Parelaphostrongylus tenuis*.

Because the prion causing scrapie is not confined to the intestinal lymphoid tissue and nervous system as it is with BSE, ante mortem testing is possible in suspect cases. The Scrapie Eradication Uniform Methods and Rules are standards that have been adopted by USDA's Animal and Plant Health Inspection Service (APHIS) for controlling and eradicating scrapie in the United States and have application to all groups of animals, including those cared for by rescue organizations. Testing and identification of suspect animals must be done by, under the supervision of or verified by an APHIS or state representative or a USDA-accredited veterinarian. Live animal specimen collection often involves biopsy of the rectal mucosa at the mucocutaneous junction between haired and nonhaired skin of the rectum or the lymphoid tissue of the third eyelid. Samples are placed in 10 percent formalin and submitted for immunohistochemical testing. Positive results must be verified by a national veterinary services laboratory. For the complete Scrapie Eradication Uniform Methods and Rules, as well as detailed instructions on sample collection and submission and a list of approved scrapie and TSE laboratories, visit www.aphis.usda.gov. All

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tested animals, regardless of result, must be permanently identified with an official metal or tamper-resistant plastic ear tag or another USDA-provided approved tag. Genetic testing can also be performed on animals with compatible clinical signs, as well as in-contact herdmates. Although this test is not diagnostic for infection, it can identify susceptible individuals within a flock. Once present in a flock or herd, scrapie can be difficult to eliminate as the prion is resistant to heat and normal cleaning processes. Because the disease is progressive and fatal with no known treatment or cure, eradication of positive animals is mandated by the USDA, regardless of whether the animal is in a production setting, rescue, or kept as a companion.

Although working with animals in rescue and sanctuaries presents a unique set of challenges to the veterinarian, it also allows for unique opportunities to address challenging medical scenarios that may otherwise go untreated in a production setting. Animals with congenital malformations, debilitating diseases, or neoplasia, which under normal production settings would be removed from the herd, are given second chances by many charitable organizations. Each organization has its own set of financial limitations and philosophy governing the decisions regarding treatment of an animal's condition, but frequently these groups provide rare chances for veterinarians to formulate innovative solutions to previously untreated conditions.

Some noteworthy examples of groundbreaking treatments that have occurred in rescued or sanctuary animals in our hospital include the treatment of B-cell lymphoma in a large hog with the implantation of a vascular access port and subsequent chemotherapeutic therapy, surgical excision and radiation therapy for extrathoracic and intrathoracic thymoma in a goat, and surgical intervention and a prosthetic application for a 1½-year-old Jersey heifer. In this latter case, the heifer was acquired by a rescue organization at 1 year of age. After sustaining a traumatic injury to the left carpus during calving, she developed a severe angular limb deformity and inability to extend the limb, with the result being that she ambulated on her carpi. Additionally, carpal varus was present in the right limb. After acquisition by the sanctuary, radiography under general anesthesia revealed malformation and distinct absence of the distal row of left carpal bones, which were considered partially fused to the third and fourth metacarpal bones. Distal to the carpus, the limb was deviated palmarly and medially, and the soft tissue dorsal to the carpus was thickened due to callous formation secondary to standing and walking on the carpi. After extensive discussion regarding cost and prognosis for function and quality of life, the sanctuary elected to proceed with surgical correction of the deformation. The distal row of carpal bones was removed and a block osteotomy of the third metacarpal bone performed in order to allow for full extension of the limb. Tenotomy of the flexor carpi ulnaris and flexor carpi radialis muscles was performed, and arthrodesis of the proximal row of carpal bones to the third and fourth metacarpal bone achieved with application of a plate along the dorsal aspect of the limb, preserving the radiocarpal joint. The limb was cast in extension and a splint applied to the right forelimb from just distal to the elbow extending distal to the fetlock. After 7 months of physical therapy, cast changes, and bandaging, the cow was able to ambulate well on all four limbs, although she had developed marked digital flexor tendon laxity of both forelimbs. Under anesthesia, full limb casts of each forelimb were made so that custom orthotic splints (Veterinary Inclusive Prosthetics) could be created. Multiple adjustments to the splints were made based on measurements taken at recheck examinations. At the time of this writing, the heifer continued to ambulate on all four limbs.

RECOMMENDED READINGS

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CHAPTER 4

Fluid Therapy

SallyAnne L. Ness
(The authors and editors would like to acknowledge the previous author, Dr. Allen J. Roussel)

Patients who undergo surgery often require rehydration and electrolyte therapy, particularly in cases of surgery of the gastrointestinal tract. Dehydration and shock are the most important indications for rehydration, especially intravenous (IV) therapy. Failure to institute appropriate fluid therapy can result in case failure, regardless of surgical expertise.

ESTIMATING REHYDRATION NEEDS

Maintenance fluid requirements for bovine patients are highly variable, and depend on ambient temperature, dry-matter intake, and lactation status. Nonlactating adult cows in temperate conditions generally require approximately 3.5% to 5% of body weight in water daily. This is equivalent to approximately 40 to 60 mL/kg/day, or 20 to 25 L of fluids per day for a 500-kg animal. Lactating animals require additional water intake equivalent to 85% to 90% of their daily milk production. Patients with ongoing losses due to diarrhea, fluid sequestration in the third compartment, or excessive urinary losses will also require fluid replacement in addition to maintenance requirements. Preruminant calves have increased water requirements relative to adults and for these patients maintenance rates of 80 to 100 mL/kg/day are often used.

Fluid therapy in any patient should aim to 1) replace existing deficits; 2) replace ongoing water and electrolyte loss; and 3) meet maintenance requirements. IV fluid therapy can be costly and is rarely indicated as the sole means of fluid delivery; thus fluid therapy in the bovine patient often includes a combination of IV, intraruminal, and oral fluids.

Constable and coworkers showed that the time required for cervical skin to return to its normal position after tenting and the degree of eyeball recession in dehydrated preruminant calves are reasonably accurate methods to determine the state of hydration for calves. Table 4-1, based on this work, is a guide for estimating dehydration. Rehydration by IV fluid administration is recommended once dehydration reaches 8%. When skin pinched on the neck takes 6 seconds to return to normal and an eyeball is recessed 4 mm, it indicates the 8% dehydration point has been reached. Similar quantitative studies of the relationship between clinical signs and degree of dehydration for mature ruminants have not been undertaken. In the absence of data to suggest otherwise, the values for estimating dehydration in calves by using skin tent is probably a reasonable guide for mature cattle. However, emaciation can cause eyeball recession and loss of skin turgor, thus making these tests more difficult to interpret in cattle that have recently lost substantial weight. The body weight of mature ruminants can change dramatically based on the amount of ingesta and water in the rumen; therefore estimates of percent dehydration measured as a percent of body weight are probably not very accurate. Therefore from a clinical standpoint, we predict that a cow that is 10% dehydrated will have a normal or near-normal hydration status if 10% of her body weight in fluids is restored. She may still be well under her "normal" body weight because of lack of rumen fill. On the other hand, a cow with fore stomach distension from vagal indigestion or carbohydrate engorgement may gain weight from fluid sequestered in the third space compartment (inside the rumen) during the disease process but lose significant extracellular body water. Even if the hydration status of a ruminant patient could be predicted with certainty, factors other than hydration must still be considered in planning and executing the rehydration process. At times an experienced veterinarian can or must break the 8% rule. Sometimes cattle with severe dehydration and normal gastrointestinal function will recover uneventfully with only oral or intraruminal rehydration or with a combination of intraruminal rehydration and a small amount of fluids administered intravenously. In these cases, breaking the rule saves substantial time and expense. However, endotoxemic or hypovolemic cattle or those in shock—with only mild or moderate dehydration—should receive IV fluids. Acute strangulating gastrointestinal disease and acute mastitis are examples of conditions that result in this situation. Rapidly correcting or preventing shock is particularly important if a standing surgical procedure is planned. Finally, patients with fatty liver, chronic or refractory ketosis, and pregnancy toxemia may benefit from IV glucose therapy regardless of hydration status.

A flow rate of less than 80 mL/kg/h has been recommended for calves because of studies of central venous pressure in clinically dehydrated calves. Similar studies have not been performed to determine the maximum safe flow rate in mature cattle or small ruminants. However, significant elevation in central venous pressure occurred when approximately 40 mL/kg/h of an isotonic crystalloid was administered intravenously to dehydrated cattle with experimentally induced intestinal obstruction, even though no clinical signs were observed. Although this is a much slower flow rate than the maximal flow rate recommended for calves (80 mL/kg/h) and dogs (90 mL/kg/h), a 20 L/h total flow rate for an average dairy cow is a volume difficult to achieve with a single 14-gauge IV catheter. Therefore in most situations, IV fluids can be administered to mature cattle through a 14-gauge catheter as quickly as they will flow. Exceptions include cattle with heart disease, oliguric renal failure, or hypoproteinemia and those in recumbency.

A significant energy penalty is incurred if fluids are intravenously administered cold and must be warmed by the patient, especially neonates. Commercially prepared solutions ideally should be used. However, optimal solutions for many ruminant conditions are not readily available in some countries. In those cases, sterilizing locally prepared fluids is recommended. All of the usual components of solutions for cattle can be heat sterilized except sodium bicarbonate, which must be filtered. Alternatively, sterile distilled water

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Table • **4-1**

Guide for Estimating Dehydration of Calves

% DEHYDRATION	0	2	4	6	8	10	12	14
Eyeball recession (mm)	0	1	2	3	4	6	7	8
Skin-tent duration (seconds)	2	3	4	5	6	7	8	9

and reagent-grade salts can be used to formulate solutions. Contamination should be carefully avoided during and after preparation and solutions should be used immediately after they are made. Bacteria can be eliminated by autoclaving, but heat-stable endotoxins and pyrogens may be present in rural and municipal tap water. Therefore the use of pyrogen-free water is important.

CHOICE OF SOLUTION

Ideally, a rehydration solution is formulated after determining the individual patient's needs by laboratory evaluation. However, this is usually not practical or necessary. In general, ruminants, especially cattle, have rather consistent acid-base and electrolyte abnormalities associated with particular diseases, especially surgical diseases. The following data illustrate that alkalinizing solutions are not indicated in most sick cattle, especially those with surgical diseases.

In a study of over 500 cattle older than 1 month of age, blood gas and electrolyte determinations were made from patient venous blood samples. Dehydrated cattle were about twice as likely to have metabolic alkalosis as metabolic acidosis. If cattle with three diseases that are easily recognized (pneumonia, carbohydrate engorgement, and diarrhea) were excluded, only 16% of dehydrated cattle had metabolic acidosis. About 20% of the dehydrated cattle were hyponatremic or hypokalemic, whereas over 40% were hypochloremic. In another study of 350 sick cattle, approximately 60% had pH values within the reference range. However, many had compensated acidosis or alkalosis. About 53% had abnormally elevated concentrations of HCO_3, whereas about 10% had decreased HCO_3 concentrations. The only conditions of mature cattle in which metabolic acidosis was more common than metabolic alkalosis were carbohydrate engorgement, urinary tract disease, acute small intestine strangulation/obstruction (torsion of the root of the mesentery, intestinal volvulus, etc.), and enteritis/diarrhea. Cattle with abomasal displacement or volvulus, vagal indigestion, cecal displacement, or torsion and (in our study and experience) intussusception are usually alkalotic.

Fluid Therapy in Cattle with Metabolic Acidosis

Although relatively few in number, those conditions in cattle that are consistently associated with acidosis in ruminants are important to remember. Acidosis is the norm for calves with diarrhea and dehydration but not for other sick calves such as those requiring surgery for umbilical masses, fractured limbs, or gastrointestinal diseases. Calves with abomasal and intestinal surgical diseases are similar to mature cattle in their metabolic abnormalities. The most consistent causes of acidosis in cattle older than 1 month of age include carbohydrate engorgement and choke or dysphagia. Carbohydrate engorgement results in systemic acidosis because large amounts of volatile fatty acids and lactic acid are produced by bacterial fermentation. Both D- and L-lactic acid are produced, but only the L isomer is efficiently metabolized by mammalian tissues. Choke or other causes of salivary loss also cause acidosis because ruminant saliva is rich in bicarbonate. Diarrhea, fatty-liver disease, severe ketosis, and urinary-tract disease are relatively common diseases that have the potential to cause serious acidosis. In the author's experience, cattle and small ruminants with urethral obstruction or uroperitoneum are unpredictable in their acid-base and electrolyte status. Some diseases usually associated with alkalosis may be accompanied by acidosis in their later stages. These include abomasal volvulus, intussusception, and other intestinal obstructions.

Alkalinizing Solutions

Bicarbonate or metabolizable bases in alkalinizing solutions results in a hydrogen ion being consumed. This means the strong ion difference is increased. Lactate, acetate, gluconate, and citrate are some of the metabolizable bases commonly used to treat acidosis. Research has shown that simply restoring extracellular fluid volume is insufficient to rapidly correct acidosis in calves with naturally occurring diarrhea. Sodium bicarbonate is the most economical and readily available alkalinizing agent. However, it cannot be heat sterilized and forms an insoluble compound if used in solutions that contain calcium.

Alternative alkalinizing agents offer advantages and disadvantages. Lactate is probably the most widely used alkalinizing agent in veterinary medicine in the United States. Commercial preparations of lactated Ringer's solution contain racemic mixtures of D- and L-lactate. Only the L-isomer is metabolized efficiently, whereas most of the D-isomer is excreted unchanged in the urine. Therefore the racemic mixture has only about half the alkalinizing potential of an equimolar amount of the L-isomer. Unlike lactate, acetate is metabolized by peripheral tissues (not just the liver), has no significant endogenous source, and has no unmetabolized isomer. Citrate is used in some oral-rehydration–solution products, but its calcium-chelating properties preclude its inclusion in solutions for IV administration. Gluconate, an alkalinizing agent used in combination with acetate in commercially prepared solutions for IV administration to humans, dogs, and horses, is ineffective as an alkalinizing agent in calves. Widespread dire warnings in the veterinary and medical literature about the dangers of rapid administration of sodium-bicarbonate solution appear to be based on scant evidence and unfounded in cattle practice. Much anecdotal experience and a recent research report suggest that rapid correction of acidosis in cattle is usually without the complication of cerebrospinal-fluid acidosis. A study comparing intravenous hypertonic-saline solution to hypertonic bicarbonate solution in neonatal diarrheic calves found that hypertonic saline (5.85%; 5 mL/kg of body weight administered intravenously over 4 minutes) was appropriate for improving the hydration status within the first week of life in calves with slight-to-moderate metabolic acidosis (base excess ≥10 mM), whereas hypertonic bicarbonate solution (8.4%; 10 mL/kg body weight administered intravenously over 8 minutes) was useful for calves more than 1 week old with more severe metabolic acidosis (base excess -10 to -20 mM). In this study, both treatments were immediately followed by oral administration of 3 L of isotonic electrolyte solution and hypertonic bicarbonate solution was not recommended for calves with concurrent pulmonary disease due to impaired removal of CO_2 by the respiratory system.

When administering oral alkalinizing solutions to diarrheic calves, electrolyte solutions containing a high bicarbonate concentration (>70 mM) is not recommended, because

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the resulting sustained abomasal alkalinization may encourage growth of enteropathogenic bacteria. In these patients, isotonic electrolyte solutions containing the alkalinizing agents acetate or propionate may be more appropriate.

Calculating Base Deficit

Total base replacement needs for mature cattle are calculated by the following formula:

$$BD \times 0.3 \times BW = \text{Base required}$$

BD is base deficit in mEq/L, 0.3 is a conversion factor for extracellular water or the "bicarbonate space," and BW is body weight in kilograms (which is equivalent to liters of water). The base required is expressed as total mEq of base. Because a larger percent of body weight in neonates is extracellular water than in mature cattle, a 0.6 conversion factor is used for calves instead of 0.3.

When the acid-base status cannot be measured but acidosis is suspected based on the diagnosis, the veterinarian can correct for a base deficit of 10 mEq/L without substantial risk. Calculating the total base deficit in a 500-kg cow yields the following:

$$10 \text{ mEq/L} \times 0.3 \times 500 \text{ kg} = 1500 \text{ mEq}$$

When sodium bicarbonate is the chosen alkalinizing agent, one divides the total milliequivalents derived in the formula by 12, the approximate number of milliequivalents of HCO_3^- contained in 1 g of sodium bicarbonate, to arrive at 125 g, the calculated replacement needs. Because approximately 13 g of sodium bicarbonate dissolved in enough water to make 1 L of solution is isotonic, it would require just under 10 L of isotonic (1.3%) sodium bicarbonate solution to correct a BD of 10 mEq/L in this cow. Therefore about 10 L of isotonic sodium bicarbonate solution, or 125 g of sodium bicarbonate, is needed empirically to treat moderate acidosis in an average-sized cow.

Electrolyte Needs

Although acidosis is often accompanied by hyperkalemia, potassium moves from the intracellular to the extracellular compartment during acidosis and much is excreted in the urine; therefore a total body potassium deficit may exist. Serious hypokalemia may result when potassium moves from the extracellular to the intracellular compartment while acidosis is being corrected. For this reason, potassium should be included in alkalinizing fluids or should follow immediately after correction of acidosis. A moderate concentration of 10 mEq of K^+/L is safe for hyperkalemic acidotic cattle, even at the 20 L/h rate, if it is administered simultaneously with bicarbonate. If possible, additional potassium should be supplied orally or intravenously after the acidosis is corrected.

Some cattle with acidosis, especially those with carbohydrate engorgement, are hypocalcemic. Because acidosis causes a relative increase in ionized calcium, clinical signs of hypocalcemia may not appear until the acidosis is corrected. Because all patients, especially those with acidosis, that receive IV calcium therapy may develop potentially fatal cardiotoxicity, they should be monitored very closely. Subcutaneous or oral administration is certainly safer than IV administration.

Small ruminants suffering from obstructive urolithiasis and presenting with hyperkalemia and azotemia often benefit from fluids containing glucose or glucose/insulin as part of their preoperative stabilizaton. These patients rarely display profound acid-base derangements; one study of 108 goats with urolithiasis found 44.8% had mild to moderate metabolic alkalosis whereas 10% had mild-to-moderate metabolic acidosis.

Summary

In summary, neonatal diarrheic ruminants commonly suffer from metabolic acidosis. Clinically important is the fact that metabolic acidosis is not common in mature ruminants except in those with specific diseases. Calves—and perhaps other ruminants—should receive alkalinizing therapy when they have moderate or severe acidosis. Bicarbonate is the most efficient IV alkalinizing agent, but lactate and acetate are also effective. In acidotic calves, oral electrolyte solutions containing acetate or propionate may be more appropriate alkalinizing agents than those containing bicarbonate.

FLUID THERAPY IN CATTLE WITHOUT METABOLIC ACIDOSIS

Alkalosis is treated by providing extracellular anions in relative excess to cations. The strong ion-difference theory explains how this works: administering a relative excess of chloride ions increases the amount of plasma strong ions and reduces the strong- ion difference, thereby acidifying the extracellular fluid. In practice, this is accomplished with chloride-rich, potassium-rich solutions. Given adequate circulatory volume and plasma electrolytes, the kidneys can usually correct the alkalosis. Numerous surgical and nonsurgical conditions can result in significant metabolic alkalosis, including vagal indigestion, abomasal displacement or volvulus, traumatic reticulitis, abomasal ulcer disease, peritonitis, renal disease, and almost any condition that results in anorexia and gastrointestinal stasis. Hypochloremia and hypokalemia often accompany metabolic alkalosis in cattle. For efficient renal correction of metabolic alkalosis and prevention of recurrence, replacing sodium, chloride, and potassium, as well as extracellular fluid volume, is necessary.

Nonalkalinizing Solutions

For large volume replacement, isotonic or nearly isotonic solutions are used. Sodium chloride (0.9%) solution or Ringer's solution (*not* lactated Ringer's) is a good base solution. Potassium chloride should be added to either solution at a rate of 20 to 40 mEq/L. For ease of calculation, one can remember that 1 g of potassium chloride contains about 14 mEq of potassium ion. Therefore 2 g of potassium chloride/L yields 28 mEq/L, a reasonable concentration for most cattle without acidosis. Oral potassium supplementation should be provided as well because safely administering adequate IV potassium replacement is often difficult. A recent study by Constable et al evaluating oral potassium chloride administration to hypokalemic, hypochloremic, alkalemic lactating dairy cows found that administering a 24-h oral potassium chloride dose of 0.4 g/kg of body weight divided into two or more doses not only corrected electrolyte and acid-base derangements but also decreased peripheral fat mobilization. Surgical diseases, such as abomasal displacement or volvulus, often occur in dairy cattle in early lactation and risk for metabolic disease such as ketosis or hypocalcemia is great. Therefore including glucose and/or calcium in intravenously administered solutions is often desirable.

A 5% glucose solution can be administered at a slow IV rate for several days. It is usually preferable to infuse 2.5% to 5% glucose in 0.45% to 0.9% sodium chloride or other electrolyte solution. The veterinarian should base his or her decision on the relative energy, electrolyte, and fluid volume needs of the patient. Using hypertonic solutions of 550 mOsm/L or less has not caused adverse clinical effects

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Box • 4-1

Ruminant Electrolyte Solution

NaCl	140 g
KCl	25 g
$CaCl_2$ or	10 g
23% Calcium Gluconate	500 mL
Water qs to	20 L

in our hospital when electrolytes contribute 350 mOsm/L or less of the total osmolality with glucose contributing to the balance. Urine glucose is monitored so that the flow rate can be adjusted to minimize glucosuria. A minidrip administration set can be used to administer 50% glucose as an alternative to large-volume isotonic glucose therapy.

Calcium may be added to solutions for IV administration. Ringer's solution contains 5 mEq of calcium/L. Not only is calcium necessary for skeletal-muscle contraction and neuronal function and as an intracellular messenger for countless cellular processes, it is also essential for gastrointestinal smooth-muscle contractility. Calcium homeostasis is precariously balanced in postpartum dairy cattle and is particularly important in cattle that require surgery for gastrointestinal disease. Consequently, inclusion of calcium is recommended in all fluids administered intravenously to lactating dairy cows unless calcium supplementation has been administered within the previous 12 hours. As a rule of thumb, 500 mL of a commercial calcium borogluconate solution may be added to 20 L of solution for IV administration. Alternatively, 10 g of calcium chloride may be substituted.

A solution has been formulated and administered in our hospital by the intraruminal and IV routes (Box 4-1). It is prepared by adding reagent-grade electrolytes to filtered, deionized water for IV administration or feed-grade electrolytes to tap water for intraruminal administration. This solution is superior to calf oral rehydration solution, which usually contains unneeded alkalinzing agents and glucose and is rapidly metabolized by ruminal microbes. Calf oral rehydration solution is also relatively expensive in comparison to alternative homemade solutions.

Hypertonic Saline Solution

The merit of hypertonic-saline solution combined with intraruminal water or rehydration solution has been documented and offers another option for rehydration. The usual dose is 4 to 5 mL of hypertonic-saline (2400 mOs/L) solution/kg body weight administered intravenously over 5 minutes and 20 L of water administered orally. Water should be pumped into the rumen of cattle treated with hypertonic saline if they do not drink when allowed access to water. If electrolytes other than sodium and chloride are required, they should be added to the oral fluids. Hypertonic oral fluids (>300 mOs/L) should not be administered to calves, as they decrease abomasal emptying rate relative to isotonic electrolyte solutions, with profound inhibition of emptying occurring when solutions of >600 mOs/L are administered. In a study performed by Leah et al, diarrheic calves treated with IV hypertonic saline followed by isotonic oral electrolyte solution displayed a more rapid improvement in hydration status than those treated with isotonic oral-electrolyte solution alone. In that same study, calves treated with IV hypertonic saline alone continued to display signs of dehydration and metabolic acidosis at 24 hours posttreatment.

Summary

In summary, replacement electrolyte solutions for IV administration to cows with normal acid-base status or metabolic alkalosis should contain approximately 300 to 500 mOsm/L. The solution should contain sodium (135-155 mEq/L), chloride (150-170 mEq/L), and potassium (10-20 mEq/L). Lesser concentrations of electrolytes may be included if glucose is added to the solution. In dairy cows, calcium borogluconate (5-8 g/L) or calcium chloride (0.5 g/L) should be added. Cattle with ketosis, fatty liver, or negative energy balance may benefit by adding 10 to 50 g/L glucose. Hypertonic-saline (2400 mOs/L) solution administered at a dose of 4 to 5 mL/kg body weight intravenously and accompanied by intraruminal fluid is an alternative to large-volume IV isotonic fluid therapy.

EQUIPMENT AND TECHNIQUES

Although IV administration is sometimes essential, the time and supply costs for complete rehydration of mature cattle with isotonic electrolyte solution is great. Fortunately, the rumen provides a large reservoir that may allow reduction of the cost and time for administrating large volumes of fluids. In many cases, a combination of IV and intraruminal administration provides the optimal cost-benefit balance.

Intraruminal Administration

Intraruminal administration may be accomplished by using a Frick speculum and orogastric tube, a nasogastric tube, or a specially designed cattle-pump system with a self-retraining flexible esophageal probe.[1] Nasogastric intubation is probably the least stressful technique in mature cattle, although it requires a bit more finesse and a smaller tube than orogastric intubation requires. The pump system is the quickest and most efficient technique, but it is also the method most likely to lead to complications if care is not taken. The oral-pump–system flow rate must be moderated in some cattle, especially very sick ones, to avoid regurgitation and aspiration. In hospital pens or veterinary clinics, gravity flow devices can be constructed to facilitate oral-fluid administration. Special attention should be paid to cows suffering from endotoxemia, alkalemia, hyperinsulinemia, hyperglycemia, and/or hypokalemia, as these systemic conditions are associated with altered abomasal emptying and may affect fluid absorption and transit through the gastrointestinal tract.

IV Administration

The jugular vein is most commonly used for IV administration in adult cattle and is also the most useful for administering large volumes very rapidly. However, the auricular vein is quite satisfactory for longer-term administration (Figure 4-1). It provides easy accessibility and seemingly tends to have less catheter failure (accidental removal, kinking, or clotting). Besides fluids, other medications can also be easily administered via an auricular vein catheter. A 14-gauge catheter can usually be inserted in an auricular vein of a mature cow. Flow rates greater than 7.5 L/h have been achieved with a 14-gauge catheter in the auricular vein. Auricular-vein catheters have been maintained for more than 96 hours with heparinized saline flushed just twice daily. Tape secured around the chest just behind the elbows and/or around the ears (Figure 4-2) can be used to secure fluid lines to the patient and prevent them from tangling, detaching, or breaking when the cow moves about the stall. The neck and/or ear may also be wrapped to prevent catheter damage.

[1]Magrath Cattle Pump System, Magrath Manufacturing Co, McCook, NE, USA.

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Figure 4-1 Proper site to place auricular-vein catheter in the ear of a cow. Note that, so as to avoid a kink, the vein is entered distally so the tip is at least 3 cm from the base of the ear when the entire catheter is inserted.



Figure 4-2 Cow with a wrapped jugular catheter and tape belts around the chest and base of the ears. These are used to secure fluid lines to the patient and prevent tangling, detachment, and breakage.

RECOMMENDED READINGS

Constable PD, et al: Use of hypertonic saline-dextran solution to resuscitate hypovolemic calves with diarrhea, *Am J Vet Res* 57:97–104, 1996.

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Roeder BL: Acute effects of intravenously administered hypertonic saline solution on transruminal rehydration in dairy cows, *Am J Vet Res* 58:549–554, 1997.

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CHAPTER 5

Sedation, General Anesthesia, and Analgesia

Jordyn M. Boesch and Luis Campoy

PREPARATION FOR SEDATION OR GENERAL ANESTHESIA IN FARM ANIMALS

Preparation of the Patient

A complete history should be taken before sedating or anesthetizing a farm animal. This should include details about the chief complaint(s) as well as any comorbidities, medication history, previous sedation/general anesthesia/surgery (including anesthetic drugs administered and any complications), and, if the patient is a breeding female, pregnancy status and/or dates of important events in the reproductive cycle (e.g., breeding, freshening, parturition).

A complete physical examination should be performed by the anesthetist, especially in a patient with a history of systemic illness. Particular attention should be paid to the cardiopulmonary system: vital signs, mentation, mucous membrane color, capillary refill time, degree of dehydration, auscultation over all four heart valves, heart rhythm, lung sounds over all fields, pulse quality, and synchronicity with heartbeat. Pain is considered a vital sign, and the anesthetist should evaluate each patient for the presence/severity of pain. Some farm animal patients can be difficult to handle without some degree of chemical restraint, in which case the owner should be cautioned about the risk of administering anesthetic drugs without being able to perform a physical examination.

Fasting before elective general anesthesia reduces the volume of rumen contents. This reduces pressure on the diaphragm that can impair ventilation. It also decreases the risk of passive regurgitation and subsequent aspiration and rumen tympany. Although regurgitation can still occur, the volume of regurgitated ingesta is usually far less. Adult cattle should be fasted for 18 to 24 hours; water should be withheld for 6 to 8 hours. Young ruminating cattle and small ruminants should be fasted for 12 hours before general anesthesia; water deprivation is unnecessary. Swine should be fasted for 6-8 hours; water need not be withheld. Nursing farm animals, which are essentially monogastric animals, require minimal fasting (2-4 hours). Emergent anesthesia precludes fasting.

The necessity of preanesthetic blood work in patients that appear healthy based on history and physical examination is controversial. Obtaining packed cell volume (PCV) and concentrations of total solids (TS) and creatinine rules out major problems that should be addressed before induction and helps guide fluid therapy during anesthesia. Blood glucose (BG) concentration should be obtained in pediatric patients. Further laboratory work may be necessary in more complicated cases. A blood sample should be collected (before administering IV fluids) in systemically ill patients undergoing emergent general anesthesia to evaluate, at minimum, PCV, TS, acid-base status (including lactate concentration), and concentrations of creatinine, electrolytes (that is, Na^+, K^+, Cl^-, ionized Ca^{++}), and BG. A point-of-care analyzer such as the i-STAT 1[1] or the Stat Profile Critical Care Xpress[2] is useful for obtaining many of these values (Figure 5-1*A* and *B*). A complete discussion of acid-base physiology is beyond the scope of this chapter, but any clinician dealing with critically ill farm animal patients should have at least a basic understanding of this topic. A venous sample can be used for preanesthetic assessment of acid-base status, but only an arterial blood sample can be used to evaluate oxygen exchange in the lungs (that is, arterial partial pressure of oxygen). This may be important in farm animal patients suffering from diseases such as pneumonia.

Systemically ill patients requiring emergent general anesthesia should be stabilized before general anesthesia. Complete stabilization may not be possible, but correction of fluid, acid-base, electrolyte, and BG derangements and transfusion of blood products should at least begin before induction.

Preparation of Facility and Equipment/Supplies

Farm animal patients may be sedated or anesthetized in a hospital (in a dedicated area or in their stalls) or in the field. In practices that sedate/anesthetize a large number of farm animals in house, it can be helpful to designate a separate area for this purpose, if possible, that can be set up ahead of time with commonly used supplies (Figure 5-2). This area should be cleaned and disinfected between patients to help prevent transmission of infectious diseases. A quiet site will minimize sympathetic tone that can override drug-induced central nervous system depression and prevent distraction of the anesthetist that could cause anesthetic errors. If a standing procedure is to be performed (with or without sedation), a level, nonslip surface is essential. If recumbent sedation is to be performed, the patient should never be placed on a hard surface, which increases the risk of myoneuropathy, especially in large, heavy patients like adult cattle. Grass or a deeply bedded stall is a reasonable option in the field; shavings and straw can be aspirated and should be kept away from the patient's nose and mouth. An escape route for any people involved in the case should be readily accessible when dealing with large and/or fractious animals and should not be blocked by equipment or other obstacles. The area selected should be devoid of anything that might endanger human or patient safety, such as sharp objects or holes in the floor.

Adequate preparation of equipment and supplies before sedation or general anesthesia is very important, particularly in patients undergoing heavy sedation or general anesthesia or systemically ill patients. This includes, but may not be limited to, items needed for securing the patient's airway;

[1]VetScan i-STAT 1 Handheld Analyzer, Abaxis, Union City, CA 94587, USA.
[2]Stat Profile Critical Care Xpress, NOVA Biomedical, Waltham, MA 02454, USA.

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Figure 5-1 A, The VetScan i-STAT 1 Handheld Analyzer. **B,** The Stat Profile Critical Care Xpress.

providing positive pressure ventilation; supplementing oxygen; establishing IV access; administering emergency drugs; monitoring the patient; and providing thermal support. The precise items that may be needed will vary with the case. Emergency doses of epinephrine, atropine, and lidocaine should be calculated before sedation or general anesthesia.

Somewhat arbitrarily, a pediatric circle system has been recommended for patients weighing 7 to 10 kg, and an adult circle system has been recommended for patients weighing >10 to 136 kg (Figure 5-3). A large animal circle rebreathing system is used for patients weighing >136 kg (Figure 5-4*A* and *B*). A reservoir bag that holds three times the patient's tidal volume should be selected. Improperly checking anesthesia equipment before use can result in patient injury or death. In 1993 a preanesthesia checkout was developed by the FDA. In 2008 the American Society of Anesthesiologists (ASA) published new guidelines on items that should be checked before anesthesia. Although it is beyond the scope



Figure 5-2 A surgery suite designated for induction of general anesthesia in farm animals. Note the anesthesia machine with ventilator and roller cart with multiple drawers for supplies.

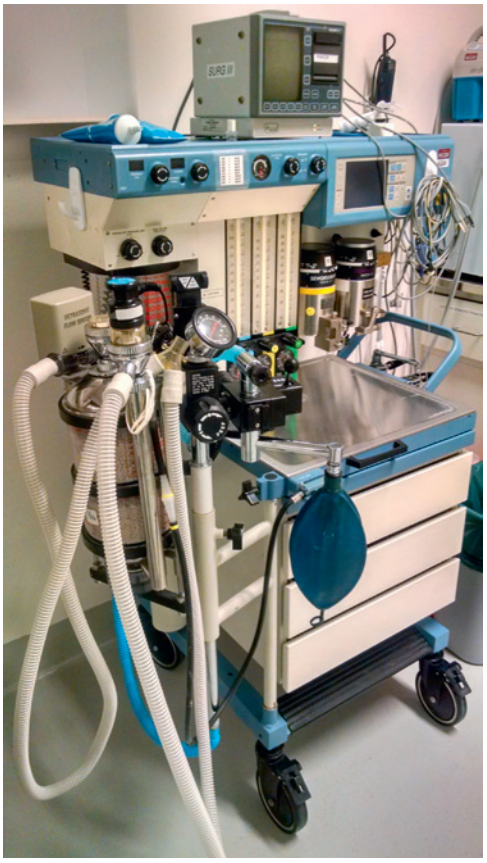


Figure 5-3 An anesthesia machine (Narkomed GS, North American Drager) for patients weighing ≤136 kg. Pediatric or standard adult hoses can be used on this machine.

of this chapter to discuss the preanesthesia checkout in detail, veterinarians are strongly encouraged to consult these references and use them as a template for developing checkout procedures that are appropriate for each individual anesthesia machine design and practice setting.

It is important to have a discussion with the patient's owner before the procedure about the risks of sedation and general anesthesia and whether resuscitation should be attempted if the patient suffers cardiac arrest.

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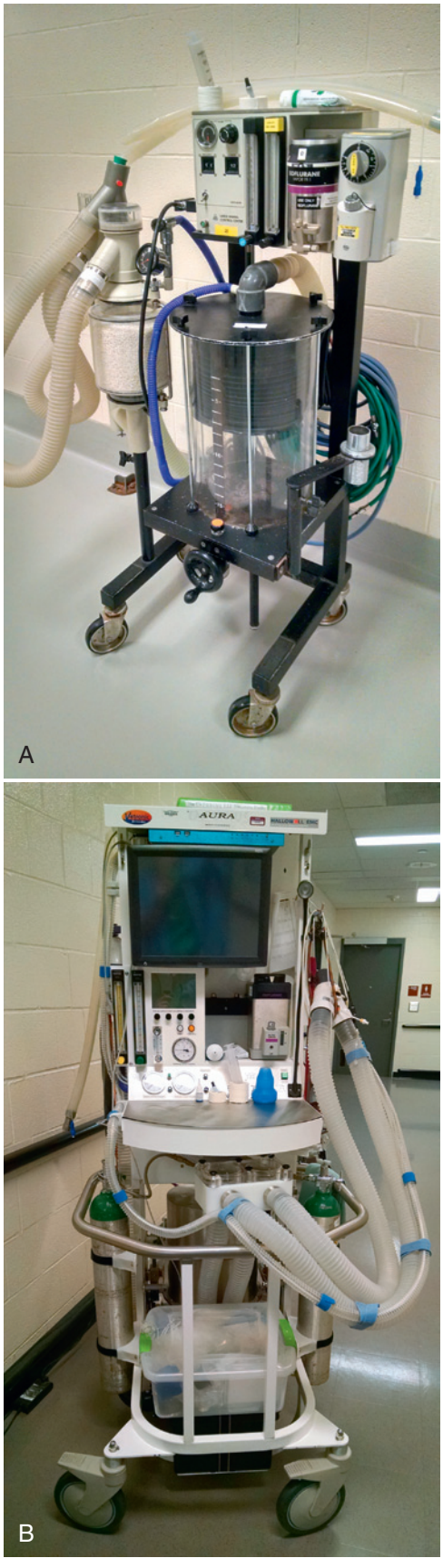


Figure 5-4 (*A*), Large-animal control center (North American Drager). (*B*), The Tafonius (Hallowell EMC) large-animal anesthesia machine. This machine can also be used with standard adult hoses for patients weighing 50-136 kg.

SEDATION OF FARM ANIMALS

General Considerations

Farm animal patients may be sedated for diagnostic or routine husbandry/surgical procedures, or they may receive sedative/analgesic drugs for IV catheter placement, after which general anesthesia may be induced via the catheter. Sedative/analgesic drugs can also be administered IV just before induction of general anesthesia (covered in Induction and Intubation).

IV catheters are not necessarily required for short, minor procedures in lightly sedated farm animals. IV catheterization are recommended in heavily sedated patients, systemically unhealthy patients, or patients in which it might be difficult to rapidly achieve venous access in an emergency (e.g., swine).

Monitoring and supportive care delivered during sedation depend on many factors, particularly the health of the patient. The sedated patient should be monitored closely for mucous membrane color, capillary refill time, heart rate/rhythm, respiratory rate/depth/character, pulse quality, and synchronicity with heartbeat. Placing a pulse oximeter is recommended if possible, because hypoxemia is common in sedated farm animals, particularly in lateral or dorsal recumbency. Oxygen supplementation (e.g., by facemask or intranasal administration) may be necessary (Figure 5-5*A* and *B*). An oxygen concentrator is very useful for field anesthesia and can deliver 3 to 5 L/min. The clinician should be prepared to intubate and ventilate (e.g., using an anesthesia machine or Ambu bag) with supplemental oxygen in case of emergency. The necessity of other monitoring is dictated by the individual case.

The recumbent ruminant or camelid should be kept in sternal recumbency whenever possible to facilitate ventilation and decrease the risk of regurgitation and aspiration. If lateral recumbency or dorsal recumbency is necessary, the patient should be positioned as described for general anesthesia. In all cases, locoregional anesthesia should be used for painful procedures.

Cattle

Cattle are usually sedated with an alpha-2 agonist, most commonly xylazine but occasionally detomidine. The other alpha-2 agonists are not yet routinely used in this species. The alpha-2 agonists have physiologic effects in cattle similar to those in other species, including sedation, analgesia, initial hypertension and reflex bradycardia followed by hypotension and bradycardia, decreased cardiac output, decreased gastrointestinal motility, interference with the effects of antidiuretic hormone and production of a large volume of dilute urine, hypoinsulinemia and hyperglycemia, increased uterine contractility, and decreased uterine blood flow. They should be used at the lowest possible doses or avoided in cardiovascularly compromised patients. Although concern has been expressed about administration to pregnant cattle, xylazine does not appear to result in abortions. Until further work is done on the effects on the calf in utero, these drugs should be used with caution in pregnant cattle.

Cattle require about one tenth of the xylazine dose that horses do, whereas the detomidine dose is similar to that used in horses (Table 5-1); note that the lower end of the dose range should be used in quiet cattle, whereas the higher end is recommended for very anxious/fractious cattle. As a general rule of thumb, the intramuscular (IM) dose is twice the IV dose. IV administration results in faster onset (within 2-3 minutes) and deeper sedation of shorter duration than IM administration. The relatively fast onset when administered IV allows the clinician to administer an initial low dose

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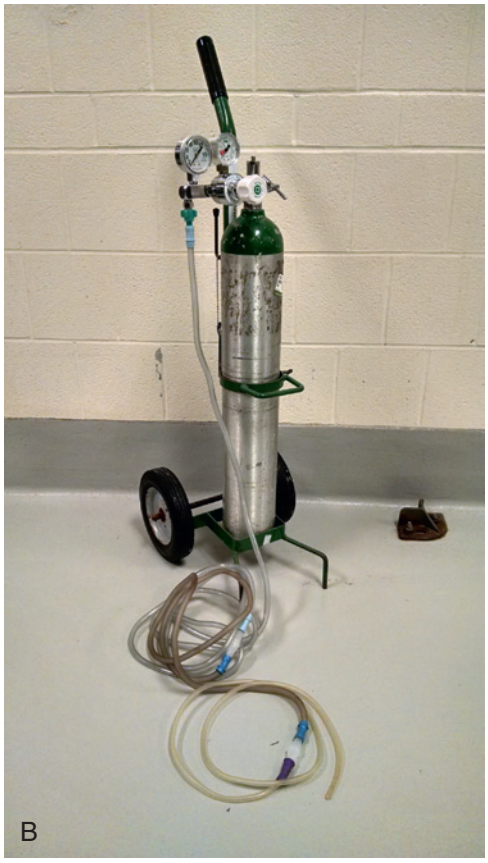


Figure 5-5 Methods of oxygen supplementation in sedated farm animals in a hospital setting. (*A*), An oxygen flowmeter connected to the hospital's piped distribution system at a wall outlet. Plastic connecting tubing delivers oxygen to the patient and can be adapted to a stallion catheter (pictured) or red rubber tube for intranasal oxygen administration or to a face mask. (*B*), An E-cylinder with oxygen flowmeter on a dolly that can be transported through a hospital to a patient's stall.

and then administer additional low doses to achieve the desired degree of sedation. Titrating the dose in this way also minimizes adverse effects. Sublingual detomidine (80 mcg/kg) has been used to sedate calves for cornual nerve block and dehorning, although peak sedation only occurred 40 minutes after administration. Cattle sedated with an alpha-2 agonist alone generally only tolerate uncomfortable or mildly painful procedures. An opioid such as butorphanol (0.02 to 0.05 mg/kg IV) or morphine (0.05 to 0.2 mg/kg IV) can be administered to improve sedation and analgesia and to decrease the dose of alpha-2 agonist needed. Morphine is

Table • 5-1

Recommended IV Doses of Xylazine and Detomidine in Cattle*

DRUG	DOSE	DESIRED EFFECT
Xylazine	0.01-0.05 mg/kg	Standing sedation with low risk of recumbency
Xylazine	0.05-0.1 mg/kg	Recumbent sedation
Detomidine	0.002-0.015 mg/kg	Standing sedation with low risk of recumbency

*Modified from: Abrahamsen EJ: Chemical restraint and injectable anesthesia of ruminants, *Vet Clin Food Anim* 29:209-227, 2013.

recommended for moderate to severe pain. The addition of a small dose of ketamine to the alpha-2 agonist/opioid combination discussed in this section (known as the "ketamine stun") can dramatically improve analgesia and patient cooperation during husbandry/surgical procedures, particularly if also combined with locoregional anesthesia (Table 5-2). This technique is effective and inexpensive. Mild vocalization and movement should be expected. For aggressive cattle, xylazine (0.05 to 0.1 mg/kg) and ketamine (2 mg/kg) IM can be administered to produce recumbency and permit mildly painful procedures. If IV access is available, xylazine (0.025 to 0.03 mg/kg) can be administered first; ketamine (1 mg/kg) is given once the animal becomes recumbent. Calves less than 4 weeks old can be sedated with a benzodiazepine (midazolam, 0.05 to 0.1 mg/kg or diazepam 0.1 to 0.2 mg/kg IV) instead of an alpha-2 agonist, avoiding the cardiovascular side effects of the latter class of drugs.

An alpha-2 antagonist (yohimbine 0.125 to 0.2 mg/kg, tolazoline 0.2 to 2 mg/kg, or atipamezole 0.003 to 0.03 mg/kg) can be used to pharmacologically reverse xylazine or detomidine, if necessary, at the end of a procedure. Antagonists will also eliminate analgesia produced by alpha-2 agonists, so the minimum amount necessary should be given. One strategy involves giving 25% to 50% of the calculated dose initially, then redose as needed. IM rather than IV administration (except in emergency situations) is recommended to prevent cardiovascular, gastrointestinal, and central nervous system side effects.

Sheep and Goats

Sheep and goats can be lightly sedated using an opioid (e.g., morphine 0.1 mg/kg or butorphanol 0.05 to 0.1) plus a benzodiazepine (midazolam 0.1 to 0.2 mg/kg IV or IM or diazepam 0.25 to 0.5 mg/kg IV). (Diazepam formulations contain the solubilizing agent propylene glycol, which is very irritating to muscle, so diazepam should not be given IM.) The combination of an opioid and benzodiazepine is an appropriate choice for critically ill sheep and goats. All alpha-2 agonists can cause hypoxemia in sheep and goats, particularly when administered IV, because of alveolar hemorrhage and pulmonary edema. This occurs within minutes of an IV dose and appears to have both hydrostatic (pulmonary hypertension) and permeability (activation of a population of cells called pulmonary intravascular macrophages) origins. Pulmonary intravascular macrophage activation has been correlated with production of vasoactive and cytotoxic inflammatory mediators. Extensive damage to the capillary endothelial and alveolar type I cells has been documented. Although these changes are mostly resolved within 12 hours and great individual variation exists, this class of drugs must

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Table • 5-2

*Doses for the "Ketamine Stun" Technique**

DRUG COMBINATION	DOSE (mg/kg)	ROUTE	STANDING VS. RECUMBENT	ONSET	DURATION
Xylazine + butorphanol or morphine + ketamine	0.025 0.02-0.05 or 0.05-0.2 0.25-0.5	IV	Recumbent	1 min or less	15 min
Xylazine + butorphanol + ketamine	0.05 0.025 0.1	IM or SQ	Recumbent	10 min or less	30-45 min
Xylazine + butorphanol or morphine + ketamine (after xylazine/opioid)	0.02-0.0275 + 0.02-0.1 or 0.05-0.2 0.05-0.1 slow, to effect	IV	Standing	2-3 min ≤1 min	15 min
Xylazine + butorphanol or morphine + ketamine	0.02 0.01 or 0.05 0.04	IM or SQ	Standing	10 min or less	60-90 min

*Adapted from: Abrahamsen EJ: Chemical restraint and injectable anesthesia of ruminants, *Vet Clin Food Anim* 29:209-227, 2013.

be used with extreme caution or avoided in sheep and goats. Low doses administered IM (e.g., 0.05 mg/kg xylazine or 2 to 3 mcg/kg medetomidine) or as a constant rate infusion (CRI) without a loading dose appear to be safer. Other cardiovascular effects (i.e., bradycardia, increased followed by decreased arterial blood pressure, decreased cardiac output) are similar to those in other species. A low dose of ketamine (ketamine stun) as described in cattle can also be used (see Table 5-2); the ketamine is added to an opioid and benzodiazepine.

Swine

Acepromazine, a phenothiazine tranquilizer, has been used at 0.11-0.44 mg/kg IM to facilitate nonpainful procedures such as physical examination. However, swine may rouse and resist if a painful procedure is attempted. It is not approved for use in swine. The most significant cardiovascular side effect is dose-dependent vasodilation and decreased arterial blood pressure. Azaperone (Stresnil), a butyrophenone tranquilizer that was approved for use in swine, is currently only available in the United States through the compounding pharmacy Zoopharm. The dose is 0.5-2.2 mg/kg IM; doses higher than 1.0 mg/kg are not recommended in mature boars due to the risk of priapism. Azaperone also decreases arterial blood pressure. Acepromazine and azaperone do not provide analgesia. Innovar-Vet (fentanyl-droperidol) is no longer available in the United States. Benzodiazepines, although usually combined with other drugs, can also be administered alone to sedate pigs. Midazolam and diazepam are most commonly used in the United States. Diazepam contains propylene glycol and thus should not be given IM. Midazolam may be given IM, IV, orally (PO), or intranasally. A dose of 0.5 mg/kg IM was determined to be ideal for sedation in one study. The author has used 0.1 to 0.2 mg/kg PO to produce mild to moderate sedation in large swine. The optimal intranasal dose of midazolam in laboratory piglets was determined to be 0.2 mg/kg. Benzodiazepines do not provide analgesia. The alpha-2 agonists are not nearly as potent in swine as they are in other species. They are typically combined with other drugs.

Most commonly, because of their temperament, swine are injected IM with a combination of drugs to produce heavy sedation to general anesthesia. These combinations are discussed under Induction and Intubation.

INTRAVENOUS CATHETERIZATION

Cattle

The jugular vein, at the junction of the cranial and middle thirds of the neck, is the most common site for venous access in cattle. They can usually be catheterized using a combination of physical restraint and infiltration of lidocaine over the vein. Cattle can be positioned in a head gate wearing a halter; the halter is then tied to one side of the head gate (Figure 5-6). Fractious cattle can be sedated before positioning in the head gate. Calves can usually be manually restrained (Figure 5-7); backing them into a corner is helpful. After hair clipping, aseptic skin preparation, and lidocaine infiltration, a stab incision must usually be made through the skin, which is very thick (Figure 5-6 and Figure 5-8*A* and *B*). A 14-gauge, 13-cm over-the- needle catheter is appropriate in most cases. A large-gauge catheter (e.g., 10 gauge) can be used to rapidly deliver a large fluid volume into an adult cow. For neonatal calves, 16-gauge catheters may be more appropriate. The catheter must be inserted through the incision at nearly a right angle to the neck until it has passed through the skin (Figure 5-9); the angle can then be decreased to 30° to 45° to penetrate the jugular vein. The catheter should be sutured to the skin and wrapped to keep the patient from rubbing it out. The cephalic vein can also be catheterized (Figure 5-10).

Sheep and Goats

Most goats and sheep can be catheterized using light manual restraint (being careful to control horns if present), as long as the skin and subcutaneous tissue overlying the vein is infiltrated with lidocaine. Backing the patient into a corner helps control the hind end. The jugular vein is most commonly catheterized; however, the cephalic vein and the auricular veins (in goats with large ears, such as Nubians) are also accessible. For the jugular vein, 14- to 18-gauge catheters can be used depending on the size of the patient. A stab incision through the skin may be needed. The catheter should be wrapped if the goat or sheep will be left unattended or in the company of conspecifics, as they will often chew or rub catheters out.

Swine

Swine almost invariably must be heavily sedated or anesthetized before IV catheterization (as discussed under Induction

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Figure 5-6 Physical restraint of an adult cow for jugular catherization.

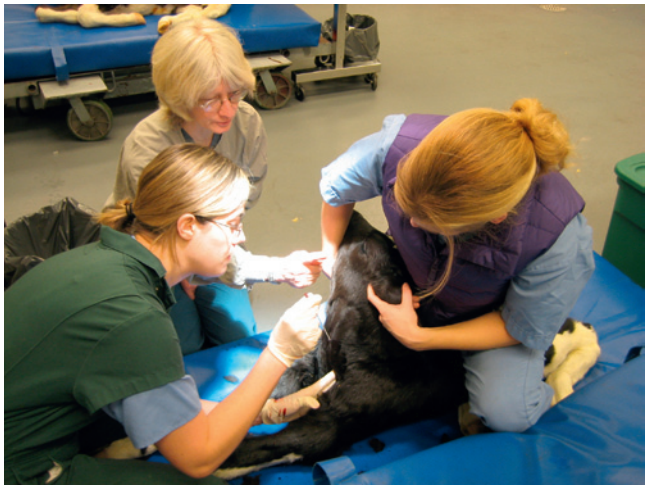


Figure 5-7 Restraint of a calf for jugular vein catheterization.



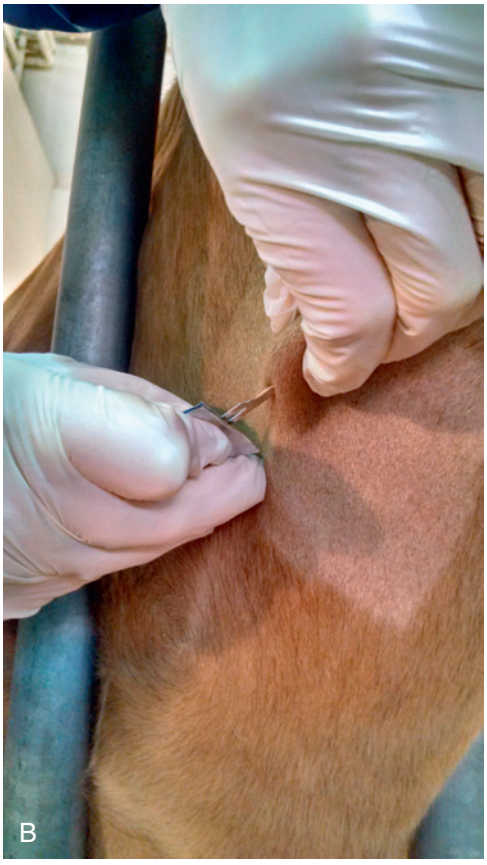


Figure 5-8 (*A*), Lidocaine infiltration. (*B*), A #15 scalpel blade is used to make a stab incision through the skin.

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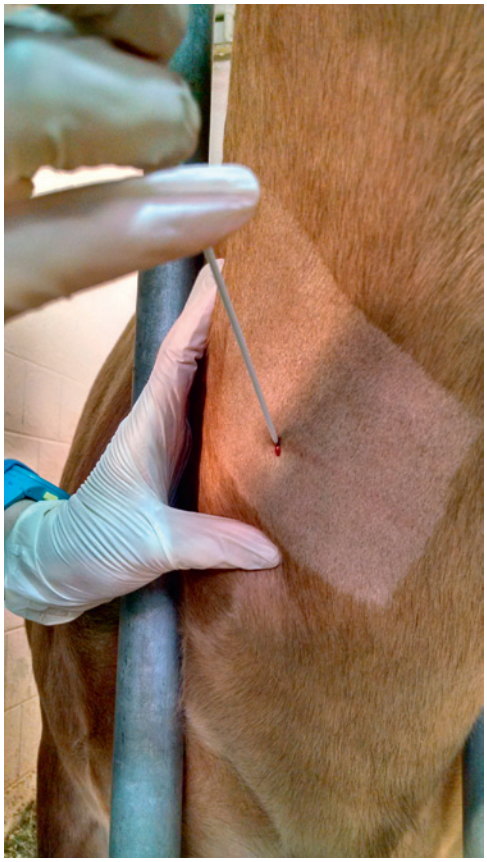


Figure 5-9 The catheter is inserted nearly perpendicular to the vein until it has passed through the skin, at which point the angle can be decreased.



Figure 5-10 Cephalic vein catheter in a cow.

and Intubation) due to their propensity to scream and struggle. In swine, the lateral and medial auricular veins are most commonly used (Figure 5-11). Clipping hair, aseptically preparing the skin, and applying a tourniquet (e.g., IV tubing, gauze strip) around the base of the ear help with visualization and engorgement of these veins. They are small and very superficial, but a cut through the overlying skin may still be necessary. Only short, small-gauge (20-24 gauge)



Figure 5-11 Auricular vein catheterization in a pig.



Figure 5-12 **An auricular catheter that has been supported using a roll of gauze behind the pinna.** The pinna and gauze roll are then wrapped together with tape.

catheters can usually be placed and should be flushed gently. The catheter can be glued or sutured to the ear or taped in. A roll of gauze can be placed against the inner pinna to serve as a splint, and strips of tape can then be wrapped around the catheter and the roll of gauze to secure the catheter (Figure 5-12). Occasionally, the cephalic vein can be catheterized.

GENERAL ANESTHESIA

Induction and Intubation

General Recommendations

Flushing the oral cavity before induction of ruminants helps dislodge feed that can be aspirated after induction.

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Delivery of 100% oxygen before induction of anesthesia, called preoxygenation, is routine in humans. The goal is to replace alveolar nitrogen with oxygen to achieve an intrapulmonary oxygen reserve, fully saturate hemoglobin, increase arterial partial pressure of oxygen, and increase the time to onset of hypoxemia. This can be challenging in adult cattle but is more feasible and recommended in small ruminants and swine in which intubation can be difficult.

Administration of sedative/analgesic drugs before induction of general anesthesia, known as *premedication*, is recommended whenever possible to reduce the stress associated with induction and to provide analgesia. If these drugs were given to facilitate catheter placement, they may or may not need to be redosed. If so, they can be administered IV. The dose(s) of drug(s) used for induction depends on many factors, such as patient temperament/health and level of sedation. Parasympatholytics (that is, atropine, glycopyrrolate) are no longer administered as routine premedications. They decrease gastrointestinal motility, can produce tachycardia, and do not decrease salivation enough to eliminate the risk of aspiration.

Suction should be available before induction in case saliva or feed obstructs the airway (Figure 5-13).

Adult Cattle

If a catheter was placed without sedation, an alpha-2 agonist (xylazine 0.01 to 0.05 mg/kg) and opioid (butorphanol 0.02 to 0.05 mg/kg or morphine 0.05 to 0.1 mg/kg) can be administered IV for premedication. If the patient required sedation to place the catheter, additional drugs may or may not be needed. Adult cattle can be cast into sternal recumbency before induction if well sedated (or after induction as they become unconscious). General anesthesia is induced with ketamine (2-4 mg/kg) preceded by, or mixed with, a benzodiazepine (midazolam 0.05 to 0.1 mg/kg or diazepam 0.1 to 0.2 mg/kg). Alternatively, 500 mg of ketamine can be added to 500 mL of 5% guaifenesin ("double drip"); 0.5 to 1.0 mL/kg is infused rapidly IV to effect (e.g., using a pressure bag). "Triple drip," created by adding 500 mg of ketamine and 25 to 50 mg of xylazine to 500 mL of 5% guaifenesin, can also be used (e.g., in cattle that were not well premedicated). Intubation is strongly recommended in adult cattle undergoing general anesthesia. The cow should remain in sternal recumbency for intubation. A bovine gag (Figure 5-14) is inserted between the incisors, and an assistant straddles the cow's neck and keeps the head up and neck extended. Depending on patient size and the size of the anesthetist's arm, adult cattle can usually be intubated digitally. The nondominant bare arm of the anesthetist is inserted into the oropharynx to palpate the rima glottides (Figure 5-15). An appropriately sized lubricated and cuffed endotracheal tube (20 to 28 mm) is then inserted with the dominant arm, sliding it along the nondominant arm into the trachea. This must be done quickly because the anesthetist's hand



Figure 5-13 Suction should always be available when intubating ruminants. A Yankauer suction tip is useful because it is made of rigid plastic.

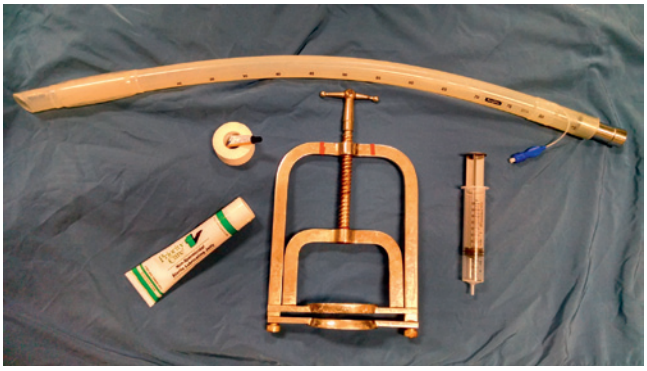


Figure 5-14 Equipment needed for intubating an adult cow. A cuffed, silicone rubber 24-mm-internal-diameter endotracheal tube, white tape, water-based lubricant, bovine gag, and 60-mL syringe are pictured.



Figure 5-15 Digital intubation of an adult cow.

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obstructs the airway. If the oral cavity is too small for both the tube and the hand, an equine gastric tube can be inserted first, and the tube is then passed over it. The cuff is immediately inflated with 60 to 90 mL of air with a 60 mL syringe to protect the lower respiratory tract from regurgitation, and the breathing circuit is connected to deliver 100% oxygen. The tube exits the mouth via the interdental space and is secured to the mandible with white tape.

Calves, Sheep, and Goats

If a catheter was placed without sedation, premedication should be given IV. If the patient required sedation to place the catheter, additional drugs given IV may or may not be needed. Alpha-2 agonists can be used in calves older than 4 weeks (see Table 5-1). Benzodiazepines can be used in calves <4 weeks old, sheep, and goats (e.g., midazolam 0.1 to 0.2 mg/kg or diazepam 0.25 to 0.5 mg/kg, IV). An opioid should be administered for painful procedures. Morphine or methadone (0.1 to 0.2 mg/kg), fentanyl (3-10 mcg/kg), butorphanol (0.05 to 0.2 mg/kg), or buprenorphine (0.01 mg/kg) have been used by the author. The full mu agonists are recommended for moderately to severely painful procedures, although there is limited data on the efficacy of these drugs. A variety of drugs/drug combinations can then be used to induce general anesthesia (Table 5-3). Mask induction with inhalant anesthetics appears subjectively more stressful and takes longer to produce intubating conditions, which may increase the chance of regurgitation and aspiration. Therefore it is not recommended.

Intubation is strongly recommended for calves and small ruminants under general anesthesia but may not always be possible. In this case, oxygen should be supplemented, and the patient should ideally be kept in sternal recumbency (or positioned in lateral or dorsal recumbency as described under Monitoring and Supportive Care). Proper positioning for intubation is crucial in calves and small ruminants. They are intubated in sternal recumbency with the neck extended and the nose almost perpendicular to the ceiling (Figure 5-16). It is crucial that the patient be perfectly straight; multiple assistants may be needed to keep the patient positioned properly. The jaws are opened using two strips of white tape by an assistant, and the tongue is gently pulled out. The rima glottidis is visualized using a laryngoscope with a long blade (e.g., a 470-mm Wisconsin blade; see Figure 5-17). The jaws do not open widely and the oral cavity/oropharynx is long and narrow; inserting the laryngoscope blade in the commissure of the mouth may improve visualization. Inserting a guide tube (also known as a bougie) (see Figure 5-17) into the trachea first, and then passing the lubricated endotracheal tube over the bougie and into the trachea, often improves ease and speed of intubation. A stylet (see Figure 5-17) to stiffen and shape the tube can be useful as well. The internal diameter of the endotracheal tube varies significantly from 4 to 5 mm in a neonate to 12 to 14 mm in a large adult (Figure 5-17). As soon as the trachea is intubated, the cuff should be inflated to decrease the risk of aspiration; enough air should be added so that gas leaks around the tube when airway pressure exceeds 20 cm H_2O. The breathing hoses should be hooked up immediately so that 100% oxygen can be administered. The endotracheal

Table • 5-3

Drugs/Drug Combinations Used for Induction of Calves, Sheep, and Goats

DRUG	DOSE
Ketamine	2.2-4.4 mg/kg
Propofol	2-6 mg/kg to effect
Ketamine and propofol	2-3 mg/kg of each, mixed and given to effect
"Double drip"	0.5-1 mL/kg rapidly to effect
"Triple drip" (not in sheep or goats)	0.5-1 mL/kg rapidly to effect



Figure 5-16 Positioning of a goat for visual intubation with the aid of a laryngoscope.

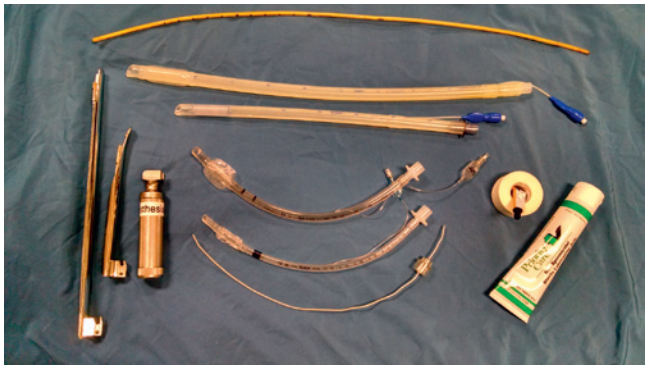


Figure 5-17 Equipment needed for intubating calves, sheep, goats, and swine. Pictured are a bougie (*top*), four assorted cuffed endotracheal tubes, laryngoscope blades (*left*), stylet (*bottom*), white tape, and lubricant.

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tube should be held in position until it can be secured so that it cannot be coughed up and swallowed or aspirated. The tube is directed out of the mouth through the interdental space and secured to the mandible with white tape, gauze, or plastic IV tubing wrapped around the mandible.

Swine

General anesthesia is usually induced intramuscularly. The most common injection sites are the muscles caudal to the ear, the epaxial muscles, and the caudal thigh muscles; injecting into the caudal thigh muscles, however, risks damage to the sciatic nerve and may affect the quality of the ham in pigs raised for food. A needle that is long enough to pass through a pig's subcutaneous fat (panniculus adiposus), which is usually substantial, and into muscle must be selected; epidural or spinal needles must sometimes be used for large pigs. Injection of drugs into muscle rather than fat will result in faster onset. Attaching an extension set between the needle and syringe will help prevent the needle from being dislodged if the pig struggles during injection.

Most protocols are based on a dissociative anesthetic. Once sufficient time has elapsed for the dissociative anesthetic to be metabolized, the alpha-2 agonist can be antagonized to speed recovery. Examples are listed in Table 5-4. Drugs can be mixed in one syringe unless noted. The volumes of some drugs, like ketamine, can be large for IM injection; practices that anesthetize swine frequently should consider investing in concentrated forms of these drugs (available through Zoopharm). In some cases, a pig can be intubated after receiving one of these combinations. If the pig cannot be intubated, the anesthetist can either place an IV catheter and administer additional drugs IV (e.g., ketamine, 1 mg/kg or propofol to effect) or administer inhalant anesthetic by facemask briefly. Pigs may be intubated in either dorsal or sternal recumbency. Sternal recumbency is typically easier for inexperienced individuals (Figure 5-18).

The endotracheal tube should be premeasured to help ensure it is not inserted past the thoracic inlet; it is possible in swine, with their short necks, to insert the endotracheal tube tip past the point at which the bronchus to the right cranial lung lobe branches off the trachea, collapsing that lobe. Strips of gauze or white tape or, in large pigs, soft ropes can be placed caudal to the upper and lower canine teeth to open the mouth. Care should be taken when doing this because the gingiva of the pig is easily irritated. A mouth wedge can also be used along with or instead of strips or ropes. The oral cavity does not open widely. The head should be extended, but not excessively. A long laryngoscope blade (e.g., a 470-mm Wisconsin blade) (see Figure 5-17) will be necessary in large pigs. The epiglottis is usually positioned dorsal to the soft palate; the tip of the blade is used to depress the base of the epiglottis ventrally and bring the rima glottidis, which is small relative to a pig's body mass, into view. Lidocaine can be sprayed onto the arytenoid cartilages



Figure 5-18 Positioning of a pig for intubation.

Table • 5-4

Some Drug Combinations Used in Swine for Induction of General Anesthesia

DRUG	DOSE	ROUTE	COMMENTS
Acepromazine Ketamine	0.4 mg/kg 15 mg/kg	IM	Used in miniature pigs. Give acepromazine 30 min before ketamine. Recumbency for 5 min. Recovery in 65-80 min.
Xylazine Ketamine	1.1-2.2 mg/kg 11-15 mg/kg	IM	Give xylazine 10 min before ketamine. Anesthesia of 30-45 min duration.
Xylazine Butorphanol Ketamine	2.0 mg/kg 0.22 mg/kg 5 mg/kg	IM	Used in miniature pigs. Mixed in same syringe. Better recovery but shorter duration compared with xylazine-ketamine.
Medetomidine Butorphanol Ketamine	80 mcg/kg 0.2 mg/kg 10 mg/kg	IM	Longer duration of anesthesia than xylazine-butorphanol-ketamine.
Tiletamine-zolazepam (Telazol)-ketamine-xylazine	1 mL/35-75 kg (commercial pigs) 1 mL/25 kg (potbellied pigs)	IM	Prepared by reconstituting Telazol powder with 2.5 mL of ketamine (100 mg/mL) and 2.5 mL of xylazine (100 mg/mL). Recovery can be long.
Tiletamine-zolazepam (Telazol) Xylazine OR Medetomidine	4.4 mg/kg 2.2 mg/kg 0.04 mg/kg	IM	Similar induction and recovery times. 60-90 min of anesthesia.
Detomidine Midazolam Ketamine	0.1 mg/kg 0.1 mg/kg 5-10 mg/kg	IM	1-2 hours of anesthesia.

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and down into the trachea to prevent laryngospasm and coughing. Endotracheal tubes should be cuffed and lubricated. Appropriate tube sizes will range from 3 to 4 mm in piglets to 14 to 16 mm in large pigs. The endotracheal tube must take a tortuous course through the pig's larynx to reach the trachea. When passing the tube without a stylet, the natural curvature of the tube is such that the tip is ventral; when it is advanced, this natural curvature causes the tip to be directed against the posterior floor of the larynx. At this point the tube must be rotated 180°; if not too wide, the tube will then slide into the trachea. The tube is then rotated another 180° back to its original position. A stylet can be used to stiffen the tube and maintain its natural curvature (see Figure 5-17). Pig intubation must be exquisitely delicate; damage to the larynx can result in hematoma or edema and airway obstruction upon extubation, whereas damage to more distal tissues can result in subcutaneous emphysema, pneumomediastinum, and/ or pneumothorax. Potbellied pigs are particularly difficult to intubate as they are commonly obese and have redundant pharyngeal tissue. The breathing circuit is immediately connected to deliver 100% oxygen. The cuff should be inflated with enough air so that gas leaks around the tube when airway pressure exceeds 20 cm H_2O. The tube exits the mouth via the interdental space and is secured to the mandible with white tape, gauze, or IV tubing.

Maintenance

Following intubation, the heart should be auscultated before delivering inhalant anesthetic. All lung fields in every patient should be auscultated to ensure normal bronchovesicular sounds; this is particularly important in swine. Currently, the most commonly used inhalant anesthetic is isoflurane. The minimum alveolar concentration, the concentration of an anesthetic that produces immobility in 50% of subjects exposed to a supramaximal noxious stimulus (which corresponds to the median effective dose), has been determined in cattle (1.14%), sheep (1.53%), goats (1.06-1.43%), and swine (1.45-1.51%). Sevoflurane is sometimes used but is currently more expensive than isoflurane. The minimum alveolar concentration of sevoflurane has been determined in sheep (3.3), goats (2.33), and swine (1.97-2.53). The minimum alveolar concentration is affected by many factors. A decrease in minimum alveolar concentration can be caused by a wide variety of anesthetic agents, hypotension, hypothermia, severe hypoxemia or hypercarbia, and pregnancy; an increase in minimum alveolar concentration can be caused by hyperthermia. These factors should be considered when administering inhalant anesthetics, and depth of anesthesia should be monitored closely. Induction, change in anesthetic depth, and recovery should occur more quickly with sevoflurane because of its low blood solubility (low blood gas partition coefficient), making it advantageous in some situations; however, because many factors influence induction and recovery, this may or may not be apparent clinically when using sevoflurane.

For short procedures, total intravenous (IV) anesthesia is an option. Double drip (discussed under Induction and Intubation) can be used to maintain anesthesia at 0.2 to 0.5 mL/kg/h, although a rate over 2.5 mL/kg/h has been used by some authors. Double drip does not contain xylazine; thus the analgesia provided by this drug combination may not compare to that provided by triple drip. However, lack of cardiovascular depression caused by xylazine makes this a better choice than triple drip for cardiovascularly compromised patients. Triple drip (also discussed under Induction and Intubation) can be used to maintain anesthesia in cattle at a rate of 1.5 mL/kg/h for calves and 2.0 mL/kg/h in adults. It has been suggested that if >2.2 mL/kg of the mixture is required to complete surgery, the amount of xylazine added should be decreased to 0.05 mg/mL so that recovery is not delayed. This mixture can also be used in swine at the same rates. Triple drip is not recommended in sheep and goats because it contains xylazine (for reasons discussed under Sedation of Farm Animals). Locoregional anesthesia should be used with either combination. Propofol (0.2 mcg/kg/min) combined with either fentanyl (0.3 mcg/kg/min) or midazolam (0.005 mg/kg/min) for total IV anesthesia has been studied in goats. Propofol (0.2 to 0.4 mg/kg/min) has also been evaluated for total IV anesthesia in sheep.

Partial IV anesthesia, in which one or more CRIs is administered in conjunction with inhalant anesthetic, is another option for maintenance of general anesthesia. Opioids, alpha-2 agonists, ketamine, and lidocaine CRIs can be used in farm animals (Table 5-5); all of these drugs have

Table • 5-5

Doses for Constant Rate Infusion of Selected Drugs for Partial Intravenous Anesthesia in Farm Animals (This Should not Be Considered an Exhaustive List)

DRUG	SPECIES	RATE
Ketamine	Cattle	10-50 mcg/kg/min
	Sheep	1.5 mg/kg loading dose, 50 mcg/kg/min
	Goats	1-1.5 mg/kg loading dose, 25-50 mcg/kg/min
Lidocaine	Cattle	2 mg/kg loading dose, 100 mcg/kg/min
	Sheep	2 mg/kg loading dose, then 50 mcg/kg/min
	Goats	2.5 mg/kg, 100 mcg/kg/min
Dexmedetomidine	Sheep or goats	2 mcg/kg/h
Fentanyl	Cattle, sheep, goats, swine	0.1-0.3 mcg/kg/min
Ketamine-xylazine-guaifenesin	Cattle	2.5 mL/kg/h
Morphine-lidocaine-ketamine	Sheep	10 mg morphine, 150 mg lidocaine, and 30 mg ketamine in 500 mL saline, 10 mL/kg/h
Ketamine-lidocaine	Sheep	10 mcg/kg/min and 20 mcg/kg/min

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Figure 5-19 The globe of the cow will rotate ventrally to ventromedially when an appropriate depth of anesthesia is achieved.

been shown to have analgesic properties in either farm animals or other species. They also reduce minimum alveolar concentration, permitting the use of lower concentrations of inhalant and thus decreasing the cardiopulmonary depression caused by these drugs.

Monitoring and Supportive Care

The anesthetist should evaluate depth of anesthesia every 5 minutes. Palpebral reflex should be weak to absent. The globes of cattle will rotate ventrally to ventromedially as an appropriate surgical plane of anesthesia is achieved; the globes will rotate back into a central position if the animal is too deep (Figure 5-19). The eyes of sheep, goats, and swine may not rotate as dramatically. Generalized muscle tone, heart rate, respiratory rate/depth/character, and blood pressure are also used to measure depth of anesthesia.

The anesthetist should frequently evaluate mucous membrane color, capillary refill time, heart rate and rhythm, respiratory rate and character (if the patient is breathing spontaneously), pulse quality and synchronicity with heartbeat, and body temperature (via rectal or esophageal thermometer). Pulse oximetry, capnography, electrocardiography, body temperature measurement, and arterial blood pressure measurement are recommended in farm animals under general anesthesia. A multiparameter monitor will typically measure all of these variables. Invasive (that is, via an arterial catheter) blood pressure should be monitored in large, heavy ruminants at risk for neuromyopathies; any patient in which hypotension or rapid changes in blood pressure are likely (e.g., due to blood loss or sepsis); and any patient in which frequent sampling of arterial blood is necessary. The most common site for arterial catheterization in ruminants is the caudal auricular artery (Figure 5-20). The saphenous artery can be catheterized in swine as it passes subcutaneously at the level of the crus. Swine have a radial artery palpable on the medial aspect of the carpus that is challenging but possible to catheterize (Figure 5-21).

Adult cattle must usually be mechanically ventilated during general anesthesia. Calves, sheep, goats, and swine may or may not require mechanical ventilation. Tidal volume is approximately 8 to 12 mL/kg, 5 to 7 mL/kg, and 10 to 20 mL/kg in cattle, sheep or goats, and swine, respectively. A respiratory rate of 6 to 10 breaths/minute and an inspiratory:expiratory ratio of 1:2 to 1:3 are good starting points in most cases. These settings should be reevaluated frequently and adjusted when necessary to maintain normocapnia based on capnography and arterial blood gas analysis.



Figure 5-20 A catheter in the caudal auricular artery of a sheep.



Figure 5-21 A catheter in the radial artery of a pig.



Figure 5-22 Proper positioning of a ruminant, in this case a goat, in lateral recumbency under general anesthesia.

Positioning of ruminants is very important due to their copious production of saliva and potential to passively regurgitate during general anesthesia. In lateral recumbency, the head and neck should be elevated above the abdomen using a pad or towels placed under the patient at the level of the poll, and the nose and mouth should be tipped down to permit saliva to drain (Figure 5-22). In dorsal recumbency,

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Figure 5-23 An inner tube positioned under the dependent thoracic limb of an adult cow under general anesthesia to help prevent neuromyopathy.

the head and neck should also be elevated, and the nose should be turned to one side and tipped down. This position can be difficult to achieve in some ruminants, such as adult cattle and ruminants with large horns. In a hospital setting, a vinyl-covered foam pad or an air cushion table are good options. In large adult cattle in lateral recumbency, an inner tube placed under the dependent thoracic limb will help guard against myoneuropathy (Figure 5-23).

Fluid therapy is strongly recommended during general anesthesia. In systemically healthy patients, any balanced electrolyte solution is appropriate (e.g., lactated Ringer's solution, Plasma-Lyte A). An hourly rate of 3 to 10 mL/kg is usually used, depending on factors such as the amount of fluid loss expected during surgery. In neonates, 50% dextrose can be added to create a 2.5% solution to prevent hypoglycemia. Patients that require correction of fluid, acid-base, electrolyte, and BG disturbances may require different fluid types and rates. PCV, TS, blood gases/acid-base status (including lactate concentration), and electrolyte and BG concentrations should be reevaluated during long general anesthetics, with frequency dependent on the patient's condition. Reassessment as frequently as every 30 minutes may be necessary in critically ill farm animal patients. An additional catheter or catheters placed after induction may be necessary if large volumes of fluid and/or many different medications must be given during surgery.

It is difficult to prevent and treat hypothermia during general anesthesia in adult cattle. In smaller farm animals, keeping the extremities warm (e.g., by wrapping the limbs in warm towels or bubble wrap) and applying a forced warm-air system (e.g., 3M Bair Hugger Therapy) over the patient for a period of time before induction ("prewarming") appears to be an effective way to prevent hypothermia. Patients with thick hair coats are at risk for hyperthermia if body temperature is not watched carefully, but even these patients can become hypothermic.

Complications

Regurgitation

Passive regurgitation can occur in any species but can be profuse in ruminants and lead to aspiration and impaired oxygen exchange. The importance of appropriate fasting, rapid intubation, ensuring the endotracheal tube cuff is properly inflated, and proper patient positioning have already been discussed. The pharynx can be suctioned before extubation. Proper extubation technique is discussed in the Recovery section.

Rumen Tympany

Rumen tympany is a side effect of anesthetic drugs and can impair cardiovascular function if severe by impeding venous return back to the heart. An orogastric tube can be passed during anesthesia or the rumen can be decompressed percutaneously. Antagonism of drugs (that is, alpha-2 agonists and opioids) that decrease gastrointestinal motility may help but will also eliminate the analgesia produced by these drugs. Aborting general anesthesia and positioning the patient in sternal recumbency may be necessary if all else fails. Ruminants usually begin eructating as they recover.

Bradycardia

Bradycardia without hypotension may not require treatment. Bradycardia with hypertension from alpha-2 agonist administration should never be treated with an anticholinergic drug because it will worsen hypertension. Any underlying cause(s) should be addressed first. Excessive anesthetic depth can cause bradycardia; the inhalant should be decreased or stopped, and 100% oxygen should be administered. Hypocarbia (partial pressure of carbon dioxide <35 mm Hg) in cattle can cause bradycardia and is confirmed via arterial blood gas analysis; tidal volume or ventilation rate or both should be decreased. Hyperkalemia (e.g., in goats with urethral obstruction) can cause bradycardia as well and must be addressed immediately. Manipulation of viscera can result in vagal outflow and bradycardia; ceasing manipulation will usually resolve the problem. Once the underlying causes have been ruled out or addressed, the heart rate can be increased using atropine (0.01 to 0.02 mg/kg) or glycopyrrolate (0.005 mg/kg) IV.

Hypotension

Mean arterial blood pressure should be maintained >80 mm Hg in adult cattle and large farm animals and >70 mm Hg in other farm animal patients. There are numerous causes of hypotension. The anesthetist should first check if the patient is excessively deep and if so decrease the percentage of inhalant being delivered. Using a partial IV anesthesia technique, as discussed in Maintenance, will minimize the percentage of inhalant necessary and thus the cardiovascular depression caused by the inhalant. Hypothermia can result in hypotension and should be prevented as discussed previously. The anesthetist should ensure that the patient's fluid needs are being met and that ionized hypocalcemia is not present. Ionized hypocalcemia can be treated with 10% calcium chloride (1 mL/10 kg), 10% calcium gluconate (2 mL/10 kg), or 23% calcium borogluconate (0.55 to 1.1 mL/kg/h). Bradycardia can cause hypotension and should be addressed. If the aforementioned issues have been addressed but the patient is still hypotensive, a sympathomimetic drug such as dobutamine (0.5 to 5 mcg/kg/min), dopamine (5-10 mcg/kg/min), or ephedrine (0.022 to 0.066 mg/kg) can be administered.

Hypoventilation and Hypoxemia

Hypoventilation, defined as partial pressure of carbon dioxide >45 mm Hg, and hypoxemia, defined as partial pressure of oxygen <80 mm Hg, are common complications in farm animals under general anesthesia. Most anesthetic drugs impede the chemoreceptor response to carbon dioxide and cause respiratory muscle relaxation, thus reducing ventilatory drive. In recumbent quadrupeds under general anesthesia, the abdominal contents tend to impede diaphragmatic

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movement and even displace the diaphragm cranially, compressing the lung. This effect is further amplified by postural differences; in dorsal recumbency the diaphragm is more impaired by the abdominal contents than it is in lateral recumbency. Pharmaceutically reduced ventilatory drive and mechanical inhibition of the diaphragm conspire to reduce alveolar ventilation and lead to hypercapnia. This is one of the principal causes of hypoxemia. Compression of the lung can lead to alveolar collapse that, in turn, provides a route for venous blood to transit the lung without being oxygenated; this ventilation:perfusion mismatching is another cause of hypoxemia.

If hypoventilation is resulting in hypoxemia, the anesthetist should evaluate the patient to ensure anesthetic depth is not excessive and institute positive pressure ventilation; if the patient is already being ventilated, tidal volume or respiratory rate or both can be increased. Increasing tidal volume is usually more effective because it decreases dead-space ventilation. Appropriate fasting to minimize rumen content and treating rumen tympany makes it easier to ventilate ruminants and is critical in adult cattle. If a cow requires exploratory laparotomy, surgically opening the abdomen and gas decompression of viscera will help as well. Doxapram is no longer recommended for stimulating ventilation because it increases tissue oxygen demand. Other strategies available for treating hypoxemia are listed in Box 5-1. Note that positive pressure ventilation, adding positive end-expiratory pressure, using an inverse inspiratory:expiratory ratio, and performing an alveolar recruiting maneuver can all significantly depress cardiovascular function by decreasing venous return to the heart and increasing the resistance to blood flow through pulmonary capillaries. Invasive arterial blood pressure must be measured and blood gas analysis performed if positive pressure ventilation is instituted in adult cattle.

Box • 5-1

Techniques for Treating Venous Admixture and Hypoxemia

- Add positive end-expiratory pressure, a ventilatory strategy in which airway pressure is maintained above atmospheric pressure at the end of exhalation via a mechanical impedance, usually a valve, within the breathing circuit to increase the volume of gas remaining in the lungs at end expiration and thus prevent atelectasis and shunting of blood.
- Increase inspiratory:expiratory ratio or use inverse inspiratory:expiratory ratio (that is, 1:1 or higher). This is done so that inspiratory time equals or exceeds expiratory time to improve gas distribution in the lung and increase mean airway pressure. RR should be set rapidly enough so the patient does not exhale completely before the next breath, resulting in some gas remaining in the lung at end expiration.
- Perform alveolar recruiting maneuver, a sustained increase in peak inspiratory pressure, e.g., 40 cm H_2O for 40 seconds, to open collapsed lung units, which is usually followed by positive end-expiratory pressure to keep them open.
- Administer aerosolized albuterol (2 mcg/kg) via endotracheal tube.
- Increase arterial blood pressure to improve lung perfusion (e.g., IV fluids, inotropic drugs).

Recovery

Farm animal patients should be recovered in a clean, dry area where they can be closely monitored and where supportive care can be continued as deemed necessary. Critically ill patients should have monitoring equipment left in place for as long as possible during the recovery period. IV catheters should be left in place in healthy patients until they have recovered completely from general anesthesia, or longer as the case dictates (e.g., systemically ill patients, patients at risk for airway obstruction following extubation). Ruminants should be positioned in sternal recumbency with the limbs in the most natural position possible. Swine can be recovered in sternal or lateral recumbency. Ruminants should only be extubated when they are vigorously rejecting the endotracheal tube (e.g., chewing, coughing); the cuff is typically left partially inflated to drag saliva and regurgitated rumen contents up out of the trachea. Swine can be extubated when they are able to swallow or cough. As soon as the endotracheal tube has been removed, the anesthetist should observe the patient for normal thoracic excursions and feel for air movement through the nares to ensure the patient's airway is patent. Supplemental heat (e.g., using a heat lamp or forced air warmer) should be available if necessary, especially in pediatric and critically ill patients. Farm animals, unlike horses, typically do not develop mania upon recovery and usually attempt to stand only when they have regained the strength and coordination to do so. Although most do not require sedation for recovery, analgesia should always be provided.

ANALGESIA

Although still in its infancy, the field of farm animal analgesia has progressed considerably over the past decade. Readers are strongly encouraged to consult several excellent references on this topic. Nonsteroidal antiinflammatory drugs and locoregional anesthesia are still the most commonly used modalities, but a number of other drug classes are now used as well. Multimodal analgesia is the administration of more than one class of analgesic drugs that act via different mechanisms and at different sites in the central nervous system; it also refers to concurrent use of systemic analgesics, locoregional anesthesia, and even nonpharmacologic therapies. This technique results in additive or synergistic effects while minimizing adverse effects and should be used in farm animals whenever possible.

There are currently no drugs approved specifically for analgesia for food animals in the United States; flunixin is approved for pyrexia and inflammation. Therefore all drug administration for analgesia in farm animals is considered extra-label drug use. Extra-label drug use is permitted under the Animal Medicinal Drug Use Clarification Act (AMDUCA) of 1994 as long as it does not result in violative tissue residues. Table 5-6 gives meat and milk withdrawal intervals for certain drugs. The online Food Animal Residue Avoidance Databank (FARAD) provides estimated withdrawal intervals for selected extra-label uses of a limited number of drugs based on available scientific evidence. Withdrawal intervals for other analgesic drugs (e.g., morphine), doses, frequencies, and routes of administration must be determined by contacting FARAD. Additional information on such drugs is discussed by species in the following sections.

Cattle

The nonsteroidal anti-inflammatory drug meloxicam has been studied extensively in cattle. The pharmacokinetics of meloxicam (0.5 mg/kg IV) have been determined in weaned

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Table • 5-6

Meat and Milk Withdrawal Intervals (WDI) for Some Analgesic Drugs in Farm Animals

DRUG	SPECIES	DOSE AND ROUTE	MEAT WDI	MILK WDI
Flunixin	Cattle	1.1-2.2 mg/kg IV once	4 days	36 hours
Flunixin (Banamine-S)	Swine	2.2 mg/kg IM	14 days	N/A
Xylazine	Cattle, sheep, goats	0.05-0.3 mg/kg IM	4 days	24 hours
		0.3-2 mg/kg IM	10 days	120 hours
		0.016-0.1 mg/kg IV	5 days	72 hours
Detomidine	Cattle, sheep, goats	Up to 0.08 mg/kg* IV/IM	3 days	72 hours
Ketamine	Cattle, sheep, goats	Up to 2 mg/kg IV*	3 days	48 hours
		Up to 10 mg/kg IM*		
	Swine	Up to 10 mg/kg* IV/IM	2 days	
Lidocaine	Cattle	Up to 15 mL of 2% solution (epidural)	1 day	24 hours
		Up to 2 g in 100 mL SQ (infiltration)	4 days	72 hours
Lidocaine with epinephrine	Cattle, sheep, goats	SQ (epidural/infiltration)*	1 day	24 hours

*Single and multiple doses.

Holstein calves undergoing dehorning without cornual nerve block; meloxicam resulted in lower heart rate, lower plasma concentrations of substance P (a neurotransmitter involved in nociception), and greater weight gain. The pharmacokinetics of meloxicam (0.5 mg/kg IV) and gabapentin (15 mg/kg PO) have been studied in 4- to 6-month-old beef calves. In the same study, the efficacy of either meloxicam or meloxicam plus gabapentin given 4 hours after induction of a chemical synovitis/arthritis was investigated. The activity level was evaluated with pedometers, and lameness was evaluated using pressure mats and a visual analog scale; both treatments improved lameness. The pharmacokinetics of PO meloxicam (0.5 mg/kg) have been compared in ruminant calves medicated via gavage, preruminant calves medicated via gavage, and preruminant calves medicated via milk replacer; calves medicated via milk replacer achieved lower maximum plasma concentrations of meloxicam but absorbed meloxicam more quickly. Meloxicam (1 mg/kg PO) either 12 hours before or at the time of dehorning in bull calves resulted in lower cortisol, substance P, and cortisol concentrations than no treatment; prostaglandin E_2 was lower in calves that received meloxicam at the time of dehorning for 3 days postoperatively. Meloxicam administered for pain would be permissible under AMDUCA. Pharmacokinetics of IV and PO firocoxib have been determined in calves and showed high oral bioavailability and prolonged terminal half-life. Morphine appears to be an effective analgesic in cattle based on an increase in thermal nociceptive threshold in one study in 12 dry, nonpregnant cows. Although there is currently little data on systemic morphine in cattle, empirically 0.1 to 0.2 mg/kg IV every 2 to 4 hours in combination with other analgesics seems to be effective. Although lidocaine CRI has been used in calves under general anesthesia, there is little data on its analgesic efficacy in the postoperative period. It is sometimes administered as a CRI, particularly for visceral pain, at rates similar to those used in other species (loading dose 1 to 2 mg/kg, 25 to 50 mcg/kg/min).

Sheep and Goats

A single-dose pharmacokinetic study of meloxicam (0.5 mg/kg IV once) in sheep and goats has been published. To maintain assumed therapeutic plasma concentrations, this dose should be administered every 12 hours in sheep and every 8 hours in goats. A small number of goat kids (n = 6) that received 0.5 mg/kg meloxicam IM for disbudding were subjectively less painful in the first 24 hours than goat kids that received placebo (n = 5). Based on a pharmacokinetic study of PO meloxicam in adult goats, 0.5 to 1 mg/kg every 24 hours is recommended. A recent study of oral meloxicam pharmacokinetics in sheep recommended a loading dose of 2 mg/kg followed by 1 mg/kg every 24 hours. Fentanyl patches have been investigated in sheep; a patch placed on the lateral antebrachium that delivered 2 mcg/kg/h maintained plasma concentrations above the assumed therapeutic level. This author has used fentanyl CRI (1- to 5-mcg/kg loading dose, 2 to 3 mcg/kg/h) and ketamine CRI (0.05- to 0.1-mg/kg loading dose, 3 to 5 mcg/kg/h) with apparent success. A low IM dose of xylazine (that is, 0.05 mg/kg) has been shown to increase antinociception for at least 60 minutes in lambs. In adult sheep, a CRI of xylazine (5-mg loading dose, 2 mg/h) increases antinociception. A dexmedetomidine (0.5 to 2 mcg/kg/h) CRI, though not yet assessed for its antinociceptive efficacy, is another option. In pregnant ewes, intraperitoneal medetomidine (3 mcg/kg/h) infused via an osmotic pump increased thermal nociceptive threshold after laparotomy.

Swine

Nonsteroidal anti-inflammatory drugs (flunixin, meloxicam) have been studied in swine. Meloxicam (1 mg/kg PO) and flunixin (2.2 mg/kg IM) administration to lame sows increased nociceptive threshold as measured using pressure algometry. Opioids (buprenorphine, including IV buprenorphine, sustained-release SQ buprenorphine, and buprenorphine patch), fentanyl infusion or patch, morphine, and tramadol have been investigated in swine.

LOCAL AND REGIONAL ANESTHETIC TECHNIQUES

The use of local or regional anesthetic techniques in farm animals may be preferred over general anesthetic techniques due to practical and financial reasons. Many surgical techniques, such as dehorning, rumenotomies, abomasal displacements, perineal surgery, or teat/udder surgery can be performed with local or regional techniques.

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Lidocaine hydrochloride is the most commonly used local anesthetic solution drug in farm animal practice. It has an analgesic duration of 90 to 180 minutes. No other local anesthetic solution is licensed for use in farm animals in the United States (see Table 5-6 for withdrawal times for cattle); therefore clients must be advised of appropriate withdrawal times.

Other drugs have been coadministered with lidocaine to prolong its local anesthetic effects. Epinephrine at concentrations of 5 to 10 mcg/mL (1:200,000 to 1:100,000) has been suggested to prolong local anesthesia and possibly reduce toxicity by causing vasoconstriction.

Regional Anesthesia for Procedures Involving the Head

Ocular surgery and dehorning are the two most common procedures carried out in the head in farm animals. Local anesthetic procedures are performed in standing animals in conjunction with adequate head restraint. Mild sedation may be required.

Anesthesia of the Eye

Topical Anesthesia

One or two drops of proparacaine hydrochloride 0.5% can desensitize the cornea and pain associated with it. Within approximately 30 seconds and for 10 to 15 minutes this ophthalmic solution also relieves the blepharospasm associated with corneal disease or superficial irritation, facilitating minor procedures such as ocular examination, staining of the cornea, and removal of foreign bodies. Proparacaine is approved for use in farm animals in the United States.

The auriculopalpebral nerve is occasionally palpable along the zygomatic arch (ventral to the zygomaticoauricularis muscle and to the zygomatic process of the temporal bone). Infiltration of 5 to 15 mL of 2% lidocaine in this region will desensitize this motor-only nerve, causing akinesia of the corresponding eyelid. If necessary, the eyelids themselves can be infiltrated with 10 mL of 2% lidocaine approximately 1 cm from the edges of the dorsal and ventral lids.

Anesthesia for Ophthalmic Surgery

Peterson Block. Complete motor (allowing proptosis of the globe) and sensory block of the eye (except the eyelid) is to be expected.

The Peterson eye block is performed by using a $3\frac{1}{2}$-inch, 18-gauge needle. Landmarks for this procedure are the zygomatic process of the frontal bone, the zygomatic process of the temporal bone, the frontal process of the zygomatic bone, and the rostral edge of the coronoid process of the mandibular ramus. The puncture site is located in the space delineated by these landmarks. The needle should be advanced into the pterygopalatine fossa toward the foramen orbitorotundum at an approximate depth of 7 to 10 cm with the aim of desensitizing the oculomotor, trochlear, and abducens nerves and the three branches of the trigeminal nerve (ophthalmic, maxillary, and mandibular). Fifteen milliliters of lidocaine can be deposited at this location.

The Peterson eye block may be technically challenging to perform but has a lower risk of hemorrhage, penetration of the globe, damage to the optic nerve, or injection into the meninges than the retrobulbar block.

Retrobulbar Block. The four-point retrobulbar injection will desensitize all the ocular muscles and the optic nerve. Injections are made using a 3- to 4-inch 18-gauge needle with a large curve. The eyelids are penetrated at the medial and lateral canthus and at the dorsal and ventral orbital rims. The needle is inserted at the medial and then the lateral canthus while using the finger to reflect the globe away from the needle. The needle is advanced through the conjunctiva in a curve medially to the orbital apex (7-10 cm). The needle is aspirated to ensure that it is not placed within the optic nerve or meninges, and a total of 15 mL of 2% lidocaine, divided among the four sites, is slowly injected as the needle is withdrawn from the orbit. Disadvantages of this procedure include possible damage to the globe, intraneural or meningeal injection, retrobulbar hemorrhage, or damage to the optic nerve.

Auriculopalpebral Nerve Block. Blinking, either spontaneously or in response to a stimulus, is affected by the orbicularis oculi muscle, which is innervated by cranial nerve VII (facial). Akinesia of the eyelid can be achieved by blocking the auriculopalpebral branch of the facial nerve.

The auriculopalpebral nerve can be palpated at the caudal aspect of the zygomatic arch. From 5 to 10 mL of local anesthetic solution is deposited at the dorsolateral aspect of the zygomatic arch, caudal to the coronoid process.

Care of the cornea is mandatory because blinking will be prevented once an auriculopalpebral nerve block is administered; therefore adequate eye ointment should be applied to prevent desiccation, abrasion, and/or ulceration of the cornea.

Additional infiltration of the eyelid with 5 to 10 mL of lidocaine will achieve sensory blockade of the eyelid.

Anesthesia for Dehorning

Anesthesia of the base of the horn for dehorning or disbudding requires anesthesia of the cornual nerve, a branch of the zygomaticotemporal nerve, which is part of the trigeminal nerve.

The cornual nerve is often palpable along the ventrolateral aspect of the frontal ridge, halfway between the lateral canthus of the eye and the base of the horn (Figure 5-24). Anesthesia is performed by using a 20-gauge, 1- or $1\frac{1}{2}$-inch needle inserted just under the frontal ridge. Five to 10 mL of 2% lidocaine can be infiltrated to desensitize the nerve. Older animals may also require hemicircumferential infiltration of the caudal aspect of the horn base to anesthetize cutaneous branches that originated in the second cervical spinal nerve.

Goats have different innervation of the horn base region. In addition to the cornual nerve, branches of the infratrochlear nerve extend to the horn base (see Figure 5-24). In adult goats, the cornual branch of the zygomaticotemporal nerve is desensitized with a 22-gauge, 1-inch needle and 2 to 3 mL of lidocaine at a location halfway between the lateral canthus

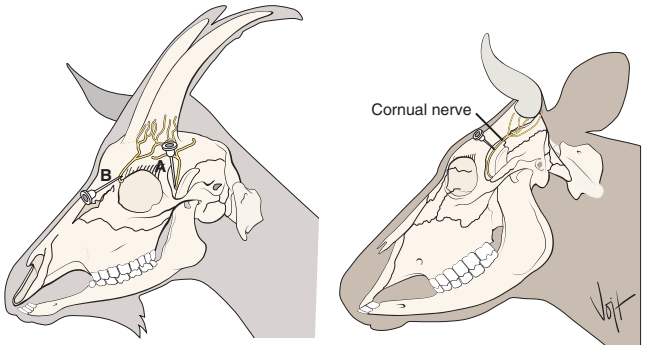


Figure 5-24 Cornual nerve block in the cow and the goat. Note the additional location for infiltration in the goat. (From Muir WW, Hubbel JAE, Skarda RT, Bednarski R: *Handbook of veterinary anesthesia*, ed 3, St. Louis, 2000, Mosby.)

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of the eye and the lateral horn base, as close as possible to the ridge of the supraorbital process. The infratrochlear branches are desensitized by injecting 2 to 3 mL of lidocaine halfway between the medial canthus of the eye and the medial horn base dorsal and parallel to the dorsomedial margin of the orbit. This infiltration should be performed as a line block because the nerve is branched. It is important to use as small an amount of lidocaine (maximum dose of 10 mg/kg) as possible in goats because of their extreme sensitivity to lidocaine toxicity. When disbudding kids younger than 14 days of age, one can divide 1 mL of 2% lidocaine among the four sites to desensitize the horn bud.

Anesthesia for Abdominal Surgery

Regional anesthesia in the bovine is commonly used to access the abdominal cavity. This can be accomplished by infiltration anesthesia, paravertebral nerve blocks, or, in smaller animals, epidural anesthesia. All have the potential to provide anesthesia of the flank region for surgical procedures such as abomasal displacements, rumenotomy, cesarean section, or intestinal surgery.

Infiltration Anesthesia

Infiltration of lidocaine at or around the incision site can provide adequate analgesia for most minor surgical procedures. Infiltration anesthesia is usually performed by using a line block or an inverted L. The line block is performed by making multiple subcutaneous (1 cm deep) and deep (2-7 cm deep) injections of 1 to 2 mL of 2% lidocaine along a proposed incision line. Up to 100 mL of 2% lidocaine may be required in adult cattle, depending on the required incision size and thickness of the body wall. Small amounts of lidocaine should be used for line blocks in small ruminants, especially goats, because of their sensitivity to the drug. Potential disadvantages of this technique include possible increased surgical bleeding due to local vasodilation (this can be minimized by adding epinephrine 1 : 100,000 to 1 : 200,000), delayed healing as a result of lidocaine in the incision site, incomplete anesthesia of the deeper layers, increased amounts of lidocaine required, risk of toxicity, and inability to extend the incision during surgery without additional lidocaine infiltration. In the author's experience these issues rarely are significant.

An inverted-L infusion of anesthetic is used for flank laparotomy and is performed by first injecting lidocaine along the last rib and then horizontally just ventral to the transverse processes. The technique is similar to the line block, with multiple subcutaneous injections (1 cm deep) and deeper muscle injections (2-7 cm deep). The disadvantages are the same as for the line block, except lidocaine is not in the incision site and therefore should not interfere with healing.

Paravertebral Block

Paravertebral anesthesia has the potential to provide excellent anesthesia of the entire flank region through blockade of the last thoracic (T13) and first two lumbar (L1 and L2) spinal nerves (Figure 5-25).

The nerves can be approached from the dorsal aspect of the transverse processes of the lumbar vertebrae. The ends of the transverse processes are palpated, starting caudally just in front of the tuber coxa with L5 and working cranially to the often very small, shorter, and harder-to-palpate L1. The puncture site is located abaxial to the spinous process. An 18-gauge, $3\frac{1}{2}$-inch needle is advanced in a ventral direction until the transverse process is encountered at an approximate depth of 5 to 7 cm in an adult dairy cow. The needle is then walked off the cranial edge of the process and advanced ventrally to penetrate the costotransverse ligament and intercostal membrane (best felt with a Tuohy needle). After penetration of the costotransverse membrane, usually palpable as a pop, 10 to 15 mL of 2% lidocaine per site may be injected. Infiltration of the epaxial musculature as the needle is advanced may be recommended to minimize spasms of these muscle groups and discomfort to the cow. There is potential, but unlikely, difficulty in palpating landmarks in overconditioned cattle, scoliosis, moderate unilateral ataxia (should the injectate migrate to L3 or further caudad), and moderate to severe bilateral ataxia (should the injectate migrate epidurally) and a risk of penetrating major blood vessels or the spinal canal. Alternatively injections can be made with an 18-gauge, $1\frac{1}{2}$-inch needle inserted parallel to the tips of the processes of L1, L2, and L4 (Figure 5-26).

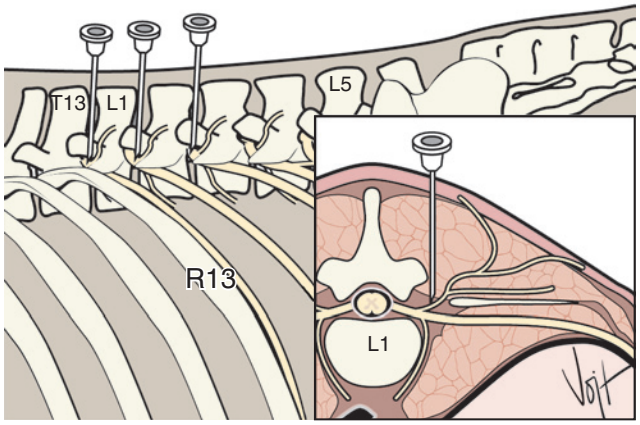


Figure 5-25 Proximal paravertebral nerve block. Note that the needles are placed just cranially to the transverse processes and less than 2.5 cm from midline. (From Muir WW, Hubbel JAE, Skarda RT, Bednarski R: *Handbook of veterinary anesthesia*, ed 3, St. Louis, 2000, Mosby.)

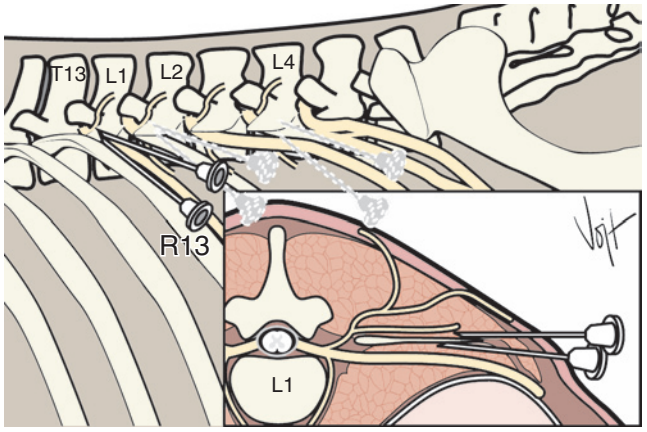


Figure 5-26 Distal paravertebral nerve block. Note that the needles are placed just above and below each transverse process, and lidocaine is infiltrated in a fan pattern. (From Muir WW, Hubbel JAE, Skarda RT, Bednarski R: *Handbook of veterinary anesthesia*, ed 3, St. Louis, 2000, Mosby.)

Epidural Anesthesia

A lumbosacral approach can be performed for procedures involving the cranial abdomen. A similar dermatome can also be obtained by administering larger volumes of local anesthetic solution at the sacrococcygeal space (S5-Cx1) or the first coccygeal space (Cx1-Cx2). Paralysis of the pelvic

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limbs will invariably occur. The L6-S1 space may be palpable (difficult or impossible in pigs) as a depression in the spinal column just caudal to a line drawn between the wings of the ilium (see Figure 5-25). The block is performed with a 3- to 5-inch 18-gauge needle. The dosage of lidocaine is approximately 0.5 to 1 mL of 2% lidocaine per 4.5 kg body weight for cattle. At either of the lower epidural locations, 40 to 150 mL (average 80 mL) may be required for adult cattle and 5 to 25 mL (average 15 mL) in calves. The volume of lidocaine injected is determined by the animal's response to the injection and the desensitization area size required by the procedure. Adult cattle that are recovering from epidural anesthesia with involvement of the pelvic limbs should have excellent footing with their hind legs "hobbled" to prevent abduction of the hind limbs and damage to the inner thigh musculature.

Either lumbosacral or intercoccygeal spaces may be accessible in swine (Figure 5-27). The dose for swine is the same as that for cattle (0.5 to 1 mL of 2% lidocaine per 4.5 kg body weight). Evidence suggests that a smaller dose may also work (1 mL per 7.5 kg, plus 1 mL for every 10-kg increase over 50 kg). Epidural xylazine has been examined in swine by using 2 mg/kg in 5 mL of saline. This produced effective immobilization and analgesia for 120 minutes after administration. In sows, 1 mg/kg xylazine in 10 mL of lidocaine produces anesthesia and analgesia of the hindquarters.

Anesthesia for Perineal Surgery

Anesthesia of the perineal region may be required for surgeries of areas such as the tail, vagina, vulva, anus, rectum, caudal prepuce, or scrotum; for repair of a prolapsed rectum or vagina; difficult parturition; fetal manipulation during dystocia; or perineal urethrostomy. Perineal anesthesia is also useful to control tenesmus and uterine contractions. Anesthesia of the perineal region is obtained by epidural anesthesia and is performed at the sacrococcygeal region.

Epidural Anesthesia

A sacro- or intercoccygeal approach is commonly performed in farm animals. The puncture site may be located at the sacrococcygeal (S5-Cx1) or first coccygeal (Cx1-Cx2) space (particularly in bovine, ovine, and caprine species, although it may also apply to porcine). The S5-Cx1 interspace is caudal to the spinal cord, and only the coccygeal nerves are present. The correct location is palpated by moving the tail up and down with one hand while palpating the dorsal spinous processes of the sacrum and coccygeal vertebrae with the other hand (Figure 5-28). The sacrococcygeal space is generally ossified in older animals, especially in cows, whereas the intercoccygeal space is larger in most cows, making penetration of this interspace more straightforward. A 22-gauge, 2-inch needle (ideally Tuohy) may be used to penetrate the space directly on the dorsal midline in an adult cow. The needle is advanced with the bevel directed cranially until a pop (best done with a Tuohy needle) is felt (usually 2 to 4 cm deep). A hanging drop or a loss of resistance technique may indicate when the needle is entering the epidural space. Injection should be easy and without resistance. Injection of 1 mL lidocaine per 100 kg body weight (0.2 mg/kg) is recommended in adult cattle. This approximates 5 to 6 mL for an average adult cow. Larger doses may migrate too far cranially and block sciatic dermatomes causing moderate to severe ataxia and even recumbency. Onset time is usually 10 to 20 minutes, with a 30- to 150-minute duration range.

Xylazine alone or coadministered with the local anesthetic solution has been reported to potentiate the duration of anesthesia. Xylazine at 0.03 mg/kg is diluted with lidocaine to a 5-mL volume for an adult cow to provide anesthesia of the entire perineal region. Onset of action is within 3 to 4 minutes, and duration is approximately 100 minutes.

Caudal epidural anesthesia in small ruminants or swine is performed by administering approximately 1 mL 2% lidocaine per 50 kg at the sacrococcygeal or intercoccygeal space with a 20- to 22-gauge needle (see Figures 5-26 and 5-27).

Anesthesia of the Foot

Anesthesia of the foot may be required for debridement of severe foot abscesses, interdigital fibromas (corn) removal, digit amputation, or laceration repair. Anesthesia can be accomplished by performing a ring block of the limb above the surgical site; however, this provides only minimal anesthesia and is often incomplete in its distribution. For interdigital surgery, such as interdigital fibroma removal, adequate anesthesia can be provided by injecting 5 to 10 mL of 2% lidocaine deeply (5 cm) approximately 2 to 3 cm proximal to the interdigital space to desensitize the branches of the medial dorsal and palmar (plantar) axial digital nerves.

The Bier block (IV regional anesthesia) requires placement of a tourniquet in an area proximal to where the

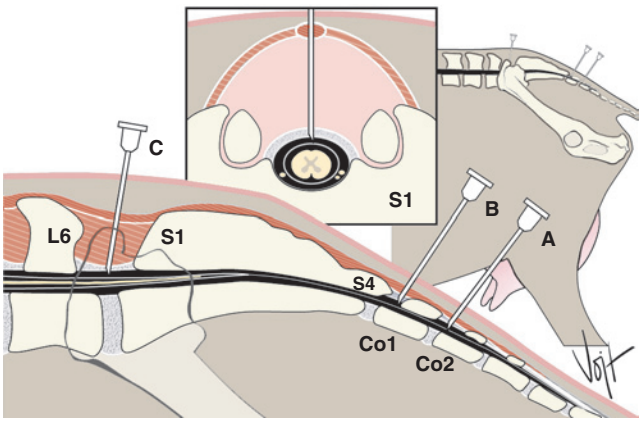


Figure 5-27 Cranial epidural in swine. Note the large amount of soft tissue overlying the lumbosacral space in the pig, necessitating the use of a long needle. (From Muir WW, Hubbel JAE, Skarda RT, Bednarski R: *Handbook of veterinary anesthesia*, ed 3, St. Louis, 2000, Mosby.)

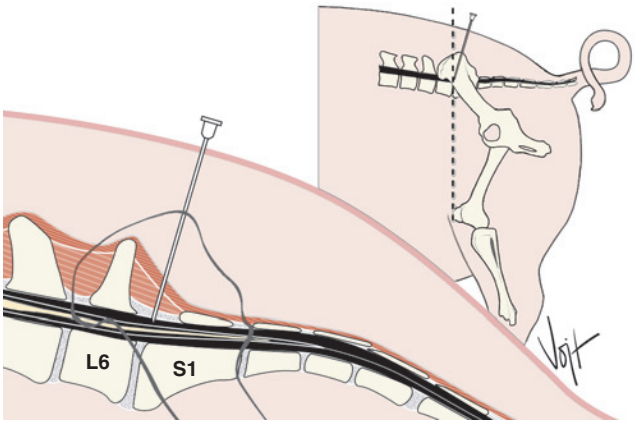


Figure 5-28 Locations for cranial and caudal epidural in a goat. The locations are similar for the cow and sheep. The sacrococcygeal location is usually ossified in the adult cow. (From Muir WW, Hubbel JAE, Skarda RT, Bednarski R: *Handbook of veterinary anesthesia*, ed 3, St. Louis, 2000, Mosby.)

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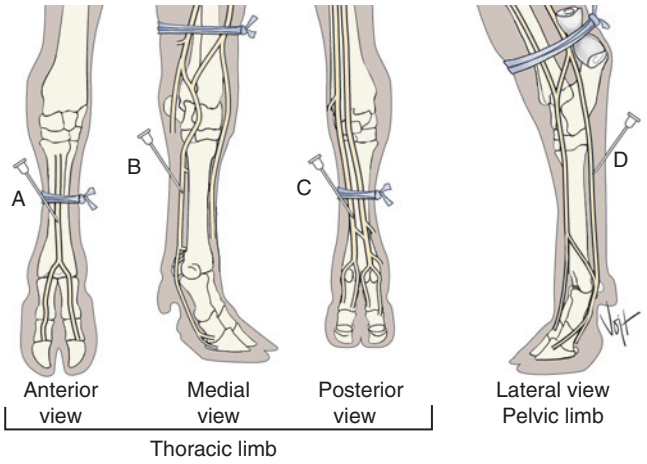


Figure 5-29 Intravenous regional anesthesia of the distal limb in the bovine. The suggested sites are only for reference; any visible or palpable vessel may be used. (From Muir WW, Hubbel JAE, Skarda RT, Bednarski R: *Handbook of veterinary anesthesia*, ed 3, St. Louis, 2000, Mosby.)

surgical lesion is located and injecting lidocaine into the distal limb veins. Regional anesthesia is produced for as long as the tourniquet is in place. Up to 30 mL of 2% lidocaine may be injected into one of the following veins: the dorsal metacarpal (metatarsal) vein, palmar (plantar) digital vein, dorsal digital vein, or lateral saphenous vein with a 20- or 22-gauge butterfly catheter (Figure 5-29). Advantages of IV regional anesthesia include complete anesthesia of the foot, only one injection required, a smaller amount of lidocaine required, and rapid onset of anesthesia. The tourniquet should be released slowly to prevent signs of lidocaine toxicity from rapid release of the lidocaine into the systemic circulation. A tourniquet can be safely left in place for up to 90 minutes without loosening.

Anesthesia of the Udder and Teat

The udder has a complex innervation. It is served from fibers originating from L3 and L4 (caudal aspect) as well as L1 and L2 (cranial aspect). A paravertebral block or an epidural block with a large amount of local anesthetic can be done to provide anesthesia. However, weakness of the pelvic limbs may result, and animals can injure themselves when standing after the procedure. For procedures that involve the external teat surface, such as laceration repair, a ring block or IV regional anesthesia of the teat is usually adequate. For procedures that only affect the cistern, infiltration of local anesthetic solution into the cistern itself may be sufficient.

Ring Block

An elastic band (tourniquet) may be placed around the base of the teat. With a 25-gauge needle, 5 to 6 mL of lidocaine can be infiltrated around the teat. Gentle massage will facilitate diffusion into deeper tissues.

Cistern Infusion

For procedures affecting the mucous membrane lining of the teat, such as polyp removals or opening of spider teats, an infusion into the teat cistern of approximately 10 mL of local anesthetic with a teat cannula is usually sufficient to provide anesthesia. A tourniquet needs to be applied to the base of the teat to prevent any milk diluting the local anesthetic solution.

IV Regional Anesthesia of the Teat

After a tourniquet is placed at the base of the teat, any superficial vein can be catheterized and infused with approximately 5 to 7 mL of lidocaine. This will anesthetize the entire teat distal to the tourniquet.

RECOMMENDED READINGS

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CHAPTER 6

General Principles of Minimally Invasive Surgery

André Desrochers, Marie Babkine and Sylvain Nichols
(The authors and editors would like to acknowledge the previous author, Dr. Jerry Roberson)

LAPAROSCOPIC SURGERY

André Desrochers and Marie Babkine

Laparoscopy is a minimally invasive technique that permits the observation of the abdominal organs. Several authors have used laparoscopy on the bovine species in order to describe their normal anatomy, evaluate the reproductive system, or help diagnose traumatic reticuloperitonitis. However, in 1998, Janowitz described a laparoscopic technique for the correction and fixation of a left displaced abomasum that popularized the technique and has been used in field conditions since then. It is thoroughly described in Chapter 14.

There are three basic approaches in ruminants: ventral, right, or left flank approach. The surgeon must have a preliminary diagnosis before choosing the laparoscope insertion site. The laparoscopic instruments have limited length, preventing complete exploration or access by one approach. Although the left and right sides can be easily prepared surgically, the surgeon might switch from one side to the other if needed.

LAPAROSCOPIC TECHNIQUE

Equipment

Laparoscopes have different lengths, diameters, and lens angles depending on the procedure, size of the animal, or the surgeon's preference. The light source must be powerful for adequate viewing of such a large cavity. It consists of a 300-watt xenon bulb. Depending on the company, abdominal insufflators use either CO_2 (Richard Wolf, Knittlingen, Germany) or filtered ambient air (Dr. Fritz, Tuttlingen, Germany) or simply passive abdominal distention. Conventional insufflators are equipped with a pressure control system (Richard Wolf, Knittlingen, Germany) (Figure 6-1). A 0-degree laparoscope is most commonly used in cattle. It allows direct vision with a limited field, which is enough for most common procedures. However, a 25-degree to 30-degree laparoscope gives you access to laterally deviated organs or structures (Figure 6-2).

A Veress needle is usually recommended to create a pneumoperitoneum. Its design allows a safe abdominal insertion. However, the thickness of the abdominal wall makes it difficult to use effectively in cattle. It has a tendency to abut on the peritoneum with subsequent retroperitoneal insufflation compromising further insertion.

Alternatively, there are many different types of trocar/cannula units, and those that are frequently used in cattle are reusable, 5 to 12 mm of diameter, blunt or sharp points, and of different lengths depending of the approach (Figure 6-3). The outside of the cannula is usually smooth, allowing easy insertion. However, it has a tendency to come out (that is, retract) easily; consequently, the surgeon can lose abdominal distention. Threaded cannulas or distal cuffs (intraabdominal) are designed to avoid this annoyance. Special gaskets allow a smaller instrument to be safely used in a larger diameter cannula without losing the pneumoperitoneum.

Preparation and Anesthesia

Fasting for 24 to 48 hours is always recommended to decrease the volume of the forestomachs, especially if the animal is in dorsal recumbency, to avoid bloating and to improve viewing. Furthermore, fasting decreases the chances of perforating an organ while entering the abdomen with the primary trocar. Note: cattle undergoing laparoscopic abomasopexy do not necessarily have to be off feed because they were most likely anorexic; therefore their forestomachs are already smaller.

The flank or ventral abdomen is surgically prepared. Usually laparoscopic procedures are performed under sedation and local infiltration of lidocaine 2%. Xylazine, acepromazine, butorphanol, or solution containing ketamine-butorphanol and xylazine (see Chapter 5) have been used by the authors according to the surgical condition and surgical approach.

Pneumoperitoneum

Right and left flank pneumoperitoneum in cattle is obtained after the direct insertion of a 5-mm trocar-cannula unit into the abdominal cavity. On the left side, its insertion is through a 1- to 2-cm cutaneous incision, 5 cm behind the caudal aspect of the last rib and 8 cm ventral to the extremity of the transverse processes (Figure 6-4). The exact insertion site will vary depending on a potentially distended organ in the paralumbar fossa. A more caudal entry site, 5 cm below the point of the tuber coxae in the hollow of the flank, can also be used especially on the right side. The trocar-cannula unit must be aimed caudodorsally on the right side to avoid organs. The trocar itself and the top portion of the cannula are removed to let the air enter faster into the abdomen. This technique precludes the use of an insufflator in some situations. The same technique can be used on the left side and is actually safer even if followed by a laparoscopic examination with a right flank celiotomy. It can be left in place afterward or removed after the other ports are positioned. To ensure that a digestive organ has not been perforated, the air escaping the abdomen must be odorless. Sterile saline can also be injected into the cannula and should flow easily. If needed, the insufflator may then be attached, and a pneumoperitoneum is induced. At this time, a possible complication besides the accidental penetration of a digestive organ would be the insufflation of the retroperitoneal space leading to detachment of the peritoneum. This is due to an insufficiently long or incorrectly positioned needle as mentioned earlier.

With a ventral approach, the pneumoperitoneum can be obtained by one of two approaches through a full-thickness abdominal incision with an 8- to 10-mm trocar-cannula unit: 10 cm caudal to the xiphoid process or just left to the umbilicus if a ventral laparoscopic abomasopexy is to be performed. After the tip of the insertion trocar is through the wall, it is oriented parallel to the body wall and inserted further inside. The trocar is removed and the laparoscope inserted to first confirm adequate positioning by viewing the spleen and the diaphragm. Accidental penetration of the

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Figure 6-1 A typical laparoscopic tower: 1, monitor; 2, light source; 3, video camera; 4, CO_2 insufflator.

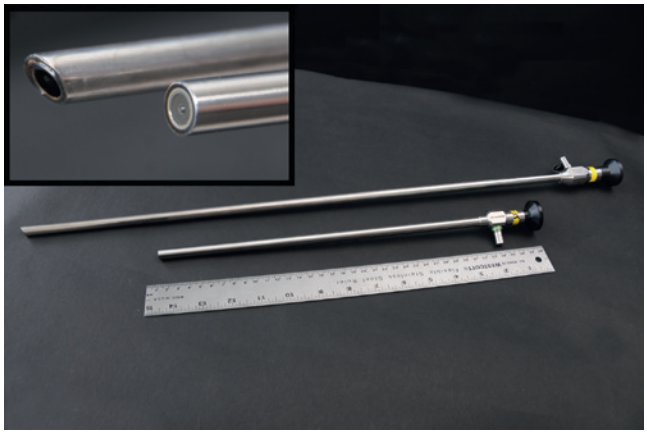


Figure 6-2 Laparoscopes of different lengths and lens angle. Both have a diameter of 10 mm. *A*, 30-cm laparoscope with a lens angle of 30 degrees. *B*, 30-cm laparoscope with a lens angle of 0 degrees.

omental leaves might happen. If it does, the laparoscope is withdrawn at the near end of the cannula, which is pulled gently until the peritoneum can be seen. Only then can the insufflation begin.

NORMAL ANATOMY

Right Flank

With the laparoscope pointed cranially, the following organs can be identified (Figure 6-5): caudal lobe and right lobe of the liver; the diaphragm; a portion of the cranial duodenum; the sigmoid flexure; the descending duodenum; the greater and lesser omentum; the right kidney surrounded by adipose tissue in the retroperitoneal space; the epiploic foramen; and the pancreas (Figures 6-6 to 6-8).

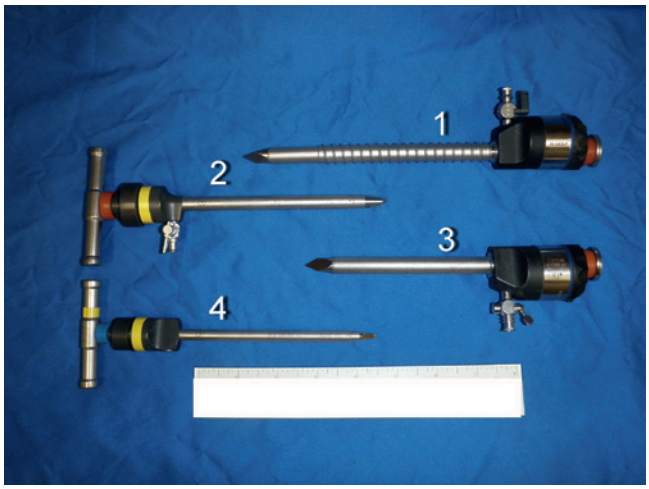


Figure 6-3 Different cannula-trocar units: 1, 10-mm threaded cannula; 2, 8-mm cannula; 3, 10-mm smooth cannula; 4, 5-mm cannula.

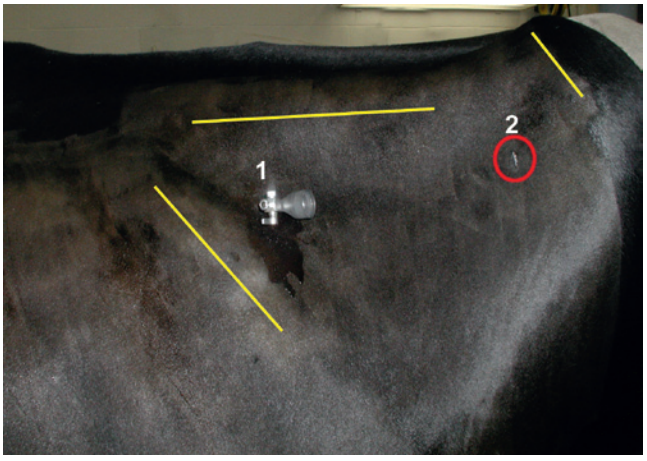


Figure 6-4 Insertion sites of a 5-mm cannula-trocar unit to obtain a pneumoperitoneum in the left flank. The lines show the important landmarks: last rib, transverse processes, and tuber coxae. 1, cranial insertion site; 2, caudal insertion site.

The following organs can be seen with caudal orientation of the laparoscope (Figure 6-9): part of the descending duodenum and the greater omentum where it forms the supraepiploic bursa. If the laparoscope is long enough or if it is inserted more caudally, it is possible to view the genital system of the cow, dorsal sac of the rumen, the cecum, the intestines, and the descending colon (Figure 6-10). It is also possible to see the bladder if the uterus is raised by an assistant doing a rectal palpation (Figure 6-11). The ovarian structures can equally be identified using this technique (Figure 6-12). Therefore the assistance of a person performing a rectal palpation, lifting the rectum, and manipulating the reproductive system of the cow can permit a better visualization of the right caudal abdomen of the cow.

Left Flank

The exploration of the left side of the abdominal cavity is achieved by orienting the laparoscope caudally (Figure 6-13): the dorsal sac of the rumen, the left kidney covered

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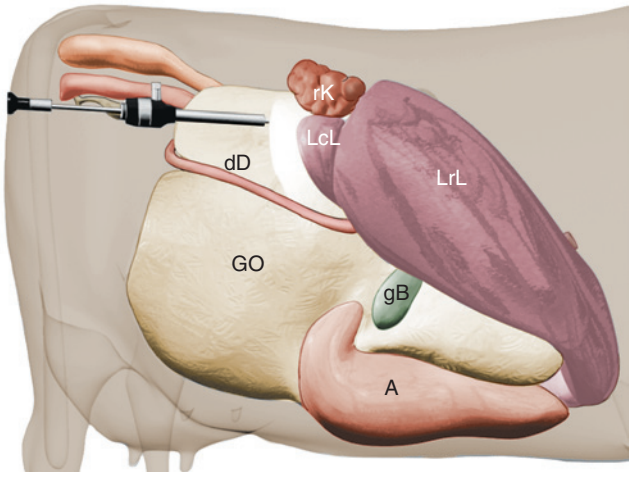


Figure 6-5 Right flank laparoscopy. The laparoscope is oriented cranially. Light source is highlighting the visible organs from this position. dD, descending duodenum; GO, greater omentum; rK, right kidney in the retroperitoneal space; LcL, caudate lobe of the liver; LrL, right lobe of the liver; gB, gall-bladder; A, abomasum. (With permission. Babkine M, et al: Laparoscopic surgery in cattle, *Vet Clin North Am Food Anim Pract* 21:251-279, 2005.)

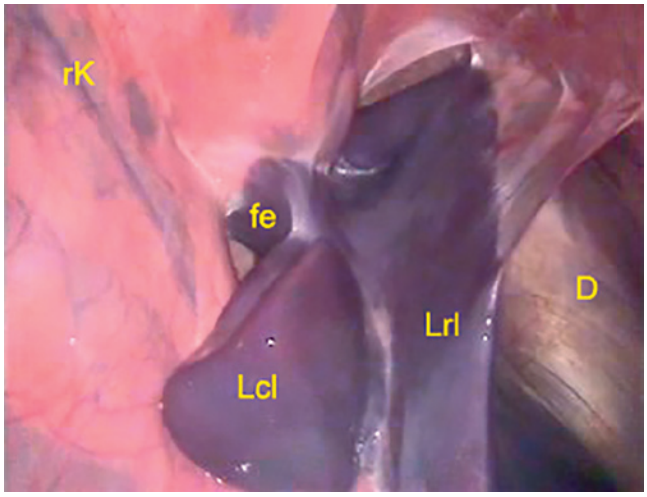


Figure 6-6 Right flank laparoscopy, cranial view. rK, right kidney; fe, epiploic foramen; Lcl, caudate lobe; Lrl, right lobe of the liver; D, diaphragm.

in retroperitoneal fat, the rectum, part of the intestines, a portion of the spiral colon, and the uterus are visible (Figure 6-14). The spiral colon, uterus, and left ovary are more easily visualized by manipulating the rectum during a transrectal palpation. A cranial orientation of the laparoscope (Figure 6-15) will allow the observation of part of the diaphragm, the spleen, the rumen, and possibly the greater omentum's attachment on the rumen (Figure 6-16). If there is a left displaced abomasum, it will be easily identified between the abdominal wall and the rumen.

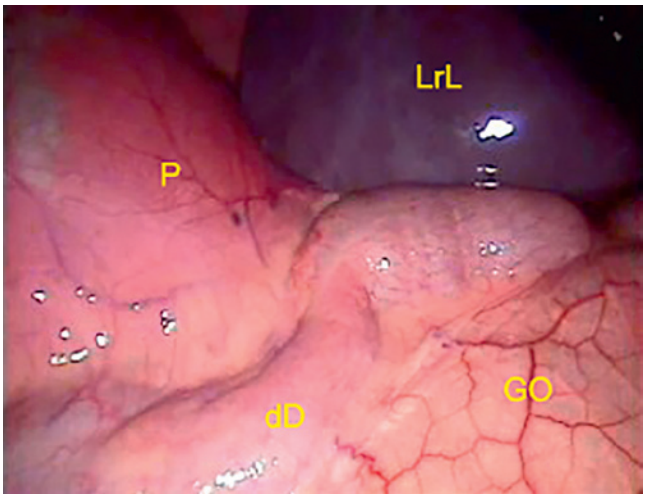


Figure 6-7 Right flank laparoscopy, cranioventral view. P, pancreas; LrL, right lobe of the liver; dD, descending duodenum; GO, greater omentum.

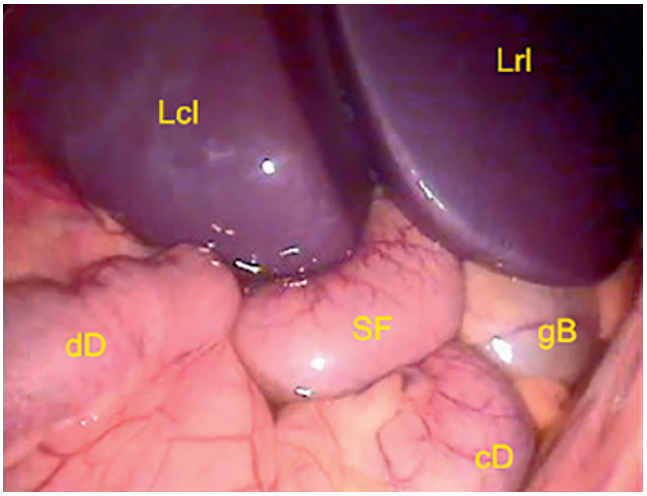


Figure 6-8 Right flank laparoscopy, cranioventral view. dD, descending duodenum; Lcl, caudate lobe; Lrl, right lobe of the liver; SF, sigmoid flexure of the duodenum; cD, cranial duodenum; gB, gallbladder.

Ventral

The laparoscope is inserted to the left of the umbilicus and is oriented toward the left cranial portion of the abdomen (Figure 6-17). The diaphragm, the spleen, and the rumen are easily identified (Figure 6-18). By manipulating the laparoscope left to right in the cranial portion of the abdomen, the diaphragm, the reticulum, sometimes part of the liver, and the omentum covering the rumen are visible. The reticulum is recognizable by its biphasic contractions. If the abomasum is dilated, it is visible against the right ventral abdominal wall. The abomasum is recognized by its serosa and the insertion of the greater omentum. The reticuloabomasal ligament can sometimes be identified (Figure 6-19). A portion of the pyloric part of the abomasum may be identified against

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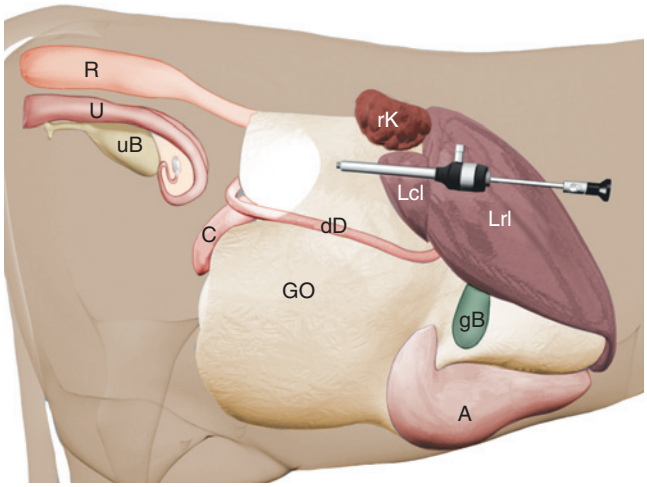


Figure 6-9 Right flank laparoscopy. The laparoscope is oriented caudally. The light source is highlighting the visible organs from this position. U, uterus; uB, urinary bladder; R, rectum; C, cecum; dD, descending duodenum; GO, greater omentum; rK, right kidney in the retroperitoneal space; LcL, caudate lobe of the liver; LrL, right lobe of the liver; gB, gallbladder. (With permission. Babkine M, et al: Laparoscopic surgery in cattle, *Vet Clin North Am Food Anim Pract*, 21:251-279, 2005.)

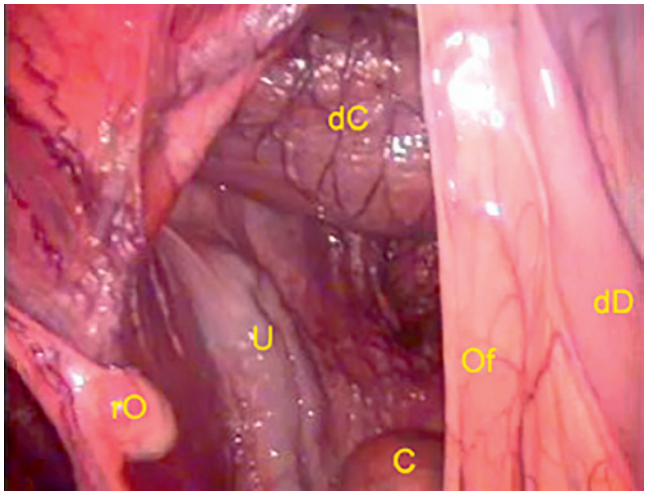


Figure 6-10 Right flank laparoscopy, caudal view. rO, right ovary; U, uterus; dC, descending colon; C, cecum; Of, omental fold; dD, descending duodenum.

the right abdominal wall by moving the laparoscope the most dorsally possible, in the same axis as the umbilicus.

INDICATIONS

The main indication of laparoscopy in cattle is for diagnostic purposes and for abomasal decompression and fixation. Because the procedure can be easily done on an animal standing under sedation and local anesthesia, it can be performed easily in a field situation. The laparoscopic examination of the abdomen might replace the use of ultrasound as a diagnostic tool in certain conditions when the dorsal

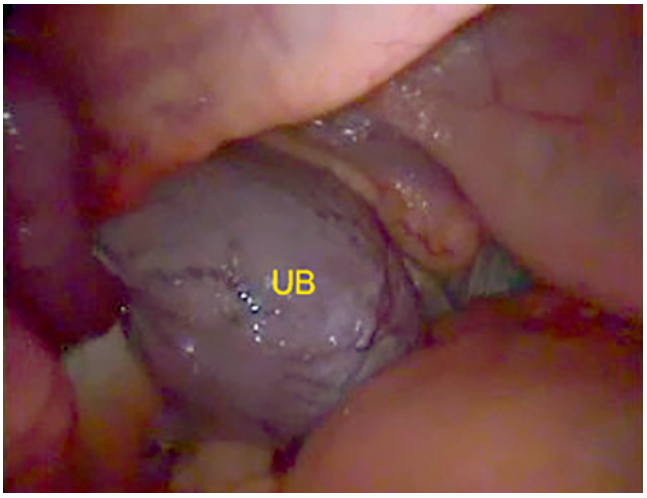


Figure 6-11 Right flank laparoscopy, caudal view with the uterus moved away by rectal manipulation. UB, urinary bladder.

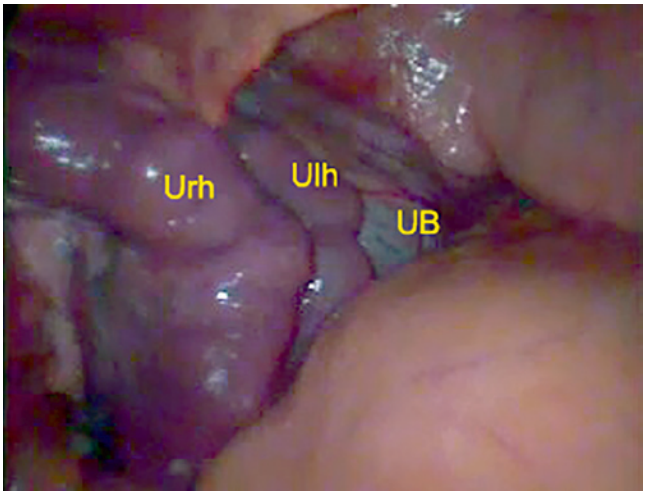


Figure 6-12 Right flank laparoscopy, caudal view. Urh, right horn of the uterus; Ulh, left horn of the uterus; UB, urinary bladder.

abdominal cavity must be investigated. Laparoscopic abomasopexy will be discussed thoroughly in Chapter 14.

The advantages of the use of laparoscopy-guided biopsy techniques are the direct visualization of the target organ and the selection of the exact biopsy site. In this way, biopsies of the wrong organ are avoided, and possible hemorrhages are identified and controlled. The direct view of the target organ can also provide additional information concerning the condition and eventually its prognosis. In the equine species, biopsy techniques are described for the liver, kidneys, spleen, lymphatic nodes, and other masses. Similarly, in the bovine species, the first reports on organ biopsy by laparoscopy guidance involved the kidney, which is described by Naoi and associates (1985). In this technique, the laparoscope is introduced in the middle of the right paralumbar fossa after the site has been surgically prepared (local anesthesia and a 2-cm cutaneous incision).

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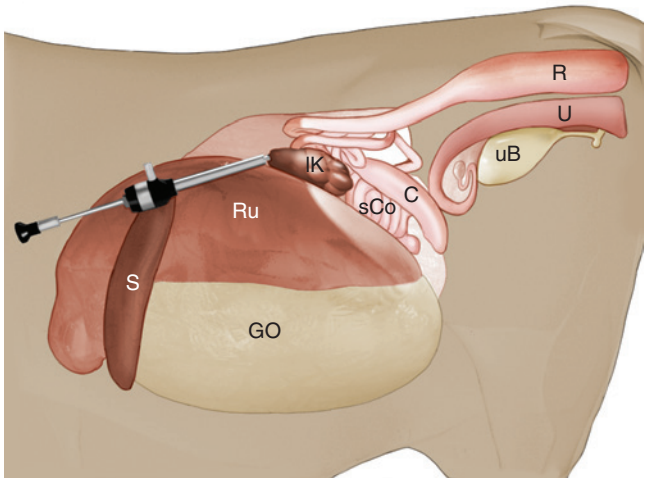


Figure 6-13 Left flank laparoscopy, caudal view. The light source is highlighting visible organs from this position. R, rectum; U, uterus; uB, urinary bladder; lK, left kidney from the retroperitoneal space; sCo, spiral colon; C, cecum; SI, small intestine; Ru, rumen; GO, greater omentum at its insertion on the rumen; S, spleen. (With permission. Babkine M, et al: Laparoscopic surgery in cattle, *Vet Clin North Am Food Anim Pract* 21:251-279, 2005.)

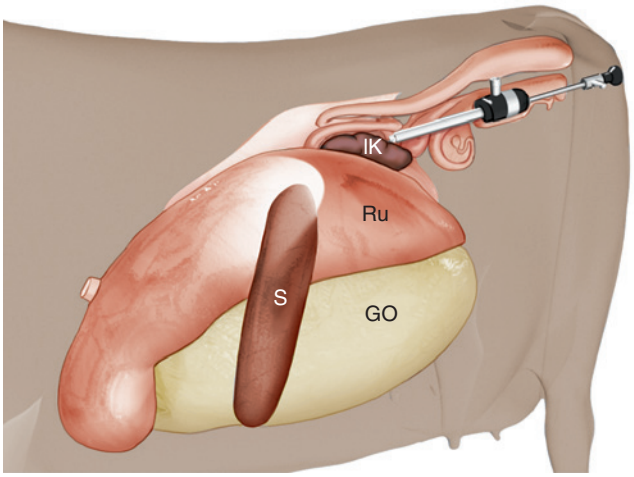


Figure 6-15 Left flank laparoscopy, cranial view. The light source is highlighting the visible organs from this position. lK, left kidney retroperitoneal; Ru, rumen; GO, greater omentum; S, spleen. (With permission. Babkine M, et al: Laparoscopic surgery in cattle, *Vet Clin North Am Food Anim Pract* 21:251-279, 2005.)

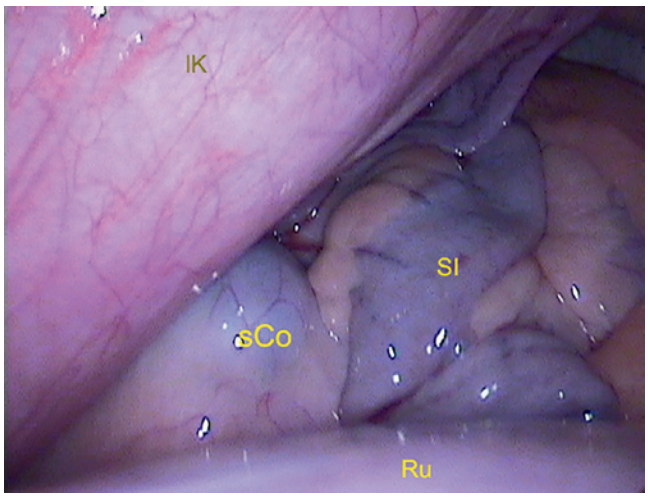


Figure 6-14 Left flank laparoscopic view, dorsal to the rumen. sCo, spiral colon; SI, small intestines; lK, left kidney; Ru, rumen.

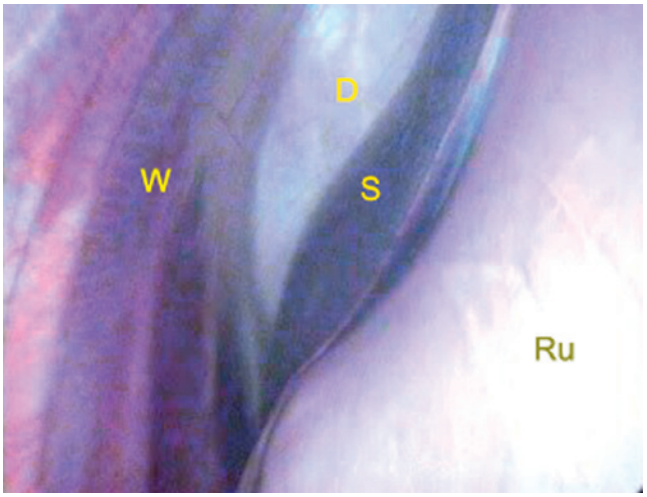


Figure 6-16 Left flank laparoscopy, cranial view. W, body wall; D, diaphragm; S, spleen; Ru, rumen.

A Franklin-Silverman biopsy needle is used and is introduced 5 cm below the transverse processes, behind the last rib. The biopsy is completed using the sharp part of the needle. It allows one to take a biopsy that is on average 1.5 mm in diameter and 16 mm in length.

Klein and associates (2002) describe an intestinal biopsy technique. This technique is described on calves and sheep placed under general anesthesia in dorsal recumbency. The biopsy is performed outside of the abdominal cavity after the intestine is caught and held laparoscopically with grasping forceps.

Abdominal exploration via laparoscopy can be extremely useful in the diagnosis and prognosis of certain conditions. For example, the authors have evaluated important consequences of ischemias of the uterine blood vessels after severe torsion of the uterus. Despite successful interventions to correct this condition, the uterus may remain devitalized and undergo necrosis, explaining slow recovery after the torsion reduction. Incorrect fixation of the abomasum may prevent normal transit. The motility and organ position can be evaluated by ultrasound but not the fixation itself. Although the abomasum can still be sutured to the body wall, functional stenosis may occur from malpositioning or suturing errors.

Cranioventral adhesions are common in cattle. They are usually secondary to reticuloperitonitis or abomasal ulcer. Exploration of the cranioventral abdomen by laparoscopy using a ventral approach allows for a good view of the

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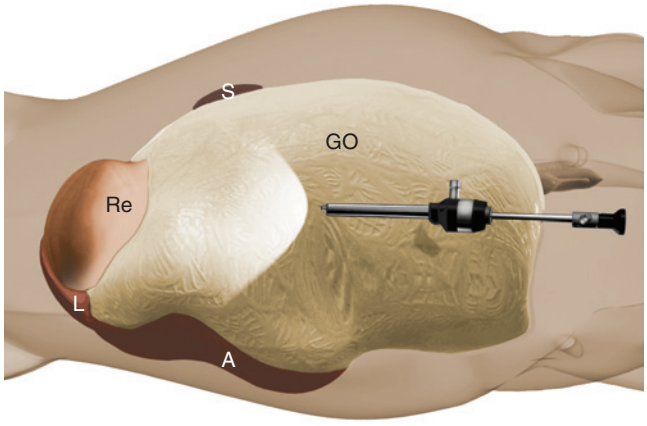


Figure 6-17 Ventral laparoscopy, cranial view. The light source is highlighting the visible organs from this position. S, spleen; Re, reticulum; L, part of the right lobe of the liver; A, abomasum; GO, greater omentum. (With permission. Babkine M, et al: Laparoscopic surgery in cattle, *Vet Clin North Am Food Anim Pract* 21:251-279, 2005.)

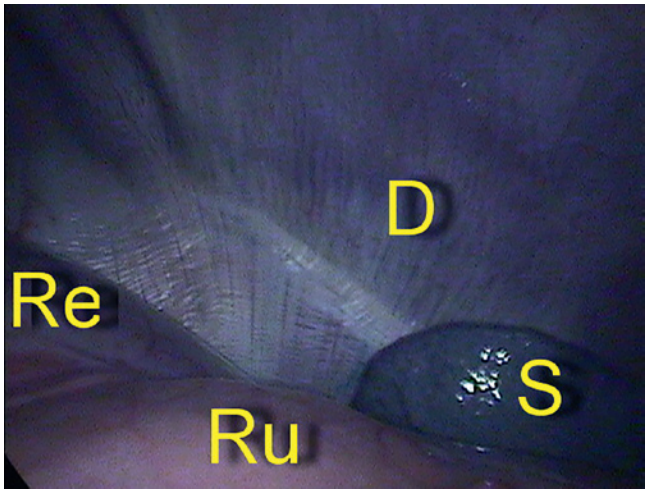


Figure 6-18 Ventral laparoscopy, cranial view. Re, reticulum; Ru, rumen; D, diaphragm; S, spleen.

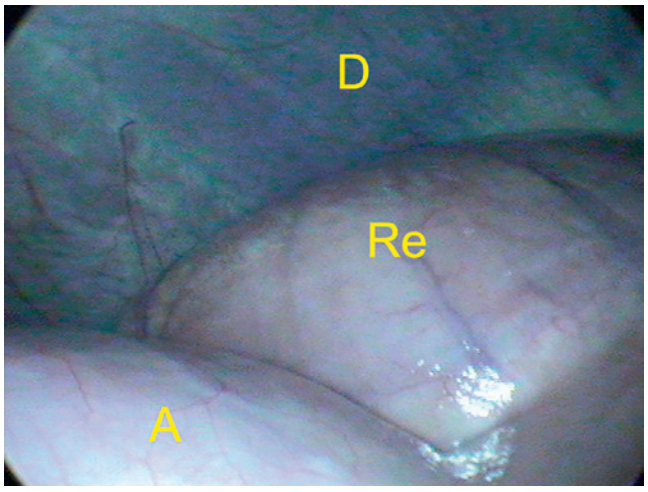


Figure 6-19 Ventral laparoscopy, cranial view. D, diaphragm; Re, reticulum; A, abomasum.

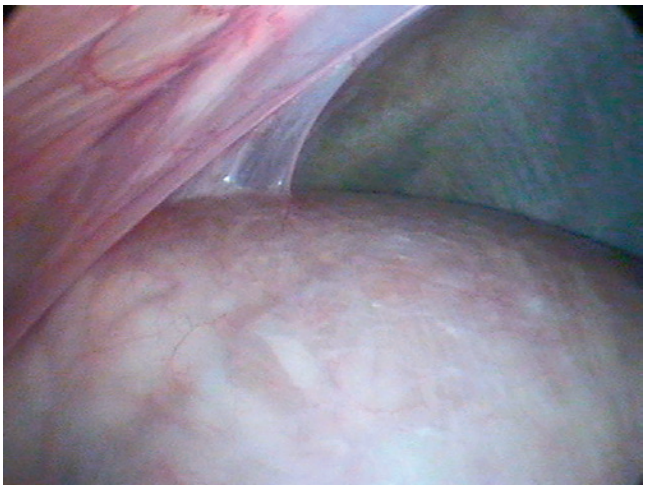


Figure 6-20 Ventral laparoscopy, cranial view: adhesions between the right ventral abdominal wall and the reticulum.

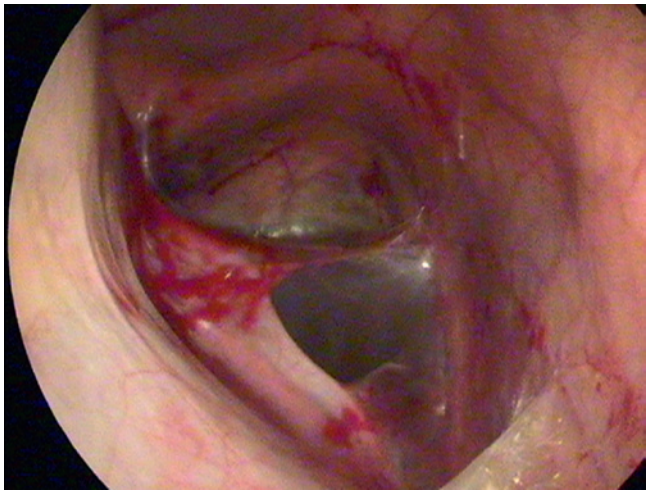


Figure 6-21 Right flank laparoscopy cranial view: adhesions are mostly present ventrally, leaving a small portion of the dorsal abdomen to be viewed.

abomasum and the reticular region without massively invading the abdomen (Figure 6-20).

Postoperative evolution can be slow in some animals. Diagnostics of adhesions or local peritonitis is somehow difficult to confirm without performing a second laparotomy. Without knowing exactly which organs are involved and where the possible lesion is, it can be hazardous to perform a laparotomy. A second look can be done by laparoscopy with less stress on the animal. Then the surgeon can decide whether or not to intervene with few consequences on the animal (Figure 6-21).

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THORACOSCOPY

Sylvain Nichols

Thoracoscopy is a minimally invasive surgery that may be used as a diagnostic or therapeutic tool. It is complementary to other imaging modalities (radiography and ultrasonography) in the diagnosis of pulmonary (abscess, emphysematous bulla, neoplasia), esophageal, and cardiac pathologies. It can help establish drainage of a pulmonary abscess or idiopathic pericardial effusion.

The surgical technique has been described in healthy cattle. The ninth intercostal space (ICS), in the middle of the upper third of the thoracic cavity, is the ideal location for the insertion of the scope (Figure 6-22). It allows localization of most of the pleural structures with minimal discomfort to the animal. Using the seventh or eighth ICS, in the middle of the middle third of the thoracic cavity, may allow better evaluation of the cranioventral structures (pericardium). However, movement of the scope, at this location, is difficult and is painful for the animal.

PREOPERATIVE TREATMENTS AND SURGICAL PREPARATION

Keeping the cow off feed, before the procedure, is not mandatory. Nonsteroidal antiinflammatory drugs (NSAIDs) are indicated. Nervous animals can be sedated with acepromazine (0.05mg/kg IM). This molecule is better than alpha-2 agonists (xylazine) because it causes less cardiovascular depression and is less likely to cause the cow to lie down during the procedure. The cow is restrained in a standing chute, and the thoracic cavity, on which the procedure will be performed, is shaved and cleaned. At this stage, the pleural cavity can be evaluated with the ultrasound to determine that the site chosen for surgery is free of adhesions or any other pathology. Then a combination of locoregional block and local anesthesia is used to desensitize the surgical site. Fifteen milliliters of 2% lidocaine is infiltrated, dorsal to the surgery site, at the neurovascular bundle of the eighth, ninth, and tenth ICSs (see Figure 6-22). Another 10 mL of 2% lidocaine is infiltrated in the subcutaneous tissue and the intercostal muscles at the surgery site. The shaved area is aseptically prepared. Because it has been shown that creating a unilateral pneumothorax has a significant effect on blood gas values (saturation and PaO_2) on healthy cattle, an intranasal cannula is secured to the cow's nostril, and O_2 supplementation is begun just before the surgery.

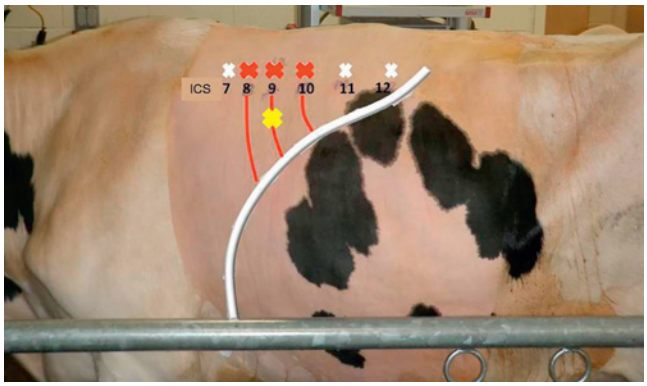


Figure 6-22 Adult cow is shaved and cleaned before local block. The "X" is marking the ninth ICS where the scope will enter the left thoracic cavity. Therefore locoregional anesthesia will be performed at the eighth, ninth, and tenth ICS. Local anesthesia will also be realized at the surgery site. The white line represents the caudal border of the pleural cavity. The border was determined by ultrasonography using a 7.5-mHz linear probe.

SURGICAL TECHNIQUE

A 1-cm skin incision is created with a No. 21 blade in the middle of the ICS prepared. With the same blade, the subcutaneous tissue and the external fascia of the intercostal muscle are incised. A blunt, 3-inch-long, sterile teat cannula is then inserted in the pleural cavity. Room air is allowed to penetrate the pleural cavity for four or five breathing cycles. The teat cannula is replaced by a 15-cm-long, 10-mm diameter, pyramidal trocar-cannula unit. By twisting gently, the unit is pushed into the pleural cavity. The trocar is replaced by a 57-cm-long, 10-mm-diameter rigid scope with a 30-degree viewing angle. A shorter scope or a scope with 0-degree viewing angle limits the evaluation of the cavity. Insufflation of the pleural cavity is not necessary but can be used. If no insufflation is used, the stopcock of the scope is left open during the procedure. If insufflation is used, it is important not to exceed 3 mm Hg of pressure to avoid cardiovascular collapse. At the end of the procedure, the negative pressure is reestablished by removing the air with a suction device attached to the cannula. The lung inflation is observed by retracting the scope within the cannula. When all the air has been removed, the cannula and the scope are removed. A cruciate suture is placed on the skin incision.

ANATOMIC PARTICULARITY

Most of the pleural and mediastinal structures can be seen from both sides of the thorax. However, the esophagus, the vagal nerve, and the aortic arch are better viewed from the left pleural cavity (Figure 6-23). The pericardium is difficult to see. It is seen more frequently from the right side (Figure 6-24).

POSTOPERATIVE TREATMENTS AND COMPLICATIONS

After resolution of the pneumothorax, the vital parameters (heart rate and respiratory rate) and blood gas values (saturation and PaO_2) quickly return within normal limits. NSAID administration, after a thoracic exploratory, does not need to be repeated. The pleural cavity can be evaluated by ultrasonography or by taking postoperative radiographs to determine the presence of a residual pneumothorax. In a

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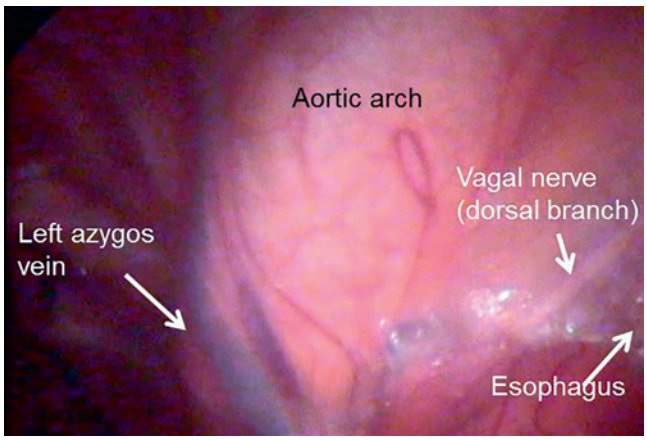


Figure 6-23 View of the left pleural cavity from the ninth ICS. A 57-cm-long, 10-mm-diameter rigid scope with a 30-degree viewing angle was used to obtain this picture.

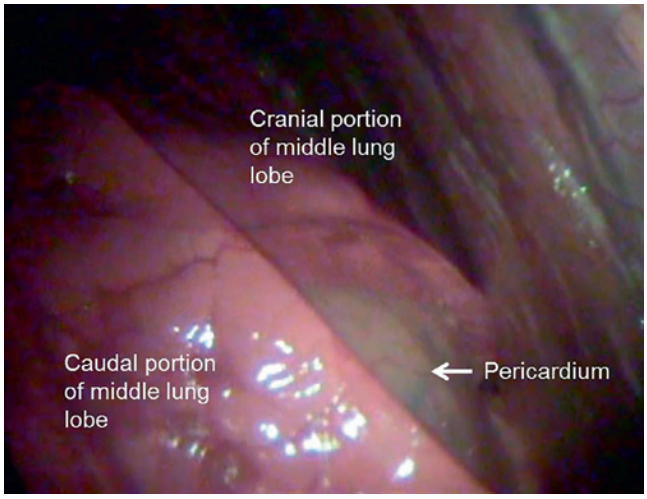


Figure 6-24 View of the right pleural cavity from the ninth ICS. A 57-cm-long, 10-mm-diameter rigid scope with a 30-degree viewing angle was used to obtain this picture.

meta-analysis performed in human medicine, it was shown that ultrasound had a better sensitivity and specificity in diagnosing a pneumothorax compared with radiography. The skin suture is removed 14 days after the procedure.

Complications can occur when the pleural cavity is penetrated by the trocar-cannula unit. The lung can be lacerated resulting in mild hemorrhage or air leakage that can cause pneumothorax in the postoperative period. During the procedure, a cow with bilateral pathology may have cardiorespiratory collapse that will reduce the time available for exploration. At the end of the surgery, when reestablishing the negative pressure, some cows may cough or become agitated if the air is removed too quickly. In the postoperative period, subcutaneous emphysema can develop without any consequences on the general attitude of the cow. The emphysema resolves without treatment. Similarly, a mild pneumothorax may still be present after the surgery. If vital parameters are altered, the air may be removed using a teat cannula attached to a suction device. A chest tube, attached to a Heimlich valve, can be used if deemed necessary.

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CHAPTER 7

Postoperative Management

SallyAnne L. Ness and Adrian Steiner
(The current author would like to acknowledge the previous edition authors Allen J. Roussel, Peter C. Rakestraw and Adrian Steiner)

The postoperative period is often characterized by altered gastrointestinal (GI) motility as a consequence of primary disease, pain, reduced food intake, and anesthesia. Special attention paid to postoperative analgesia and nutritional support of bovine patients can reduce recovery time and improve case outcome.

POSTOPERATIVE ANALGESIA

Postoperative pain management in the bovine patient is important from both a medical and ethical standpoint. Improving patients' comfort following surgery hastens their return to feed and normal GI function, thereby improving patient outcome and overall case success.

It should be noted that there are currently no drugs approved for analgesic use in cattle in the United States. Flunixin meglumine (Banamine) is the only drug with analgesic properties labeled for use in cattle, and it is indicated for the control of pyrexia and inflammation, not for the control of pain. Although there are currently no approved analgesics for use in cattle, the United States Food and Drug Administration (FDA) Center for Veterinary Medicine supports the ethical treatment and management of cattle and aims to improve the availability of safe and effective drugs for the control of pain. It is imperative that clinicians recognize that all use of analgesics in food-producing animals is extralabel and therefore must be prescribed by a licensed veterinarian within the context of a veterinarian-client-patient relationship. Extralabel drug use for pain relief in the United States is regulated under the Animal Medicinal Drug Use Clarification Act (AMDUCA). Recommended withdrawal times must always be strictly observed to avoid violative milk and meat residues. The most commonly used analgesics in cattle are summarized here.

Nonsteroidal Antiinflammatory Drugs

Nonsteroidal antiinflammatory drugs (NSAIDs) exert both antiinflammatory and analgesic effects through the reduction of prostaglandin synthesis by inhibition of the enzyme cyclooxygenase in the peripheral tissues and central nervous system.

Flunixin Meglumine

Currently, flunixin meglumine is the only NSAID approved for use in cattle in the United States; it is labeled for control of fever associated with respiratory disease or mastitis and fever and inflammation associated with endotoxemia. Flunixin is generally administered every 12 to 24 hours intravenously (IV) at a recommended dose of 0.5 to 2.2 mg/kg. Intramuscular (IM) administration of flunixin poses a significant risk of myonecrosis and tissue residues. Frequently noted side effects include GI ulcers and renal toxicity, and this drug should be avoided in dehydrated animals as well as those with renal compromise. Prolonged use should be avoided in all patients to minimize side effects.

Phenylbutazone

Phenylbutazone is associated with rare but fatal side effects in humans, including aplastic anemia, leukopenia, and thrombocytopenia and is therefore strongly discouraged as an analgesic in food-producing animals. The FDA prohibits its extralabel use in female dairy cattle 20 months of age or older. There is also a zero tolerance for phenylbutazone residues in edible tissues from any class of animal.

Meloxicam

Meloxicam is an affordable and orally bioavailable NSAID that has been experimentally shown to alleviate pain associated with dehorning, mastitis, and lameness in cattle. The recommended dose of 0.5 to 1.0 mg/kg orally every 24 hours makes this drug useful for long-term on-farm treatment. The recommended dose of meloxicam in sheep and goats is 0.5 mg/kg orally every 24 hours. An injectable form of meloxicam is approved for use in cattle in Europe; however, it remains cost prohibitive in the United States.

Ketoprofen

Ketoprofen is approved for use in cattle in the European Union and Canada for the alleviation of inflammation and pain associated with arthritis and traumatic musculoskeletal injuries and as an adjunctive therapy for the alleviation of fever, pain, and inflammation associated with acute clinical mastitis. The recommended dose is 3.3 mg/kg by IV or IM injection every 24 hours for up to 3 days.

Opioids

Opioids exert their analgesic effects through the binding of spinal and supraspinal μ, δ, and κ receptors. Although μ receptor activation produces a strong analgesic effect, it has been associated with respiratory depression, sedation, and decreased GI motility in other species, and therefore partial and mixed-receptor opioids have been developed for clinical use. Opioids are designated as schedule 3 drugs in the United States and are subject to regulation by the Drug Enforcement Administration.

Morphine

Morphine is a pure μ receptor agonist that acts on receptors in the spinal cord and central nervous system. Side effects in cattle include bradycardia, respiratory depression, hypotension, and decreased GI motility. The recommended systemic dose is 0.05 to 0.1 mg/kg IV, IM, or subcutaneously (SC) every 4 to 12 hours. Because morphine exerts its effects on receptors in the spinal cord, it can be used very effectively as an epidural medication with or without the addition of an α2 adrenergic agonist, such as xylazine. The recommended morphine epidural dose is 0.1 mg/kg every 12 hours. Xylazine may be added at a dose of 0.05 to 0.07 mg/kg. Neither morphine nor xylazine should cause ataxia or paralysis when delivered epidurally.

Butorphanol

Butorphanol is a κ receptor agonist and μ receptor antagonist. Butorphanol requires a higher dose than in other species

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and has a relatively short duration of action, making this drug cost prohibitive in some cases. The recommended dose is 0.02-0.25 mg/kg IV or SC every 4 to 6 hours. Because of its μ receptor antagonist activity, butorphanol should not be used in combination with morphine.

Gabapentin

Gabapentin is a γ-aminobutyric acid analog developed for the treatment of epilepsy and neuropathic pain. It exerts its effects via binding of the α2δ subunit of voltage-gated calcium channels in the central nervous system, thereby preventing the release of excitatory neurotransmitters. Pharmacokinetic studies in ruminants suggest that a dose of 15 mg/kg orally every 12 hours maintains plasma levels above the human effective threshold, and this drug may hold promise as an oral option for treating chronic and neuropathic pain in food animals.

NUTRITIONAL MANAGEMENT

SallyAnne L. Ness

Postoperative nutritional support focuses on returning the GI tract to normal function in the immediate postoperative period with less attention on specific long-term nutritional needs of the patient. More attention must be given to the nutritional needs of neonates and debilitated patients immediately after surgery, including partial and total parenteral nutrition. The nutritional support of these critical care patients is beyond the scope of this chapter.

EVALUATION OF GI FUNCTION

Evaluation of the GI tract, especially the forestomachs and abomasum, is fundamental to postoperative evaluation of a ruminant patient. During the immediate postoperative period, the most important GI tract features to monitor are GI fill, motility, and microflora.

Gastrointestinal Fill

In most surgical cases, the forestomachs are less full than normal because of anorexia or intentional preoperative fasting. Notable exceptions include vagal indigestion, carbohydrate engorgement, and obstructive diseases of the GI tract. As appetite returns after surgery, the rumenoreticulum and eventually the entire tract regain the appropriate fill. Gastrointestinal fill can best be evaluated by observing the abdominal contour combined with rectal palpation in cattle or transabdominal palpation and ultrasound examination in small ruminants. Discussion of evaluation of abdominal distention is discussed in Chapter 1. The most important abnormal contours of postoperative patients include the following: 1) dorsal and ventral distention on the left with ventral distention on the right; 2) prominent dorsal distention on the left with ventral distention on the right; and 3) bilateral ventral distention.

Dorsal and Ventral Distention on the Left with Ventral Distention on the Right

Dorsal and ventral distention on the left with ventral distention on the right indicates rumenoreticular distention—with or without abomasal distention—that is often, but not exclusively, caused by vagal indigestion. Rectal palpation of a full rumen with an enlarged ventral sac confirms the assessment. Deep palpation of the right ventral flank is recommended to determine whether the abomasum is involved, but experience indicates a distended ventral sac of the rumen can also be palpated in that area. Sonographic examination and visualization of an enlarged fluid-filled abomasum confirms abomasal distention. Evaluating plasma electrolytes, particularly chloride concentration, is helpful to determine if there are abomasal outflow problems. Hypochloremia and metabolic alkalosis indicate abomasal outflow failure, but postoperative intravenous fluid therapy may obfuscate interpretation of this important preoperative test in the postoperative period.

Prominent Dorsal Distention on the Left with Ventral Distention on the Right

Prominent dorsal distention on the left with ventral distention on the right usually indicates the same functional failures as the first abdominal contour, with the additional problem of free-gas bloat or eructation failure. This can be confirmed by rectal palpation and by passing an orogastric tube. Periruminal abscess and ascites are two uncommon conditions that can cause pathology (neurogenic, mechanical, or functional) that result in this abdominal contour. A periruminal abscess may also physically occupy the left paralumbar fossa, giving the external appearance of bloat. Often, the diagnosis is missed or delayed because the history includes bloating in the past, which tends to lead the examiner to assume the distention continues to be caused by ruminal tympany. There may also be a history of bloat treated with needle trocarization or intraruminal injection of antisurfactant products or by rumenotomy. On external palpation of the left paralumbar fossa, the structure may even feel like a gas-filled rumen because of gas in the abscess. However, upon rectal examination, the examiner is unable to pass a hand between the rumen and left abdominal wall, and the abscess usually feels firmer than a rumen. Sonographic examination rectally or transabdominally is useful, and centesis of the mass is confirmatory. In ascites secondary to uroperitoneum or peritonitis, the large amount of peritoneal fluid can push a rather small gas-filled rumen into the left paralumbar fossa and give the external appearance of rumen distention with bloat. Rectal palpation and abdominal sonography or centesis are confirmatory.

Bilateral Ventral Distention

Bilateral ventral distention usually indicates free abdominal fluid such as that accompanying uroperitoneum or diffuse peritonitis. It is similar to the second shape but without the dorsal distention and yields a more symmetric shape. Sonography can differentiate abdominal fluid from intestinal ileus, another possible cause of this contour. Abdominocentesis will allow characterization of the fluid and may help to determine a definitive diagnosis.

The relationships between ruminal fill and feed intake and ruminal fill and fecal production are important to consider. If the rumenoreticulum fills rapidly with the presence of dehydration or commensurate absence of fecal production during the postoperative period, there is most likely a dysfunction of the forestomach compartment or abomasum. As mentioned previously, plasma electrolytes are often useful in assessing abomasal outflow, which may indicate abnormal abomasal motility, intestinal hypomotility, or obstruction. Other means of indirectly assessing abomasal and intestinal motility are auscultation, rectal palpation, and ultrasonography. The absence of gastrointestinal sounds is a more reliable sign than the presence of sounds. The presence of sounds emanating from one area of the GI tract does not mean that the other areas of the tract are moving, nor does it prove that the area producing sounds is functioning properly. However, the total absence of auscultatable motility can be a foreboding sign. Fluid-filled, amotile intestine on rectal or ultrasound examination indicates functional or physical obstruction of the intestinal tract.

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Gastrointestinal Motility

As defined in human medicine, *postoperative ileus* is abnormal motility of the GI tract that follows almost every major surgical procedure, especially abdominal surgery. A postoperative paralytic ileus is a pathologic ileus that occurs after some surgical procedures and can cause clinical signs and serious complications. In cattle, the rumen usually continues to contract during standing surgery; postoperative ruminal paralytic ileus is not usually a problem unless ruminal stasis was present before surgery. However, other parts of the ruminant GI tract are susceptible to ileus. No studies have been performed to define the duration of postoperative ileus in the different parts of the GI tract of ruminants. In most species, the small intestine recovers within the first 24 hours and is followed closely by the stomach. The large intestine is the last region to recover. Understanding that GI motility dysfunction always follows surgery and recognizing when expected postoperative ileus turns into pathologic and serious postoperative paralytic ileus are important.

Evaluation of GI motility involves auscultation and palpation. Intestinal and abomasal sounds can be auscultated on the right side and ventrum, respectively. Rumenoreticular motility can be assessed by auscultation or by placing a fist in the left paralumbar fossa to feel the contractions. When evaluating ruminal contractions, one should note both the frequency and strength of contractions. The author prefers palpation to auscultation for initial assessment of ruminal motility. The normal rumen contracts about 2 to 3 times every 2 minutes. More complete evaluation of the rumen can be accomplished by combining auscultation and palpation through the left paralumbar fossa and rectally. In addition to frequency and strength of contractions, the physical character of the ruminal contents can be appreciated. A sutured surgical incision in the left paralumbar fossa, often present in postsurgical patients, may complicate the execution of auscultation and palpation in this area. The rumen has two contractile cycles that are called *primary* and *secondary*. The primary cycle is associated with mixing ingesta, and the secondary cycle is associated with eructation. The primary cycle stratifies ingesta so the firm fibrous material floats in a mat on top of ruminal liquid. Small particles exit the rumen, and larger ones are retained. Plant fibers more than 0.5 cm long in the feces indicate abnormal ruminal contractile activity. The primary cycle is under vagal parasympathetic control. Factors that stimulate contractions include feeding, low environmental temperature, and a slight distention sufficient to stimulate low-threshold receptors in the rumen. The low-threshold receptors can sometimes be exploited by pumping water and gruel into an empty rumen until mild distention is achieved. This helps stimulate ruminal contractions in anorectic ruminants. Factors that depress ruminal contractile activity include depression, fever, pain, endotoxin, volatile fatty acids, and abdominal distention sufficient to stimulate high threshold receptors. Ruminal motility can sometimes be improved by physically or pharmacologically reversing one or more of these inhibitory factors. Because these stimuli and suppressors of ruminal activity are mediated through the vagus nerve, an intact vagus is required for them to have an effect. Hypocalcemia reduces ruminal contractility by reducing the contractility of smooth muscle fibers irrespective of neural input.

Secondary ruminal contractions result in eructation of ruminal gas. They occur about every 2 minutes and are independent of the primary-cycle contractions. Secondary contractions are stimulated by moderate distention and inhibited by severe distention. The secondary cycle can most easily be recognized by the occurrence of eructation coincident with a contraction. Rumination is a specialized form of secondary contraction stimulated by coarse material in the reticulum and rumen. Subjectively, the occurrence of rumination is a positive prognostic sign in the postoperative patient and is always a welcome sight in any bovine patient.

The motility of the remainder of the ruminant GI tract is similar to the nonruminant. The vagus nerve plays a significant role in controlling abomasal motility, but the intestinal tract is controlled principally by locally produced substances and the enteric nervous system. In diseased animals, external factors such as electrolyte imbalances, inflammation, and endotoxemia can affect intestinal motility. In contrast to the simple and direct techniques for assessing ruminal motility, techniques for assessing abomasal and intestinal motility are indirect and not completely reliable. Auscultation, as described previously, is perhaps most useful to confirm ileus through the absence of sound but is less reliable for confirming normal motility through the presence of sound. Ultrasound is a valuable tool for visualizing motility of both the forestomachs and small intestine and for identifying abscesses, peritonitis, pneumoperitoneum, and other conditions contributing to postoperative ileus. Plasma electrolyte concentrations, especially chloride and bicarbonate ion, can be useful in determining functional or physical obstruction of the GI tract. Severe hypochloridemia and alkalosis are usually associated with abomasal outflow problems or obstruction or dysmotility of the orad small intestine. Less profound electrolyte abnormalities are observed in obstruction of the aborad small intestine and cecum.

Ruminal Microbes

The ruminant forestomachs are a physiologic and biologic wonder, a marvelous example of symbiosis. In the mature cow, the rumen and reticulum represent 64% of the total stomach capacity, whereas the abomasum makes up only 11%. During the transition from preruminant to ruminant, the stomach changes in form, function, and fauna. The rumen and reticulum become a fermentation vat containing between 10^5 and 10^{12} bacteria/mL. The vast majority of ruminant microbes of animals on a forage diet are gram-negative anaerobic bacteria. The proportion of gram-positive organisms increases as the amount of grain in the diet increases. The ruminant's ability to use poor quality roughage, inadequate to sustain nonruminant animals, is facilitated by the bacteria in the rumen. Although bacteria are more important for digestive function, the ruminal protozoa are easier to assess diagnostically, and they provide a reasonable index of ruminal health. Therefore a substantial proportion of the ruminal microbe examination focuses on the protozoal population. For clinical purposes, the ciliate protozoa can be divided into two morphologic types: holotrichs and entodiniomorphs. Holotrichs have cilia surrounding their one-celled bodies, whereas entodiniomorphs have cilia at one end (Figure 7-1).

Ruminal Fluid Analysis

Indications for clinical evaluation of ruminal microflora include suspicion of ruminal acidosis (e.g., carbohydrate engorgement), vagal indigestion, abomasal emptying defect of sheep, and rumen atony. Sometimes the analysis precedes surgery but correction of the problem occurs during the postoperative period. A weighted stomach tube or a needle and syringe can be used to collect ruminal fluid for analysis. When a weighted collection tube is used, it is simply passed into the rumen, pushed back and forth to sink the tube, and aspirated. The first 100 mL or so is discarded to reduce salivary contamination. Aspirating transabdominally through the left flank by using a 16- to 18-gauge, 5-inch needle also eliminates salivary contamination.

A relatively simple analysis is sufficient for clinical evaluation of most presurgical and postsurgical cases. Color, odor,

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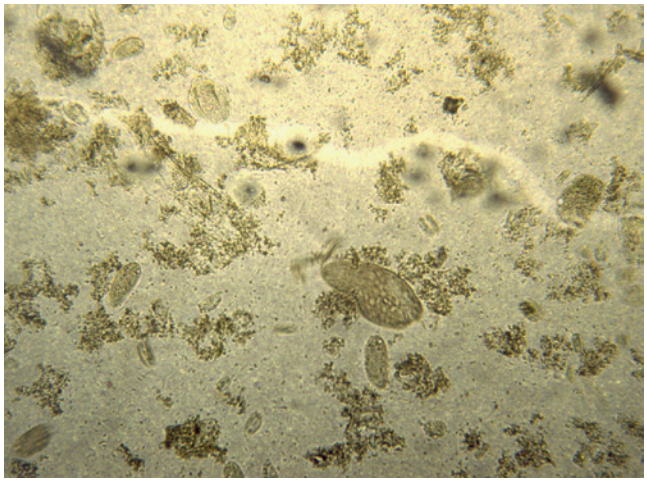


Figure 7-1 The microscopic appearance of ruminal fluid from a healthy cow. Notice the variety of sizes and shapes of the protozoa, which indicates healthy rumen microflora.

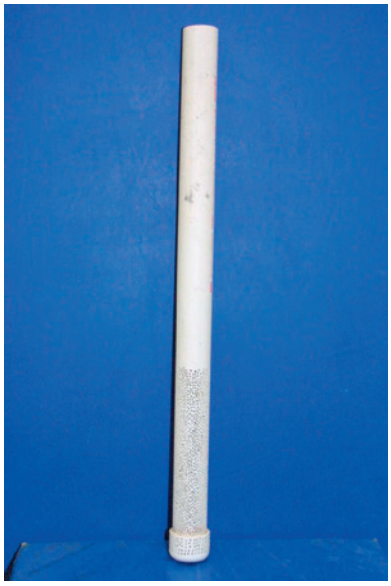


Figure 7-2 Device for collecting large quantities of rumen fluid from a cannulated cow.

and smell should be evaluated immediately. Normal color is gray-green to green to brownish-yellow, depending on the diet. Milky gray or yellow fluid is associated with carbohydrate engorgement. The pH of rumen fluid ranges from 5.5 to 7.0 in healthy cattle on a balanced ration. A pH paper with half-unit sensitivity is sufficient to diagnose ruminal acidosis or alkalosis of a single clinical case. A hand-held pH meter is required for adequate sensitivity at herd-level diagnosis of mild chronic acidosis. Cattle on high-carbohydrate diets have lower pH values than those on roughage diets. Acid pH less than 5.5 in an anorectic ruminant indicates ruminal acidosis. Ruminal pH greater than 7.0 indicates ruminal alkalosis. Simple ruminal inactivity, or anorexia, results in ruminal alkalosis. Cattle with abomasal reflux may have an unusually low pH for an animal that has been off of feed for several days (e.g., 6.5 in comparison to an expected value of 8.0). This is because the abomasal acid has refluxed or been "vomited" into the rumen.

A very simple function test, the methylene blue reduction time, can be performed rapidly without special equipment. The methylene blue reduction test measures metabolic activity of the ruminal flora by indicating the relative redox potential of the rumen. One part of 0.03% methylene blue is added to 20 parts of strained ruminal fluid in a glass blood collection tube and is incubated at 37°C. A second tube of ruminal fluid serves as a control. Clearing of the dye in 5 to 6 minutes indicates active ruminal microbes. Delayed clearing indicates diminished anaerobic bacterial activity. In some cases, measurement of ruminal chloride is indicated. Ruminal chloride can be measured by standard electrolyte analyzers if the sample is filtered. It is elevated (>30 meq/L) in abomasal impaction and some other obstructive diseases in cattle and abomasal emptying defect in sheep.

Direct microscopic examination of fresh ruminal fluid on a slide is a quick and useful way to assess the health of the ruminal microflora. Abundant, live, active protozoa of various sizes and shapes will be present in cattle with a normal rumen (see Figure 7-1). Very large entodiniomorphs are the most fragile species; their presence suggests a healthy rumen. For further evaluation of the microflora, a drop of Lugol's iodine can be added to a few drops of fresh rumen fluid. Lugol's iodine kills the protozoa and stains carbohydrate in protozoa and bacteria. If the protozoa are depleted of carbohydrate, this indicates a depletion of carbohydrate in the rumen. Transfaunation of such an animal without concomitant force feeding is likely to be ineffective because the newly introduced fauna will not have the substrate to allow them to multiply. Gram staining of the ruminal bacterial population can be useful for confirming carbohydrate engorgement. Gram staining performed on normal ruminal contents should reveal primarily gram-negative organisms of a size and shape quite different from those encountered elsewhere in veterinary medicine. In carbohydrate engorgement, chains of the gram-positive cocci *Streptococcus bovis* proliferate first; then the large gram-positive rods of *Lactobacillus* sp. become the predominant bacterial type.

Transfaunation

Transfaunation of an inactive rumen can be accomplished by providing ruminal fluid from a healthy ruminant of the same species. Ruminal contents may be obtained at a slaughterhouse or from another animal that has been fitted with a ruminal cannula. Ruminal fluid collection devices, like the one described by Geishauser, also can be used. The potential to transmit certain diseases exists; therefore a tested donor or a herdmate of the patient is desirable. Figure 7-2 shows a collection device made from polyvinyl chloride pipe. It is a meter long, 5 cm in diameter, and capped at one end. Beginning about 35 cm from the capped end and extending to the cap are hundreds of 2- to 3-mm holes drilled through the wall. The capped end is inserted into the ventral sac of the rumen through the rumen cannula, and a small stomach tube is used to siphon ruminal fluid out of the pipe. This device obviates the need for the messy process of straining the fluid after collection. In an adult cow, 4 to 6 L of freshly collected unstrained ruminal fluid can be administered alone or mixed with alfalfa meal and then chased with 4 to 8 L of water. The alfalfa meal provides nutritional substrate for the transfaunated protozoa, but caution should be paid to avoid overthickening of the transfaunate fluid leading to difficulty pumping and tube clogging. A hand bilge pump with a large-bore orogastric tube passed through an oral speculum can deliver the aforementioned volumes efficiently, often in less than 1 minute (Figure 7-3). Before administering fluids, tube placement within the rumen is confirmed by blowing into the tube

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Figure 7-3 Equipment for administering transfaunate to adult cattle, including large-bore stomach tube, hand bilge pump, cylindrical mouth speculum, fresh rumen fluid, and alfalfa meal.

while a second person auscultates the left paralumbar fossa for bubbling and gurgling noises. It is important to keep stirring the slurry during pumping to prevent it from settling and plugging the tube. If the cow regurgitates during administration (this often occurs if the speculum is allowed to slide too far caudally into the pharynx, causing the animal to gag), the tube is immediately kinked, both speculum and tube are removed, and the animal is allowed to lower its head to prevent aspiration of ruminal contents. Cross-species transfaunation may be of some benefit because some species of ciliates are common to different ruminants and total volumes administered may be extrapolated from bovine dosages to accommodate small ruminants and camelids.

POSTOPERATIVE FEEDING

Neonates

At birth, preruminant animals are physiologically similar to nonruminants. The abomasum represents over half of the total stomach capacity, and the esophageal groove allows the nursing preruminant to function as a simple-stomached animal. Groove closure is a vago-vagal reflex mediated by receptors in the mouth and pharynx. In normal suckling animals, virtually all milk is channeled directly into the abomasum. During the first several days of life, if milk or other liquid is placed directly into the rumen by esophageal or intraruminal intubation, the liquid is rather quickly emptied into the abomasum. Later in the calf's life, however, the efficiency and completeness of emptying of fluid introduced directly into the rumen is reduced, and fermentation and ruminal acidosis can occur if milk remains in the rumen. Therefore every attempt should be made to encourage young ruminants to suckle milk rather than to force feed them by intubation. Intubation with electrolyte solution does not pose the same threat to the ruminal environment as milk. When a calf is reluctant to voluntarily consume milk, it is advisable to provide fluids, electrolytes, and energy (in the form of glucose) by intravenous infusion or intraruminal intubation and refrain from administering intraruminal milk as long as possible without compromising the health of the calf (up to 48 hours). When an anorectic calf is relatively bright, alert, and not emaciated, it is preferable to maintain hydration with IV fluids and moderate amounts of intraruminal oral rehydration solution and allow the calf to become hungry. This often results in spontaneous nursing within 24 hours. On the other hand, when the caregiver is overly concerned about providing enteral nutrition to a calf and frequently intubates it with milk, the calf is less likely to nurse on its own, further delaying voluntary nursing.

Unlike foals, neonatal ruminants do not normally nurse frequently during the day. However, after surgery of the GI tract, offering four or more small feedings per day is probably best for a few days. It is difficult to make hard recommendations concerning the amount to feed. In neonatal calves, milk equaling nearly 10% of the calf's body weight is required for maintenance alone, but after GI surgery such as correction of abomasal volvulus the amount fed for 1 to 2 days should be less than the usual ration. Ideally, intravenous fluid therapy should be continued for 24 to 48 hours postoperatively and milk (and dry foodstuffs if the calf had been consuming them before surgery) reintroduced gradually. A conservative and easy guideline to follow is to feed one-fourth, one-half, three-fourths, and full rations on the four consecutive days after surgery, provided it is tolerated. In nursing beef calves, lambs, and kids, the amount of milk available to the patient can be limited by milking the dam one or more times daily and discarding the milk. Calves under 3 weeks of age should receive whole milk or milk replacer that contains only milk-derived protein. The milk replacer should contain at least 22% protein and 15% fat on a dry-matter basis. Lambs and kids should receive only milk replacer designed for their species. In a hospital situation, whole retail milk is a reasonable feed for calves. Waste milk, especially from animals from a different farm, should be avoided because it may transmit *Mycobacterium avium* subspecies *paratuberculosis*, bovine leukemia virus, caprine arthritis and encephalitis virus, mycoplasma, salmonellae, or other pathogens. Some veterinarians feed lamb milk replacer to calves as a convalescent diet because it contains higher concentrations of fat and protein than cow's milk does.

Mature Ruminants

Postoperative feeding strategies should be aimed at providing adequate nutrition for healing of the surgical wound and any other tissue damage as well as maintaining body systems, restoring or maintaining functional microflora in the forestomachs, and returning the animal to production as soon as possible, especially in dairy cows. At the same time, consideration must be given to 1) the possibility that anorexia before surgery may have rendered the rumen unprepared for a typical high-production, grain-rich diet and 2) the time for recovery of the compromised gut in cases of diseases that involve the GI tract. In cases such as intussusception and abomasal volvulus, in which ileus is likely to be a problem, small amounts of hay (1 kg) and grain (0.5 kg) 2 to 3 times daily should be fed for a few days. The amount can be increased gradually if abdominal distention is absent and feces are being passed. For other procedures, beginning with half rations and working up to full rations in 3 to 5 days is usually done without complication.

In anorectic cattle, force feeding is often beneficial. Although many recipes for force-fed rations exist, the base ration is usually a pelleted feed or alfalfa meal soaked in water to create a slurry. In areas where it can be purchased, hominy grits work well to provide energy because they flow through a tube easily. It is best to use a pellet without large pieces of grain; otherwise the slurry will plug the stomach pump. About 1 kg of feed in 12 L of water usually yields a slurry with the right consistency. Pelleted complete equine diets may also be used. A hand bilge pump with large-bore orogastric tube passed through an oral speculum or cattle pump system[1] with a self-restraining flexible esophageal

[1]Magrath Cattle Pump System (Miller Manufacturing Company, McCook, NE, USA).

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tube works well. Before administering the slurry, tube placement within the rumen is confirmed by blowing into the tube while a second person auscultates the left paralumbar fossa for bubbling and gurgling noises. It is important to keep stirring the slurry during pumping to prevent it from settling and plugging the tube. If the cow regurgitates during administration (this often occurs if the speculum is allowed to slide too far caudally into the pharynx, causing the animal to gag), the tube is immediately kinked, both speculum and tube are removed, and the animal is allowed to lower its head to prevent aspiration of ruminal contents.

Depending on the class of animal (lactating dairy cow versus wether goat) and its metabolic status, other ingredients such as yeast, electrolytes, propylene glycol, and calcium may be added. When the ruminal microflora are compromised, there may not be adequate, or at least optimal, production of B vitamins for the animal. Therefore injectable B vitamins are warranted in anorectic ruminants.

Postoperative ileus, as described previously, may complicate recovery after surgery. The most prominent clinical sign of postoperative ileus, irrespective of the location of the problem, is usually ruminal distention. From a postoperative nutritional and medical management perspective, a simple rule to follow is to cease enteral feeding at the first sign of ruminal distention. Remove excess ruminal contents if necessary with a large-bore stomach tube, and provide fluid, electrolyte, and energy by the parenteral route described in Chapter 4, Fluid Therapy.

When attempting to coax anorectic animals to eat, it is often helpful to offer small amounts of a variety of foodstuffs. Predicting which type of foodstuff the animal will consume first is difficult, and it is not always the feed to which they are accustomed. By putting small piles of a dry feed such as cracked corn or oats, a pelleted feed, and a coarse sweet feed in the trough, one offers the animal choices and enhances the chance of finding a foodstuff the animal will eat. The author's opinion is that finicky cattle eat best when just a small amount of feed is available. Perhaps this is simply because when excess feed is available consumption of small amounts cannot be detected. At any rate, this method appears to enhance consumption and certainly facilitates quantifying what is being consumed.

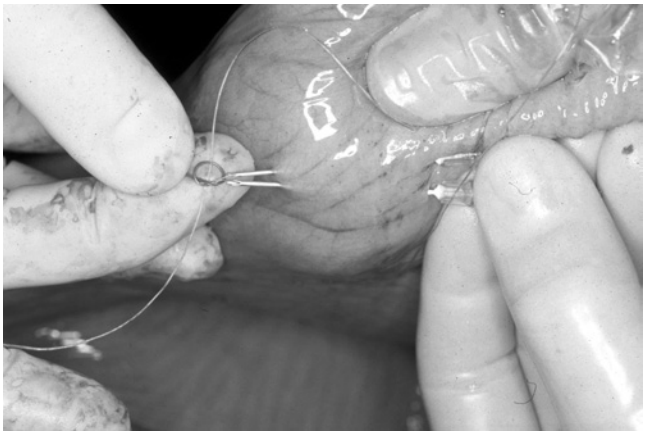


Figure 7-4 Implantation of retrievable bipolar electrodes in the cecum of an adult cow for registration of myoelectric activity.



Figure 7-5 Myoelectric activity of the pyloric antrum of a healthy adult cow. (Courtesy of Dr. Mireille Meylan.)

MOTILITY MODIFIERS

SallyAnne L. Ness and Adrian Steiner

Physiologic GI motility patterns, regulation of GI motility, pathologic motility patterns during GI disease, and pharmacologic modification of GI motility are extremely complex and far from being fully understood. The GI problems in cattle that potentially benefit from pharmacologic motility modification include intestinal obstruction, cecal dilatation/dislocation (CDD), and displacement of the abomasum (DA), DA to the left being by far the economically most important of these diseases. As a prerequisite for understanding and correct interpretation of scientific publications and results in the field of motility modifiers, the reader needs to be familiar with the basic concepts of motility monitoring, physiologic and pathologic motility patterns, and motility regulation.

MOTILITY REGISTRATION

Techniques for registration of GI motility in vivo include direct visualization, indirect visualization (using radiography, ultrasonography, or nuclear scintigraphy), acetaminophen-absorption test, transit of nonabsorbable microspheres, intraluminal and intramural pressure measurements, and analysis of myoelectric activity (Figure 7-4). Most motility studies in cattle are based on registration and analysis of myoelectric activity.

PHYSIOLOGIC GI MOTILITY

Myoelectric signals of the digestive tract in cattle follow the same basic patterns as in other species. They are characterized by slow waves (electric control activity) and superimposed spike bursts (electric response activity). Slow waves are spontaneous, regular oscillations of the smooth-muscle cell membrane potential, which remains below the depolarization threshold. If the depolarization threshold is exceeded, a maximum of one spike burst can be superimposed on one slow wave. Thus the maximal frequency of spike bursts is determined by the frequency of slow waves. Spiking activity is directly correlated with smooth-muscle contractions (that is, mechanical activity), and propulsion of gut contents is correlated with propagated smooth-muscle contractions. Therefore recording of myoelectric activity of the gut wall may be used as a technique for characterization of GI motility.

Abomasum

Myoelectric activity of the abomasal antrum is characterized by slow waves, regularly occurring at a mean frequency of 3.3 per minute. Eighty-two percent of the slow waves are superimposed by spikes (Figure 7-5). Almost half of the antral spikes are propagated to the proximal duodenum. This

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most likely represents abomasal emptying. Further coordination between antral and small intestinal motility exists. It is characterized by a reduction of the frequency of slow waves and spike bursts in the abomasal antrum immediately after phase III of the migrating myoelectric complex (MMC) occurs in the duodenum. (See next section on the small intestine.)

Small Intestine

Motility of the small intestine is well organized and consists of a 30- to 90-minute regularly recurring, aborally propagated pattern of myoelectric activity, termed MMC. The MMC is initiated in the duodenum and consists of three phases. Phase I is characterized by less than 10% of the slow waves being superimposed by spikes. It immediately follows phase III and is immediately followed by phase II. Phase II is usually the longest of the three phases. It is the phase of irregular spiking activity, with more than 10% but less than 100% of the slow waves superimposed by spikes. Intense mixing of gut contents takes place during phase II. The last few minutes of phase II are thought to be responsible for propulsion of intestinal contents. Phase III is the phase of regular spiking activity, with 100% of the slow waves being superimposed by spikes (Figure 7-6). The role attributed to phase III is to clean the lumen of debris and residual content and to prevent retrograde flow of intestinal contents (housekeeping function). In ruminants, feeding does not interrupt the MMC. Propagation velocity of phase III ranges from 30 cm per minute in the duodenum to less than 10 cm per minute in the ileum.

Cecum and Proximal Loop of the Ascending Colon (PLAC)

Cyclical activity and propagated spike sequences are also found in the cecum and PLAC. Occurrence of hyperactivity in the cecum is coordinated with phase III of each MMC in the ileum. Hyperactivity in the cecum may be responsible for mixing of the new bolus with the stored contents in the cecum. Nonpropagated spikes and spike sequences propagated in both directions are responsible for mixing of intestinal contents. Aborally propagated spike sequences are responsible for propagation of contents from the cecum to the PLAC. Regular emptying of the PLAC is well coordinated with the myoelectric motility pattern of the spiral colon.



Figure 7-6 Myoelectric activity of the ileum, cecum, and proximal loop of the ascending colon and spiral colon of a healthy adult cow, recorded over 9 hours. (Courtesy of Dr. Mireille Meylan.)

Spiral Colon

Myoelectric activity of the spiral colon is characterized by a regularly recurring, aborally propagated pattern, termed *bovine colonic MMC*. The bovine colonic MMC lasts about 3 hours and consists of four phases. More than 90% of the bovine colonic MMCs are propagated throughout the entire spiral colon. Similar to the MMC in the small intestine, phase II is by far the longest phase. The last few minutes of phase II are thought to be responsible for aboral propulsion of intestinal contents in the bovine spiral colon. The housekeeping function is attributed to phase III with its regular and intense spikes of long duration (see Figure 7-6). The function of phase IV is not clear.

PATHOLOGIC MOTILITY PATTERNS

Intestinal Obstruction

Myoelectric activity patterns occurring during small intestinal obstruction are characterized by the disorganization of the MMC in the segment oral to an obstruction. The MMC is replaced by rapidly migrating, prolonged, high-amplitude spikes that sometimes occur in clusters. This characteristic pattern is termed *colic motor complex*. The pattern occurring aboral to an obstruction is not consistent and depends on the species affected and the degree of luminal occlusion. Myoelectric activity of the PLAC during obstruction of the proximal part of the spiral colon is similarly characterized by increased spike duration, increased number of spikes propagated toward the obstruction site, and increased velocity of spike propagation. In analogy to small intestinal obstruction, this pattern was termed *colonic colic motor complex*. The colic motor complexes may represent an effort of the intestine to overcome the obstruction to reestablish the continuity of digesta passage.

Cecal Dilatation/Dislocation

Atony, or hypotony, affecting the cecum and the PLAC, have been postulated to trigger CDD. However, during the past three decades, researchers were not able to confirm this hypothesis. Attempts at scientific induction of CDD were not successful, and an accepted disease model for CDD has never been established. In cases of delayed recovery and/or recurrence after surgical evacuation of spontaneous CDD, a pattern of myoelectric activity in the cecum and PLAC similar to the colic motor complex was found. It was suggested that atony and/or hypotony of the cecum were not the cause of recurrence of CDD. An alternative hypothesis offered was that an obstruction of the spiral colon might be responsible for recurrence of CDD after surgical correction of spontaneous CDD.

Displacement of the Abomasum

In the early 1970s, abomasal atony had been postulated to precede distention and displacement of the abomasum. Since then, researchers have not been able to confirm this hypothesis. In another study, extended periods of atony preceding DA to the left were not found. However, during periods of left displacement, compared with periods of normal abomasal position, significant decrease in the number of spike bursts was found in the abomasal corpus and pyloric antrum. Therefore significant decrease of myoelectric activity was found during, rather than immediately before, DA. Smooth-muscle preparations collected from displaced abomasa compared with nondisplaced abomasa showed an increase in nitric oxide–mediated inhibition and a decrease in sensitivity to acetylcholine-mediated excitation. This suggests a malfunction at the level of the intrinsic nervous system and/or abomasal smooth-muscle cells. Whether this is a preexisting

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condition predisposing the animal to DA or a result of the displacement has yet to be determined.

PROKINETICS IN RUMINANTS

Numerous causes of hypodynamic GI motility disorders have been demonstrated in various species. These include electrolyte imbalances, such as hypocalcemia, shock, inflammation, endotoxemia, and intestinal ischemia. Although the effects of these pathologic conditions may not have been evaluated specifically in ruminants, there are enough similarities between species to suggest these abnormalities will also adversely affect motility in ruminants. Treatment plans to correct impaired GI motility should initially evaluate and correct these problems if they exist. Prokinetic drugs will have little therapeutic effect in ruminants with ischemic bowel, hypocalcemia, or a mechanical obstruction.

The primary areas of the ruminant digestive tract that have been studied in relation to the use of prokinetics to treat hypomotility disorders are the abomasum, small intestine, cecum, and proximal ascending colon. Although literature has not been able to support the thought that abomasal atony and/or delayed abomasal emptying predispose ruminants to abomasal displacement, it is possible that drugs that alter the pattern of contractile activity may be beneficial in treating these disorders in some instances. Paralytic ileus involving the small intestine, as well as the large intestine, can occur after any abdominal insult, such as impaction or volvulus, resulting in traumatized/inflamed intestine. Prokinetics may act by stimulating contractile activity directly or by attenuating the inflammatory process and resulting motility depression. Motility dysfunction of the cecum and proximal loop of the ascending colon are thought to predispose to cecal dilatation/volvulus. Drugs that promote normal motility patterns in these areas may have efficacy in the medical treatment of cecal dilation.

The following is a list of prokinetic drugs that may be beneficial in treating certain GI conditions in the ruminant.

Bethanechol

Bethanechol hydrochloride is a direct-acting parasympathetic agonist that stimulates acetylcholine receptors on the GI smooth muscle, increasing contractile activity. There is some preliminary support showing that bethanechol may improve small-intestinal motility in the ruminant. Bethanechol (0.07 mg/kg SC) increased the duodenal spike rate (associated with contractile activity) for the first hour after administration in normal yearling cattle. However, a combination of bethanechol (0.07 mg/kg SC) and metoclopramide (0.1 mg/kg SC) significantly improved propagating spike activity, which is more likely to indicate propulsive motility in the duodenum. In the large bowel, bethanechol (0.07 mg/kg SC) has been shown to increase the number of cecocolic spikes, the duration of cecocolic spiking activity, and the number of propagated spikes in normal cows. Although the underlying cause of CDD is not known, these results indicate that bethanechol at this dosage may be a suitable medical or postoperative treatment for cecal dilatation in cattle in which hypomotility of the cecum and proximal loop of the ascending colon are present. It should be kept in mind in evaluating the results of the previously mentioned studies that these were performed in normal animals and extrapolation to pathologic states may not always be valid. Excessive salivation may be observed after administration as a result of bethanechol's parasympathetic agonist activity (Figure 7-7). This side effect appears to be transient and dose dependent.



Figure 7-7 Excessive salivation observed in a cow treated with bethanechol.

Neostigmine

Neostigmine methylsulfate is a cholinesterase inhibitor that prolongs the activity of acetylcholine by retarding its breakdown at the synaptic junction. The effect of neostigmine (0.02 mg/kg) on myoelectric activity of the ileocecocolic area in normal cows was mainly to increase the number of cecocolic spikes. However, neostigmine increased the ratio of orally to aborally propagated spike sequences, suggesting that neostigmine may promote retrograde versus antegrade propagation of GI motility. Consequently, based on studies in normal cows, bethanechol may be a more suitable drug to treat cecal dilatation in cattle in which hypomotility of the cecum and proximal ascending colon are thought to contribute to the pathologic process.

Another report describes the use of neostigmine administered as a continuous drip (87.5 mg/10 L of NaCl administered at 2 drops/sec) to treat cattle with cecal dilatation. Bradycardia and restlessness were commonly seen side effects, necessitating careful monitoring of the animal.

Metoclopramide

Metoclopramide acts to stimulate progressive motility by antagonizing the inhibitory neurotransmitter dopamine, augmenting the release of acetylcholine, and acting through both inhibitory and excitatory serotonergic receptors. It has been suggested that metoclopramide improves antroduodenal coordination and consequently is an effective prokinetic to treat delayed gastric emptying in different species. Metoclopramide (0.1 mg/kg SC), used together with bethanechol (0.07 mg/kg SC) was more effective than either medication used alone in increased propagated spike activity in the abomasum and duodenum in normal cattle. Metoclopramide was not effective in improving myoelectric activity in the cecum and proximal ascending colon. Administered at a higher dose (0.5 mg/kg IM) in another study, metoclopramide transiently increased electrical activity of the proximal duodenum in goats. These results support the observation that this drug may be more suitable for proximal motility disorders, such as rumen and abomasal emptying problems,

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as well as small-intestinal hypomotility disorders. This is in agreement with findings in other species in which metoclopramide is primarily used to treat gastric and small-intestinal motility disorders. Metoclopramide has been used in the treatment of abomasal emptying defects in sheep and vagal indigestion in cattle. The recommended dose in ruminants is 0.1 to 0.5 mg/kg SC or IM. Hypotension has been reported to occur after intravenous use. Reported side effects are restlessness, excitement, and somnolence.

Erythromycin

Erythromycin is a macrolide antibiotic with recognized GI side effects. When administered at subtherapeutic antimicrobial levels, erythromycin has been shown to stimulate gastric emptying, antroduodenal coordination, increased contractile activity in the small intestine, and increased cecal emptying in nonruminant species. Erythromycin is a motilin agonist that stimulates motilin receptors on the GI smooth muscle. It also stimulates the release of acetylcholine. Because erythromycin appears to stimulate motility throughout the GI tract in other species, its use may be indicated for rumen, abomasum, and small and large intestine hypomotility disorders. In a study performed by Nouri et al., erythromycin administered to healthy suckling calves (8.8 mg/kg IM) increased abomasal emptying rate, whereas metoclopramide and neostigmine failed to alter abomasal motility or emptying rate. In lactating dairy cows, erythromycin lactobionate (1.0 mg/kg IV or IM) and erythromycin base (10 mg/kg IM) in polyethylene glycol resulted in a large and sustained increase in abomasal motility and rate of abomasal emptying. Abdominal pain and diarrhea are the most commonly reported side effects seen with this drug.

Lidocaine

Inhibitory reflexes that are confined to the gut as well as involving the prevertebral ganglia and spinal cord are involved in the pathogenesis of certain motility disturbances. These become important after abdominal surgery when the original GI insult, as well as the bowel manipulations during surgical correction, causes an inflammatory response. Endotoxemia associated with enteritis/colitis will also activate these inhibitory reflexes. Intravenous lidocaine can promote motility by reducing the level of circulating catecholamines, blocking the inhibitory reflexes, and decreasing the production of inflammatory mediators in the bowel wall, many of which are inhibitory. Some work has shown that normal small intestine and colon is under a basal inhibitory neural tone. Addition of lidocaine blocks this inhibitory tone and has been shown to increase contractile activity. For this reason lidocaine may also be beneficial in motility disorders that lack an inflammatory component. The recommended protocol is an initial bolus of 1.3 mg/kg IV administered slowly over 5 minutes followed by 0.05 mg/kg/min in saline, Plasma-Lyte, or lactated Ringer's solution as a constant rate infusion.

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CHAPTER 8

Neoplasia

Beth A. Valentine and Emily E. Barrell

NEOPLASIA IN FARM ANIMALS—GENERAL OVERVIEW

Beth A. Valentine

WHAT DOES THE PATHOLOGIST NEED TO GET AN ACCURATE DIAGNOSIS?

The description of neoplastic disorders and incidence of neoplasia in farm animals has historically relied heavily on surveys conducted on animals at slaughterhouses. The incidence of tumors reported in such surveys indicates that tumors are most common in cattle (0.23%) and are uncommon in sheep (0.002%), goats (0.009%), and pigs (0.004%). Slaughterhouse study results may be misleading, however, as shown by two university retrospective studies, one of goat samples submitted for necropsy or biopsy and another of cattle examined at necropsy; each found neoplastic disease in 8.7% of the cases. Pot-bellied pigs may be particularly prone to neoplasia, as a university study of necropsy and biopsy diagnoses found neoplasia in 34.9% of cases.

The majority of tumors are most common in adults. One study found that tumors in cattle were 10 times more likely in adults than in calves. Neoplasia in young farm animals is most common in calves and pigs, and tumors in these species can be congenital. Carcinomas are most often seen in adult to aged farm animals, whereas tumors of young animals are more likely to be of mesenchymal origin. In particular, lymphoma, mesothelioma, rhabdomyoma, rhabdomyosarcoma, and nephroblastoma (embryonal nephroma) occur typically in young animals.

Neoplastic disease is a significant economic problem, particularly in cattle. A study of culling and mortality in beef cattle found that malignant neoplasia was second only to traumatic reticuloperitonitis as the most common causes of death or euthanasia. Lymphoma was the eighth most common cause of death or euthanasia in a study of dairy cattle.

Far fewer clinical descriptions of neoplasia in farm animals exist than do clinical reports of neoplastic diseases in dogs, cats, and horses. Reports of surgical treatment of tumors of farm animals are even less common. The changing face of livestock husbandry—with the increase in small hobby farms, sanctuaries, and petting zoos—will likely result in earlier detection of clinical signs associated with neoplastic disease and increased owner interest in pursuing surgery. With the advent of improved diagnostic procedures—in particular, ultrasound—detecting internal tumors at early stages is now possible.

This chapter describes neoplastic disorders of cattle, sheep, goats, and pigs that might present for surgical biopsy or surgical excision. As such, tumors of organs such as the heart and brain have been excluded. A few nonneoplastic lesions that present as mass lesions are also included. In some cases, particularly congenital and neonatal lesions, it is unclear whether the growth is truly neoplastic or whether it is malformative (hamartoma or choristoma).

Information regarding treatment, including success rate, is included when possible. In many cases of farm animal neoplasia, extrapolation from information available on results of surgery on similar tumors in cats, dogs, and horses is the best that can be provided at this time.

THE ROLE OF CYTOGENETICS AND MOLECULAR DIAGNOSTICS IN THE DIAGNOSIS

Although some tumors—for example, fibropapillomas—have characteristic gross pathologic features, in many cases cytopathology or histopathology will be necessary to determine the nature of a mass lesion. Fine-needle aspirates of suspect neoplastic lesions are readily obtained and can yield valuable information regarding the nature of the lesion and, if neoplastic, the tumor cell type. In many cases, though, histopathologic evaluation will be essential to confirm the diagnosis and will also determine whether excision is complete.

Veterinary pathologists have relied primarily on routine processing of formalin-fixed tissue for diagnosis, although frozen-section histopathology is possible and, when available, can offer rapid diagnostic feedback. In addition to routine hematoxylin and eosin-stained sections, pathologists can use a variety of histochemical stains to aid in the diagnosis of neoplasms. Commonly utilized stains for diagnosis of neoplasms include Giemsa and toluidine blue stains for metachromatic intracytoplasmic granules to diagnose mast cell neoplasia, Fontana-Masson silver stain for melanin granules to diagnose melanocytic neoplasia, and argentaffin and argyrophil silver stains to detect neurosecretory granules in neuroendocrine tumors.

More recently, the use of antibodies to detect characteristic proteins in immunohistochemical procedures has greatly enhanced the pathologist's ability to determine a tumor cell type. For example, cytokeratins will detect epithelial cells, lymphocyte markers confirm the diagnosis of lymphoma and provide information regarding neoplastic cell type, Melan-A identifies melanocytic cells, and antibodies to proteins specific to muscle can detect and distinguish smooth muscle and striated muscle tumors. Most proteins used in immunohistochemical studies are conserved across species, and the antibodies employed often recognize multiple species, including farm animals. But validation of immunohistochemical studies through the use of appropriate controls is essential. A study of subcutaneous hemangiosarcoma in a sheep, in which the commonly employed endothelial markers anti-von Willebrand's factor and anti-CD31 did not react with normal or neoplastic sheep endothelial cells and in which antibodies to endothelin-1 were necessary to diagnose vascular neoplasia, exemplifies the importance of validation of antibodies when studying farm animal tumors.

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Other possible diagnostic procedures include viral studies, used most often in studies of papillomavirus-associated tumors. Cytogenetics has not yet gained wide use in studies of farm animal neoplasia. Cytogenetic studies of cultured cells from a piglet with rhabdomyosarcoma found a deletion of a portion of the X chromosome, and a study of a benign melanocytic tumor in a sheep did not find evidence for mutations in two genes most often mutated in human malignant melanoma. Additional molecular genetic studies of farm animal tumor cells may be found to be useful in the future, in particular in studies of congenital tumors such as skeletal muscle tumors and melanocytic tumors that may have value as animal models of human disease.

When submitting samples for cytologic or histopathologic evaluation, the actions of the surgeon can greatly increase the ability of the pathologist to provide an accurate diagnosis. In addition to gentle tissue handling, the surgeon should

- Ensure that the sample is placed into an appropriate volume of neutral buffered formalin. A ratio of 9 parts formalin to 1 part tissue is ideal.
- Know that, if a tissue is compressed to fit through a narrow-mouthed container, formalin fixation will harden the tissue and it will be necessary to break the jar to retrieve the sample.
- Use only containers with leak-proof lids. Containers designed for urine sample collection will leak no matter what the surgeon does to try to seal them.
- Enhance fixation by preincising large samples. Incisions should be no closer than 1 cm apart and should not be placed in the deep margin of samples with overlying haired skin. For larger samples, including skin, make preincisions through the skin surface. Larger samples can also be halved and placed in separate jars. Very large samples may necessitate submission of multiple representative samples from different parts of the lesion and sending either the entire remaining unfixed tissue or an image of the original lesion.
- Provide a complete signalment. In some cases, particularly cutaneous tumors, information regarding coat color can be important. If exact age is not known, using terms such as *very young*, *young adult*, or *geriatric* can be useful.
- Provide a complete history including location, rate of growth, appearance (submission of digital images is greatly encouraged), and texture. For histopathologic samples, state whether the excision was incisional or excisional. Inclusion of clinical differential diagnoses is encouraged.

In any case in which the pathologic diagnosis is not consistent with the clinical features, do not hesitate to call the pathologist to discuss the case. In some cases referral for additional opinions is useful.

TUMORS OF THE SKIN AND SOFT TISSUE

Skin tumors are the most common neoplasms in farm animals. This is in large part caused by the high incidence of papillomavirus-induced lesions in the skin of cattle. Other tumors occur less frequently, and skin tumors in general are less common in sheep, goats, and pigs. Tumors of the soft tissue (subcutis and skeletal muscle) are rare and are included in this section because they are likely to present as mass lesions visible and palpable on external physical examination.

Papilloma and Fibropapilloma (Papillomatosis)

Papillomas, commonly called *warts*, are the most common skin tumor of cattle. Shorthorn cattle appear to be predisposed to the development of cutaneous papillomatosis. These tumors in cattle result from bovine papillomavirus infection and most often occur in animals less than 2 years of age. Viral infection of skin is thought to occur most often after trauma, infections, ectoparasites, or ultraviolet light exposure that damages the skin. Virally induced cutaneous papillomatosis occurs less often in sheep and goats of any age, and a viral cause is suspected in affected goats. Papillomatosis is rare but can occur in pigs of all ages. Piglets can be born with congenital papillomas that may or may not be virally induced. Papillomas can also involve the eyelids of cattle and the genitalia of cattle and pigs and are discussed in the sections on tumors of the eye and tumors of the female and of the male genital tract. Papillomas of the udder and teats in cattle, sheep, and goats are discussed in the section on tumors of the udder and mammary gland.

Bovine papillomas can become quite large and multinodular. They may be broad based or pedunculated, they are alopecic, and surface hyperkeratosis is typical. Exophytic growths are most common, although flat plaque-like growths are also possible. Lesions can occur anywhere on the body, but the head, neck, and dewlap are common sites (Figure 8-1). In sheep, papillomatosis most often involves the skin of the face and legs. Goat papillomas most often occur on the head, neck, shoulders, and upper forelegs.

Raised lesions of the interdigital skin of adult cattle can be due to papillomavirus (Figure 8-2) or to bacteria (spirochetes). *Papillomatous digital dermatitis* is a more appropriate term for the bacterial-induced lesions, which are typically single, raised, painful growths often with surface finger-like projections of epithelium. Lameness, weight loss, and decreased milk production occur in cattle with interdigital papillomatous dermatitis. These growths can occur only in individual animals or can apparently spread to involve multiple animals.

Histologic evaluation of papillomas reveals two main types of proliferative lesions. Those with entirely squamous epithelial proliferations are classified as squamous papillomas, and those with proliferation of underlying fibrous connective tissue as well as of epithelium are classified as fibropapillomas. Papillomaviruses are known to be capable of inducing proliferation of both epithelial cells and fibroblasts. Identification of the spirochetes associated with bovine papillomatous digital dermatitis requires silver stains for bacteria.

Papillomas in farm animals can be contagious, with an incubation period of about 2 to 6 months. Herd outbreaks



Figure 8-1 Multiple papillomas caused by bovine papillomavirus on facial skin of a young cow. (Courtesy of Dr. Erwin Pearson.)

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Figure 8-2 Interdigital papilloma in a bull. (Courtesy of Dr. Christiane Löhr.)

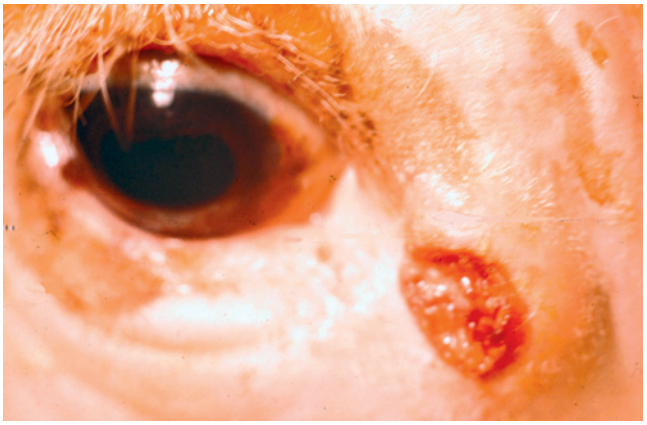


Figure 8-3 Bovine periocular squamous cell carcinoma. (Courtesy of Dr. Barry Cooper.)



Figure 8-4 Ulcerated squamous cell carcinoma in muzzle skin of a Jacob's sheep. (Courtesy of Dr. Christiane Löhr and Dr. Kelly Hughes.)

of papillomas on the pinna can occur when instruments used for inserting ear tags or for tattooing skin are not adequately disinfected between animals. Most papillomas that develop in young animals will spontaneously regress. Surgical excision of one tumor or use of immunostimulants have been said to speed the regression, but whether these procedures actually alter the natural course of the disease is not clear. Papillomas in adult sheep and goats less commonly regress spontaneously, and persistent tumors can undergo malignant transformation to squamous cell carcinoma (see Squamous Cell Carcinoma). Congenital papillomas in piglets can grow rapidly after birth. Surgical excision or cryotherapy of cutaneous and interdigital papillomas of cattle and of papillomas of sheep, goats, and piglets is often curative. In dairy cattle, treatment of papillomatous interdigital dermatitis with parenteral penicillin, ceftiofur, or topical oxytetracycline resulted in resolution of the lesions, which is good evidence that bacteria play an important pathogenic role in this disorder. Recurrence or subsequent development of new lesions, however, occurred in almost 50% of cases.

Squamous Cell Carcinoma

Squamous cell carcinoma is the second most common skin tumor in almost all farm animals. Domestic swine are the exception, as cutaneous squamous cell carcinoma is very rare in domestic pigs. This is interesting, as the development of cutaneous squamous cell carcinoma has been linked to ultraviolet light exposure of thinly haired unpigmented skin, which most domestic pigs have in abundance. Squamous cell carcinoma does occur in pot-bellied pigs. Viral papillomas can progress to cutaneous squamous cell carcinoma, especially those on the udder (see Tumors of the Udder and Mammary Gland). Squamous cell carcinoma typically occurs in adult animals. In cattle, Herefords and Ayrshires are predisposed to squamous cell carcinoma, most likely because of their large areas of unpigmented skin. Aged ewes and Merino sheep are more likely to develop squamous cell carcinoma, and both ultraviolet light exposure and exposure to photosensitizing plants are proposed etiologic factors. Saanen, Saanen cross, and Angora goats with white- or gray-haired areas appear to be predisposed to cutaneous squamous cell carcinoma. Cutaneous squamous cell carcinoma has been reported to be the second most common tumor in goats. Squamous cell carcinoma in goats is seen more often in female goats, most likely because of the syndrome of udder papillomatosis and squamous cell carcinoma (see Tumors of the Udder and Mammary Gland).

Cutaneous squamous cell carcinoma causes a raised, proliferative, and ulcerated lesion and in cattle is usually at or near mucocutaneous junctions such as the periocular skin (Figure 8-3) and skin of the vulva. Squamous cell carcinoma in the skin of sheep most often occurs on the ears and less commonly involves other areas, especially the muzzle (Figure 8-4), lower lip, and vulva. Those on the vulva occur primarily in sheep in which perineal surgery has been performed to reduce fly strike. Tumors in sheep are often multicentric. Squamous cell carcinoma of the ears of sheep can begin as a cutaneous horn or as a hyperkeratotic plaque, or can occur at the site of ear trauma such as from an identification punch. This tumor is rare in sheep less than 4 years of age. Cutaneous squamous cell carcinoma in goats is most common on

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the ears, udder, vulva, and perineum but can also occur at the base of the horn. Tumors in pigs can be single or multiple and site predilection has not been detected.

Histologic features are of well-differentiated to poorly differentiated invasive squamous epithelium with associated sclerosis and inflammation. Atypical squamous cells indicative of neoplasia can be seen on cytologic preparations.

Metastasis of cutaneous squamous cell carcinoma can occur, most commonly to local lymph nodes. Metastasis is, however, typically a late event, preceded by a long period of local invasion. Immunotherapy of ovine squamous cell carcinoma has been shown to actually increase the rate of metastasis. Wide surgical excision, cryotherapy, hyperthermia, or radiation therapy of tumors before metastasis can be curative.

Cutaneous Horn

Cutaneous horn occurs in cattle, sheep, and goats. These growths can be single or multiple and consist of firm hornlike projections up to 10 cm long (Figure 8-5). Histologically, cutaneous horn is formed by compacted laminated keratin. Surgical excision is usually curative, although histopathologic evaluation of the base of the lesion to rule out underlying papilloma or carcinoma is warranted.

Melanocytic Tumors

Both benign and malignant melanocytic tumors occur in farm animals. Melanoma is most common in Sinclair miniature and Duroc-Jersey swine and is thought to be inherited in these breeds. Melanoma also occurs with some frequency in Hampshire and Iberian pigs. Melanomas occur in the skin of cattle with some frequency, are relatively uncommon in goats, and are rare in sheep. Melanoma in farm animals does not appear to be related to ultraviolet light exposure.

Melanomas in cattle occur most often in young animals. Tumors are either present at birth or develop within the first 2 years. Melanoma most commonly occurs in gray-haired cattle and in black- or red-haired cattle such as Angus. Melanoma in sheep occurs in the skin or the base of the horn in adult to aged animals, and Suffolk and Angora sheep are predisposed breeds. Melanoma in goats occurs in adult to aged animals. Angora goats may be predisposed, as is any goat of gray or brown coat color. Melanoma in predisposed swine breeds can develop at any age but is most often present at birth or develops within 1 year of age.



Figure 8-5 Cutaneous horn in a Hereford. (Courtesy of Dr. Nita Irby.)

Melanoma is recognized clinically by areas of gray to black pigmentation within a solid fleshy raised mass. Melanomas occur within the dermis, the subcutis, or both. The overlying skin is often darkly pigmented, smooth, and partially to completely alopecic. Melanomas in cattle occur on the head (especially the jaw), neck, trunk, or legs. Most tumors arise in areas of pigmented hair. The size of tumors in cattle is variable, from less than 5 cm to up to 25 cm. Melanoma in cattle most often occurs as a solitary lesion with intact overlying skin (Figure 8-6*A* to C). Melanomas in sheep are often multiple and occur in the subcutis under areas of pigmented skin. Melanomas of goats occur most often in the perineum but can also arise in the skin of the udder or the ear, in the coronary band or hoof wall, and at the base of the horn. Melanomas in goats can be single or multicentric. Melanocytic tumors of the perineum in goats vary from infiltrative to pedunculated and often are ulcerated. Affected goats often rub and lick the area, and secondary infection is common. Enlargement of local lymph nodes and poor body condition are also common in goats with melanoma. Melanomas in predisposed pigs can be either solitary or multiple and occur as either flat plaque-like tumors or larger raised tumors, most often on the trunk (Figure 8-7).

Histologic and cytologic examination of samples from melanocytic tumors reveals the characteristic melanin-containing neoplastic cells, often admixed with heavily pigmented melanophages. Cellular pleomorphism and mitotic activity are variable. Those tumors with high mitotic indices are most often malignant. Evidence of local or epidermal invasion is also a good indicator of malignancy.

Melanocytic tumors that occur in young cattle are almost always benign and cured by wide surgical excision. Melanomas in older cattle can, however, develop metastases to local lymph nodes or internal organs. Melanomas of sheep and goats are most often malignant, with frequent metastases, although one report of a case in a black sheep had histopathologic features of melanocytoma, a benign melanocytic tumor. Perineal and horn-base melanomas of goats can exhibit widespread metastases to multiple lymph nodes; to bone; and to internal organs, including lungs, liver, adrenal glands and kidneys. Surgical excision of cutaneous melanomas in goats can be attempted, but death from metastatic tumors is common. The melanomas of predisposed breeds of pigs have an interesting behavior that has made them a useful animal model for the study of melanocytic tumors of people. The flat tumors typically spontaneously regress starting as early as 1 month of age, often leaving a halo of depigmented skin and hair. Larger, raised tumors often metastasize within the first year of life.

Mast Cell Tumors

Mast cell tumors are most common in cattle and often involve the skin. Age of affected cattle ranges from 2 months to 12 years, and Holstein and Holstein crosses may be predisposed to develop cutaneous mast cell tumors. Congenital systemic mastocytoma with multiple skin nodules occurred in a stillborn Holstein calf. Cutaneous mastocytosis occurs in domestic pigs 6 to 18 months of age. Cutaneous mast cell tumors also occur in pot-bellied pigs. An informal study of case records found that affected pot-bellied pigs averaged 7 years of age. Mast cell tumors are uncommon in goats, and young goats (less than 6 months of age) may be predisposed. No reports of mast cell tumors were found in sheep.

Mast cell tumors in the skin of cattle can be single or multiple. These tumors are raised, firm, tan nodular masses that can be ulcerated. Tumors can be discrete or infiltrative. Histologic and cytologic preparations are characterized by sheets of well-differentiated to pleomorphic mast cells with admixed eosinophils. Mitoses are rare. Tumor necrosis,

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Figure 8-6 *A*, Melanoma on sternum of an Angus cow. *B*, Close-up view. *C*, After resection. (Courtesy of Dr. S.L. Fubini.)



Figure 8-7 Multifocal congenital melanoma in the skin of a piglet. (Courtesy of Dr. Barry Cooper.)

fibrosis, and mineralization are common histologic findings in cattle. Porcine mastocytosis results in multiple nodular solid gray-white skin lesions that can be ulcerated. Tumors in pigs contain relatively homogeneous neoplastic mast cells admixed with eosinophils. Cutaneous mastocytosis in pigs may or may not have associated widespread visceral involvement. In pot-bellied pigs cutaneous mast cell tumors can be single or multiple. Cutaneous mast cell tumors in goats are composed of sheets of relatively homogeneous mast cells admixed with eosinophils.

Cutaneous mast cell tumors in cattle are associated with a relatively high rate of metastasis. Spread to lung and lymph node is most common, and metastasis to liver and muscle is also reported. Tumor cell morphology (that is, well-differentiated vs. pleomorphic) does not appear to predict metastatic behavior, as even very well-differentiated mast cell tumors in cattle have undergone widespread metastasis. Recurrence of cutaneous mast cell tumor was documented

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in some pot-bellied pigs with multiple tumors. In all species wide surgical excision is the treatment of choice. A guarded prognosis is warranted following excision of cutaneous mast cell tumors in cattle, but excision of a cutaneous mast cell tumor may be curative in pot-bellied pigs and was apparently curative in a 6-week-old goat kid.

Cutaneous Lymphoma

Cutaneous lymphoma occurs most commonly in cattle and is extremely rare in sheep, goats, and swine. Most cases of cutaneous lymphoma in cattle occur in young adults 1 to 3 years of age. Lymphoma involving the skin of cattle is associated with the sporadic form of bovine leukosis and is not associated with bovine leukemia virus (BLV) infection.

Skin lesions are most often multifocal and commonly involve the neck and trunk. Onset is sudden and initial lesions resemble an urticarial reaction. The initial lesions progress to form variably sized firm nodules within the skin and/or subcutis. The overlying skin may be normal, variably alopecic, hyperkeratotic, or ulcerated. Lesions often regress spontaneously, only to reappear. Histologic and cytologic preparations reveal sheets of a relatively homogeneous population of neoplastic lymphocytes. Effacement of tissue architecture is seen on histologic preparations. Origin from T-lymphocytes is most common in cattle. Surgical excision of cutaneous bovine lymphoma is only useful as a diagnostic procedure. No effective treatment has been reported, and eventual death caused by involvement of internal organs is typical. But it is possible that chemotherapeutic approaches can be successful in treatment of lymphoma in farm animals.

Cutaneous Vascular Tumors

Cutaneous vascular tumors are most common in cattle but also occur in sheep, goats, and pigs. Tumors can be congenital or acquired. Congenital tumors may actually be hamartomas rather than true neoplasms. Tumors of lymphatic origin (lymphangiomas) are also possible.

Calves can be born with multiple cutaneous vascular lesions. Those that involve the gingiva and tongue are described in Tumors of the Oral Cavity and Jaw. Cutaneous vascular lesions in neonatal calves are often described by owners as appearing to be blood blisters. Vascular lesions in neonatal calves can be disseminated throughout the skin and can also involve internal organs. In adult cattle, a syndrome known as *bovine cutaneous angiomatosis* occurs. Lesions can be single or multiple and often occur on the dorsum of the trunk. These tumors are soft and pink to reddish gray, can be sessile or pedunculated, and often bleed sporadically. Cutaneous vascular neoplasms occur in goats of all ages and are most often single raised pink to red lesions that often bleed. Multicentric cutaneous vascular neoplasia is also possible in goats (Figure 8-8). In pigs, hemangiomas occur in the scrotal skin, especially of Yorkshire and Berkshire boars. Scrotal hemangiomas in pigs are often multicentric and progress from tiny purple papules to raised, hyperkeratotic lesions. Lymphangioma has been reported in fetal calves.

Cytologic evaluation of vascular tumors most often reveals only blood. Histologic evaluation is necessary to identify the proliferative endothelial cells lining vascular channels in these lesions. These channels vary from capillary (most common in congenital neoplasms of calves) to cavernous and can contain a mixture of vascular structures. Very well-differentiated lesions may be classified as hamartomas. Abnormal vascular channels lined by well-differentiated endothelium are hemangiomas, whereas tumors with cellular pleomorphism and mitotic activity are hemangiosarcomas. Multicentric vascular neoplasia in a goat was described as being a mixture of hamartomatous vasoproliferation, hemangioma, and hemangiosarcoma. Lymphangioma resembles hemangioma but channels lack blood.



Figure 8-8 Multifocal dermal to subcutaneous hemorrhagic zones characteristic of vascular neoplasia in the skin of a goat. (Courtesy of Dr. Christiane Löhr.)

Vascular lesions of all types can exhibit local invasion and can recur after incomplete excision. Wide surgical excision of tumors, when possible, is often curative, as even cutaneous hemangiosarcomas rarely metastasize. Spontaneous regression of congenital multicentric cutaneous hemangioma has been reported in a calf.

Other Tumors and Tumor-like Lesions of the Skin

Uncommon skin tumors of farm animals include basal cell, sweat gland, and sebaceous tumors, histiocytoma, and hamartomas (organoid nevus and fibroepithelial hamartoma). Xanthoma is a rare nonneoplastic mass lesion.

A basal cell tumor (the current term is *trichoblastoma*) in the lacrimal pouch of a 2.5-year-old intact male Hampshire sheep has been reported, and a basosquamous tumor was reported in the tail of an adult cow. Sebaceous hyperplasia occurs rarely in adult goats. Basal cell carcinoma involved skin of the horn base in one goat, and sebaceous epithelioma of the perineum occurred in two goats. Trichoblastoma (basal cell tumor), sebaceous adenoma, and sebaceous epithelioma are raised, alopecic exophytic growths that can be ulcerated. Histologic features are of circumscribed nodular growths of relatively orderly basal-type epithelial cells with a variable amount of admixed stroma (trichoblastoma), of proliferative but well-differentiated sebaceous glands (sebaceous hyperplasia and adenoma), or basal-type epithelial cells with frequent abrupt sebaceous differentiation (sebaceous epithelioma). These tumors are benign and surgical excision is curative. Basal cell carcinoma is invasive and composed of poorly differentiated epithelial cells with frequent mitotic figures.

Sweat gland tumors are rare in farm animals. One sweat gland carcinoma was reported in a study of Brazilian cattle. A sweat gland adenocarcinoma occurred in the skin of the left shoulder of a mouflon sheep, with widespread peripheral lymph node and internal metastasis. Multiple congenital sweat gland hamartomas were found in a piglet.

Histiocytoma is most common on the scrotum of buck goats, but eyelid and ventral abdominal wall histiocytomas have also been reported in female and castrated male goats.

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Tumors are circumscribed raised lesions that are formed by sheets of histiocytic cells with a high mitotic index. Spontaneous regression of histiocytoma can occur in goats.

Organoid nevus and fibroepithelial hamartoma are nonneoplastic hamartomatous lesions composed of increased dermal collagen with admixed adnexa and, in fibroepithelial hamartoma, other tissue such as blood vessels. Organoid nevus is a localized lesion that occurs rarely in cattle and pigs. Organoid nevi can be flat plaque-like lesions or can be elongated and pedunculated. The latter are often also called *skin tags*. Surgical excision of organoid nevus is curative. A fibroepithelial hamartoma with extensive involvement of facial skin was described in a newborn piglet. Hamartomas may grow along with the affected animal but they are not expected to exhibit rapid or invasive growth. Occasionally involved adnexa can rupture, resulting in rapid lesion enlargement.

Xanthoma occurred in the subcutaneous tissue of the sacral area in a 2-year-old Saanen doe. The mass was tan with yellow-white areas on the cut surface. Characteristic histopathologic features were multiple lobules separated by fibrous tissue, with lobules composed of foamy macrophages, giant cells, abundant lipid, and cholesterol clefts.

Cysts

Cysts of the skin are uncommon lesions of cattle, sheep, goats, and swine. They can be single or multiple and can be congenital or acquired. Epidermal cysts (epidermal inclusion cysts), dermoid cysts, and follicular cysts are most common. Cysts are most common in Merino and Suffolk sheep, in which a hereditary basis is suspected. Cysts within the udder skin of older ewes involve mammary glandular epithelium and contain milk. Epidermal and dermoid cysts are less common in cattle. Cysts within the wattle of Nubian and Nubian cross goats are developmental anomalies present at or soon after birth that are suspected to arise from branchial cleft remnants. A hereditary basis for wattle cysts in goats is suspected.

Cystic skin lesions in farm animals are most often asymptomatic, although their presence will adversely affect hide quality. Cysts can rupture and develop secondary inflammation with ulceration of overlying skin or can be discrete and nodular with normal overlying skin. Wattle cysts in goats are soft and fluctuant with normal overlying skin. These lesions are further discussed and illustrated in Chapter 22, Lumps and Bumps of Sheep and Goats. Cystic skin lesions in sheep have been associated with development of carcinoma and with systemic illness.

Cytologic evaluation of epidermal, dermoid, and follicular cyst contents will reveal keratin, often admixed with cholesterol clefts and macrophages. Milk can be aspirated from udder cysts in sheep. Wattle cysts contain clear liquid. Surgical excision and histopathologic evaluation to identify the type of cells and structures within the cyst wall will allow for classification of the type of cyst present. Epidermal cysts are lined by keratinizing epithelium lacking adnexal structures. Dermoid cysts are lined by keratinizing epithelium with associated adnexa. Follicular cysts consist of dilated and keratin-filled hair follicles. Wattle cysts are lined by a single to double layer of cuboidal to columnar epithelial cells. When either a single or a small number of cysts are present, surgical excision is curative. Excision of udder cysts of sheep is neither necessary nor recommended.

Soft Tissue Tumors

Soft tissue tumors are less common in farm animals than are tumors of the skin. Included in this group of tumors are fibroma, fibrosarcoma, myxoma, myxosarcoma, neurofibroma, lipoma, smooth muscle tumor, and rhabdomyosarcoma. Multicentric lymphoma can also involve subcutaneous tissue. Most of these tumors occur in adults, but some can also be congenital.

Fibroma and fibrosarcoma occur rarely in the skin and subcutis of adult cattle, sheep, goats, and pigs. Myxomatous tumors are considered to be variants of fibroma and fibrosarcoma. Cutaneous neurofibromas are most common in adult Holstein and Hereford cattle. Multifocal neurofibromas in Holsteins are a syndrome that resembles human neurofibromatosis, in which multiple cutaneous tumors composed of admixed Schwann cells and fibroblasts occur in people with genetic defects in the neurofibromatosis gene. Neurofibromas of cattle are associated with large nerve trunks such as the brachial plexus, intercostal nerves, and cardiac nerves. Subcutaneous lipomas occur occasionally in cattle but are rare in sheep, goats, and pigs. Congenital lipomas that can be multiple and congenital infiltrative lipomas occur in calves. Congenital lipoblastoma, a benign fatty tumor, has also been reported in a calf, and liposarcoma occurred in a cow. Smooth muscle tumors are rare. Subcutaneous leiomyosarcoma has been reported in two cows, and a fibroleiomyoma occurred in the skin of a pig. Rhabdomyosarcoma within skeletal muscle has been seen in cattle, sheep, and pigs. Spindle cell sarcomas of smooth muscle or neural origin have been reported as congenital tumors in newborn piglets. Rhabdomyosarcoma and lipoma can occur in young as well as older animals. In piglets, rhabdomyosarcoma cells can have a characteristic chromosomal deletion. Intramuscular rhabdomyosarcoma has also been reported in a 1-year-old sheep.

Soft tissue tumors present as progressively enlarging masses or swellings. Fibroma, fibrosarcoma, leiomyosarcoma, and leiomyoma usually occur as single masses. Neurofibroma and rhabdomyosarcoma are often multicentric. Rhabdomyosarcoma in farm animals typically arises within skeletal muscle. Cattle with neurofibromas involving large peripheral nerve trunks can develop signs of lameness and denervation atrophy. Perineal leiomyomas occur in cattle and pot-bellied pigs and can be single or multiple. Lymphoma within the subcutis results in diffuse thickening (Figure 8-9).

Soft tissue tumors vary from fleshy to fatty to myxoid, depending on the tumor cell type. Cytologic evaluation will distinguish lipoma from other mesenchymal tumors. Histologic evaluation—and possibly immunohistochemistry—is needed to distinguish fibroma, fibrosarcoma, myxoma, myxosarcoma, neurofibroma, leiomyoma, leiomyosarcoma, and rhabdomyosarcoma.

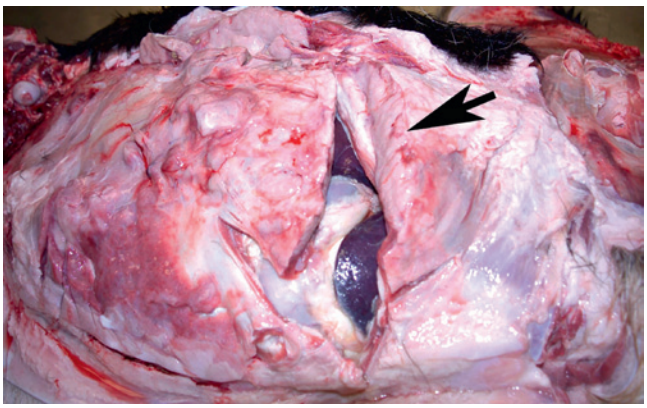


Figure 8-9 Marked thickening of the subcutis of the abdominal wall due to lymphoma in a goat. The *black arrow* is pointing to lymphomatous thickening of the body wall.

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Subcutaneous lipoma in farm animals is most often an isolated and discrete tumor, although infiltrative lipoma can occur in calves. Other soft tissue tumors are typically locally invasive but rarely metastasize (rhabdomyosarcoma may be an exception to this rule). Wide surgical excision of all soft tissue tumors, when possible, could be curative. For example, surgical excision of a perineal leiomyosarcoma in a cow was apparently curative and did not interfere with subsequent breeding and calving. Excision of a congenital sarcoma in one piglet was apparently curative, but widespread metastasis occurred in two other cases.

TUMORS OF THE EYE

Tumors involving the eyelids, conjunctiva, cornea, and orbit are relatively common in cattle and less often seen in other farm animal species. A necropsy study of cattle found that 15% of neoplastic disease identified involved the eye and periorbital tissues. Ocular squamous papilloma, squamous cell carcinoma, and orbital lymphoma of cattle are most common. A study of enucleated eyes from cattle found that 85% of cases had squamous cell carcinoma. Ocular squamous cell carcinoma can also occur in sheep, especially those at high altitudes. Only one report of ocular squamous cell carcinoma was found in goats, in which papillomavirus was proposed to be the cause of ocular squamous cell carcinoma in twin goats. Eyelid meibomian gland tumor, ocular lymphangiosarcoma, and retrobulbar meningioma are rare neoplasms in cattle. A congenital benign intraocular melanoma occurred in a calf, and multicentric malignant melanoma involving the eye was found in a bovine fetus. Intraocular tumors—iridociliary adenoma and intraocular melanoma—have been described in adult sheep. Ocular dermoids are developmental anomalies present at birth that occur sporadically in calves and pigs. Bilateral ocular dermoids can occur in calves, and dermoid cysts can also be found within the bony portion of the nasolacrimal duct in cattle.

Cutaneous papillomas caused by bovine papillomavirus can occur on the eyelids (see Figure 8-1) or corneoscleral junction of young cattle and are predisposing factors in development of ocular squamous cell carcinoma. Bovine squamous cell carcinoma is most common in the limbal and eyelid conjunctiva but can also arise in the cornea. Squamous cell carcinoma that involves the orbit and retrobulbar tissue is much less common. Bovine ocular squamous cell carcinoma occurs in all breeds, but Herefords appear to be predisposed to this tumor. Ocular squamous cell carcinoma usually occurs in cattle over 5 years of age. Lack of eyelid pigmentation and ultraviolet light are etiologic factors, although a genetic predisposition is also suspected. Up to 20% of cattle in some herds in Australia have developed ocular squamous cell carcinoma. Ocular squamous cell carcinoma occurs much less commonly in sheep. Lymphoma can involve the orbit of adult cattle and goats as part of a more generalized neoplastic process associated with BLV infection. Ocular dermoid is not a true tumor but presents as an ocular mass lesion in neonatal calves and piglets. Ocular dermoid (also called choristoma) is a developmental defect in which a zone of skin, often haired, is present at birth on the cornea or conjunctiva (Figure 8-10). Ocular dermoids are most common in polled Herefords and also occur in pigs. Lymphangiosarcoma of the limbus has been reported in an 8-year-old Holstein cow. In goats, histocytoma can involve the eyelid, and lymphoma can be retrobulbar, causing conjunctival swelling (Figure 8-11). No reports of ocular tumors were found in domestic or pot-bellied pigs.

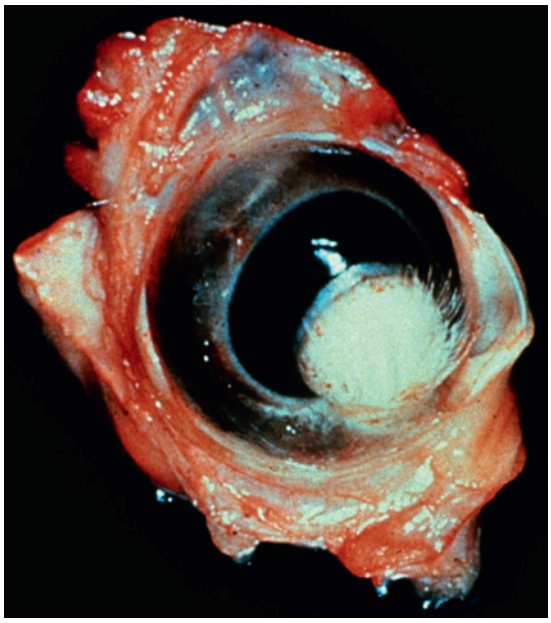


Figure 8-10 Ocular dermoid in a piglet. (Courtesy of Dr. Howard Gelberg.)



Figure 8-11 Marked conjunctival swelling due to periocular lymphoma in a goat. There is retention of fluorescein dye due to exposure keratitis. (Courtesy of Dr. Steve Brown.)

Tumors of squamous epithelium often begin as a smooth raised plaque that progress to form an exophytic squamous papilloma. Some ocular papillomas will spontaneously regress. Persistent papilloma can progress to noninvasive and then to invasive squamous cell carcinoma. Not all ocular squamous tumors exhibit this sequential development, and invasive carcinoma may be the first clinically noted lesion. Squamous cell carcinoma is a raised proliferative lesion that is often ulcerated and secondarily infected (Figure 8-12). Squamous cell carcinoma of the conjunctiva can spread to involve the globe, and corneal squamous cell carcinoma can spread to involve conjunctiva. In advanced cases, determining the initial site of malignant transformation is often impossible (Figure 8-13). Neoplastic squamous cells are seen on histologic and cytologic preparations.

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Figure 8-12 Conjunctival squamous cell carcinoma in a Hereford steer. (Courtesy of Dr. Barry Cooper.)



Figure 8-13 Orbital squamous cell carcinoma in a cow. (Courtesy of Dr. Jorge Vanegas.)

Lymphoma of the orbit and retrobulbar space most often causes progressive exophthalmos of the affected eye (Figure 8-14). In dairy cattle, early signs of exophthalmos may not be noticed, as many dairy breeds normally have mild exophthalmos. Involvement of conjunctiva can mimic chemosis. When protrusion of the globe becomes severe enough to interfere with eyelid closure, rapid development of exposure keratitis occurs (see Figure 8-14). If the lymphoma is deep within the orbit, diagnostic procedures such as biopsy or cytology will be difficult. If the conjunctiva is involved biopsy can provide the diagnosis. Complete examination to detect other affected organs and, in cattle, serologic testing for bovine leukemia virus infection are useful diagnostic procedures. Evaluation of tumor tissue by cytology or histopathology after removal of the globe reveals sheets of relatively homogeneous lymphocytes, and marked invasion and obliteration of normal architecture are seen in tissue sections.

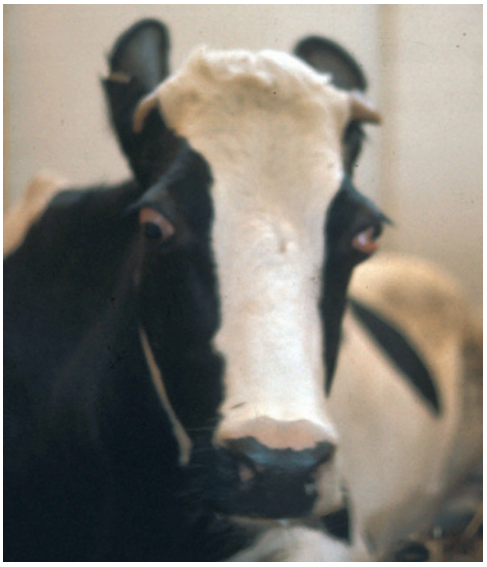


Figure 8-14 Bilateral exophthalmos due to periocular lymphoma in a Holstein cow. (Courtesy of Dr. Bill Rebhun.)

Retrobulbar intranasal adenocarcinoma and squamous cell carcinoma are rare causes of exophthalmos in aged cattle. The iridociliary adenoma reported in a sheep caused exophthalmos, and the intraocular ovine melanoma was in an atrophied bulb.

Ocular dermoids do not enlarge, but the presence of hairs often results in irritation of the lids or cornea that can become secondarily infected. Ocular lymphangiosarcoma has presented as a progressively enlarging subconjunctival mass at the limbus. Biopsy revealed irregular vascular channels devoid of blood, consistent with origin from lymphatics.

Ocular squamous cell carcinoma is locally invasive and destructive, but metastasis is uncommon. Rarely, ocular squamous cell carcinoma in cattle undergoes spontaneous remission. Surgical removal of the affected globe and lids in cattle and sheep can be curative, although in predisposed cattle carcinoma can develop in the other eye. In one study with follow-up of 22 cattle following enucleation for ocular squamous cell carcinoma, only one tumor recurred and there was no evidence of metastatic disease. Other successful therapies for ocular squamous cell carcinoma include cryosurgery, hyperthermia, radiation, and immunotherapy. In particular, peritumoral injection of interleukin-2 has resulted in remission of ocular squamous cell carcinoma in cattle, especially in tumors of the third eyelid and limbus. Removal of exophthalmic globes because of orbital or retrobulbar lymphoma should be considered only as a palliative measure to make the animal more comfortable. Complete excision of orbital lymphoma is not possible, and the involvement of other organs will lead to eventual death, usually within 6 months of diagnosis. To date we are not aware of any reports of successful chemotherapy of bovine lymphoma, but this may be possible in the future. Removal of the affected globe was apparently curative in the cow with ocular lymphangiosarcoma, in the calf with congenital intraocular benign melanoma, and in the sheep with iridociliary adenoma. Surgical excision of dermoids is curative.

TUMORS OF THE ORAL CAVITY AND JAW

Tumors involving oral soft tissue and bones of the jaw are most common in cattle, less common in sheep, and rare in

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goats and pigs. Epithelial, odontogenic, vascular, osseous, and fibroblastic tumors occur.

Oral Soft Tissue Tumors

Papilloma caused by bovine papillomavirus can occur in the oral mucosa, including the lips, of calves. Exophytic polypoid to sessile growths are seen, and tumors can be multicentric. Papillomatosis of the tongue is a common congenital lesion in piglets in China. In contrast to oral papillomas, oral squamous cell carcinoma occurs in older animals and is an invasive destructive tumor. Squamous cell carcinoma involving the oral cavity is common in Brazilian cattle, and ingestion of bracken fern is thought to be the inciting cause. Involvement of rumen and esophagus as well as oral cavity is common in Brazilian cattle. Metastasis of oral squamous cell carcinoma was typical in these cattle and was not correlated with the appearance of the primary tumor. Oral squamous cell carcinoma that can metastasize to local lymph nodes and lung occurs in aged pot-bellied pigs. Similar to squamous cell carcinoma at other sites, oral squamous cell carcinoma is an ulcerated infiltrative growth of firm, white tissue. Clinical signs are weight loss and dysphagia. Vascular tumors of the gingiva and tongue occur in young calves and can be present at birth. Most often these are single fleshy masses that can be superficially ulcerated.

Histologic examination will distinguish the relatively orderly epithelial proliferation of papilloma from the pleomorphic and invasive epithelium of squamous cell carcinoma. Vascular tumors are characterized by clusters of well-differentiated capillary-type blood vessels in a fibrous stroma. Whether these tumors represent benign neoplasia (hemangioma) or vascular hamartomas is unclear. Their presence at birth suggests that the latter is most likely. Oral tumors are less common in goats and sheep. Oral tumors reported in goats are amyloid-producing odontogenic tumor, lymphoma, rhabdomyosarcoma, and unclassified sarcoma.

Viral papillomas are benign lesions that most often regress spontaneously. Surgical excision of these masses is also curative. Squamous cell carcinoma is not likely to be recognized in farm animal species until a relatively late stage of development, when wide surgical excision is difficult or impossible. Vascular tumors often exhibit some degree of local infiltration and slowly enlarge as the animal grows. Wide surgical excision is often necessary for cure, and cryotherapy has been reported to be an effective treatment. Gingival odontogenic tumors will be cured by wide excision. Sarcomas are typically locally invasive; too little information is available to describe metastatic potential.

Tumors of Bones of the Jaw

Tumors of bones of the jaw include odontogenic tumors, osteoma, fibroma, fibrosarcoma, myxomatous, and vascular tumors. Odontogenic tumors occur most often in cattle and sheep and rarely in pigs. Odontogenic tumors are typically seen in young (including newborn) to young adult animals, but have also been diagnosed in older animals. Presumably odontogenic tumors identified in adults had been present for some time before diagnosis. Tumors of odontogenic origin have a variety of histologic features that result in various—often confusing—classifications that are prone to change. Tumor types identified in farm animals include odontoma (including ameloblastic, compound, and complex odontoma), ameloblastoma, and ameloblastic fibro-odontoma. Osteoma and fibroma also occur in the jaws of adult cattle. Fibrosarcoma of the jaw occurs in adult sheep grazing bracken fern. Myxomatous tumors (myxoma and myxosarcoma) occur in adult cattle. Vascular tumors of the gingiva of calves can invade bone, although this is rare, and a hemangiosarcoma thought to be primarily within mandibular bone has been described in a bull. The congenital malignant melanoma involving the eye of a calf (see ocular tumors) also invaded maxillary bone.

Tumors of the jaw most often present as slowly enlarging firm to bony growths. These tumors often arise at or near tooth roots and can cause loosening and malalignment of adjacent teeth. Radiographic evaluation is useful to determine the site and extent of the tumor. Histologic evaluation is necessary to distinguish the various types of odontogenic and mesenchymal tumors that occur in the jaws of farm animals. Odontogenic tumors consist of varying elements of odontogenic epithelium with or without induction of dental or mesenchymal tissue. Biopsy diagnosis of osteoma often relies on the clinical and radiographic description of the lesion, as it is not possible to distinguish the histologic features of small samples of osteoma from those of normal bone. Myxomatous tumors are characterized by proliferation of spindle to dendritic cells in a loose myxoid stroma.

Fibroma, osteoma, and odontogenic tumors of the jaw are noninvasive and can be cured by wide surgical excision. For tumors located rostrally, mandibulectomy or maxillectomy may be advised, especially if there is extensive bony involvement. Myxomatous tumors of the jaw, however, are typically locally invasive and difficult or impossible to completely excise. Recurrence is common, although metastasis has not been reported. The primary mandibular hemangiosarcoma in the bull exhibited pulmonary, subcutaneous, and muscular metastasis.

TUMORS OF THE GASTROINTESTINAL SYSTEM

Tumors of the esophagus, stomachs, and intestines are found relatively frequently in farm animals, particularly cattle. Various benign and malignant tumors can occur. In areas where pastures contain abundant bracken fern, such as Brazil, the gastrointestinal system is the most common site of neoplasia in cattle. Bovine papillomavirus is also an initiating factor contributing to a high incidence of bovine gastrointestinal neoplasia. Intestinal adenocarcinoma is common in aged sheep, and ovine intestinal adenocarcinoma has been suggested to be an animal model of colonic cancer in people. Gastrointestinal neoplasia is less common in goats and pigs. Tumors of associated exocrine glands (pancreatic and salivary) also occur but are rare.

Esophagus

Esophageal tumors are uncommon and occur mostly in cattle. Esophageal papilloma in cattle may be associated with bovine papillomavirus and with bracken fern ingestion (Figure 8-15). In areas with high bracken fern exposure (see Forestomach) esophageal squamous cell carcinoma as well as papillomas are common. Gross and histopathologic features of esophageal papilloma and squamous cell carcinoma are similar to those in the forestomachs (see Forestomach). Esophageal tumors can result in clinical signs of bloat, excessive salivation, or esophageal obstruction or can be incidental findings.

Forestomach

Tumors of the omasum, reticulum, and rumen occur most often in cattle but are uncommon in most parts of the world. Papilloma, fibropapilloma, and fibroma are the most common tumors in the forestomach of cattle. Papillomavirus has been detected by immunohistochemical studies in some, but not all, cases of bovine forestomach papillomas. These tumors are less common in sheep, and only one report of

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Figure 8-15 Esophageal papilloma in a cow. (Courtesy of Dr. Barry Cooper.)



Figure 8-16 Papillomas in the rumen of a sheep. (Courtesy of Dr. Christiane Löhr.)

forestomach neoplasia—rumen papilloma—was found in goats. Papillomas can occur at any age. Squamous cell carcinoma occurs in older cattle and sheep and often results from malignant transformation of a papilloma. In cattle in Kenya and northern England, the interaction between bovine papillomavirus infection and the mutagens present in bracken fern is suspected to be the cause of a high incidence of forestomach papillomas and of malignant transformation of papilloma to squamous cell carcinoma. Bracken fern ingestion is also suspected to explain a high incidence of rumen squamous cell carcinoma in cattle in Brazil. Lymphoma can involve the rumen and reticulum of older cattle as part of a more generalized neoplastic process associated with BLV infection. Fibrosarcoma of the rumen has been seen in an adult sheep.

Forestomach papilloma, fibropapilloma, and fibroma in cattle most often occur in the rumen near the ruminoreticular groove, causing recurrent bloat. Squamous cell carcinoma also occurs at these sites. In sheep, squamous cell carcinoma can also be found in the reticulum and omasum. Abdominal pain, bloat, and excessive salivation often accompany forestomach squamous cell carcinoma in cattle. Clinical signs have not been reported in sheep with forestomach neoplasia. Forestomach lymphoma is typically associated with concurrent abomasal involvement, as well as other organs, and generalized ill-thrift. Involvement of the omasum by lymphoma is less common. Leiomyoma of the omasum has been seen as an incidental finding in a goat.

Fibroma, fibropapilloma, and papilloma of the forestomach are benign, localized tumors that form exophytic, nodular or multinodular to multilobular, smooth-surfaced, firm, tan masses (Figure 8-16). Tumors may be sessile or pedunculated. These tumors are readily excised via rumenotomy, but they can be multiple, especially in areas with a high incidence. Histopathologic evaluation is necessary to differentiate those tumors that have epithelial proliferation (papilloma), both epithelial and fibroblastic proliferation (fibropapilloma), or only fibroblastic elements (fibroma). Histopathologic evaluation is also needed to identify evidence of malignancy in the rare cases of forestomach fibrosarcoma. The fibrosarcoma seen in the rumen of a sheep had metastasized to the liver.

Squamous cell carcinoma is an invasive and destructive tumor. Mucosal ulceration caused by squamous cell carcinoma is common. Histopathologic evaluation reveals nests of invasive squamous epithelial cells in dense collagenous stroma. Neoplastic squamous cells may be seen on cytologic preparations, but the degree of sclerosis often results in poor exfoliation of epithelial cells. Surgical excision of early and localized forestomach squamous cell carcinoma might be possible, but in most cases the extent of tumor at the time of diagnosis precludes surgical intervention.

Lymphoma most often results in locally extensive firm and nonulcerated thickening of the forestomach wall by pale tan solid tissue. Rarely, forestomach lymphoma may involve only the serosa. Sheets of relatively homogeneous lymphocytes are seen on cytologic and histopathologic preparations, and transmural involvement with obliteration of normal architecture is characteristic.

Abomasum/Stomach

Abomasal tumors occur in older cattle, usually those over 5 years of age. The vast majority are lymphomas associated with BLV infection. Abomasal lymphoma also occurs sporadically in goats. Adenocarcinomas occur in cattle but are uncommon. Abomasal mast cell tumors occur rarely in cattle. A very unusual germ cell tumor—yolk sac tumor—was reported in the abomasum of a 2-month-old calf. Gastric lymphoma and squamous cell carcinoma are rare tumors in swine. A transmural gastric carcinoma was found in a pot-bellied pig. Gastric tumors can result in clinical signs of outflow obstruction, but often generalized ill-thrift is the only sign. An abomasal adenocarcinoma in a cow was associated with abdominal distention from peritoneal effusion.

Lymphoma causes multifocal, locally extensive, or diffuse thickening of the abomasal wall by pale tan-white tissue (Figure 8-17). Borders are often difficult to discern. Abomasal lymphoma can be soft to firm. Mucosal ulceration is rare. Solid pale tan to white solid tissue is seen on section (Figure 8-18). Sheets of relatively homogeneous lymphocytes are seen on cytologic and histopathologic preparations, and this tumor is invasive and causes obliteration of tissue architecture. Adenocarcinoma and carcinoma are very firm tumors, often with extensive mucosal ulceration. Invasive

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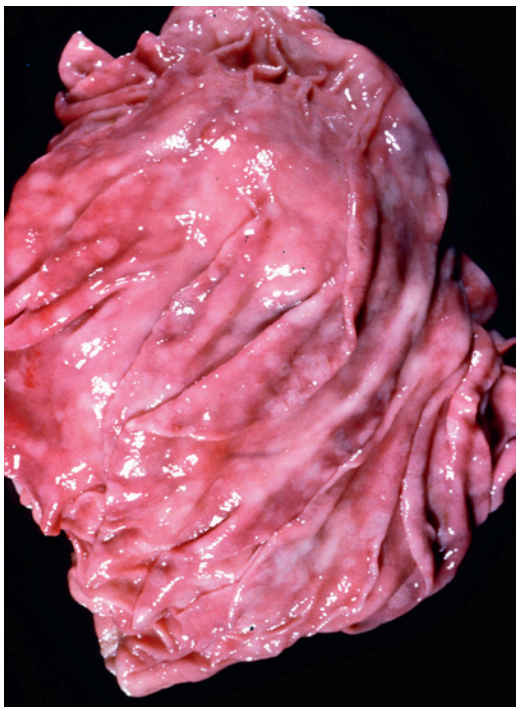


Figure 8-17 Lymphoma causing pale areas of thickening visible on the mucosal surface of the abomasum of a goat.

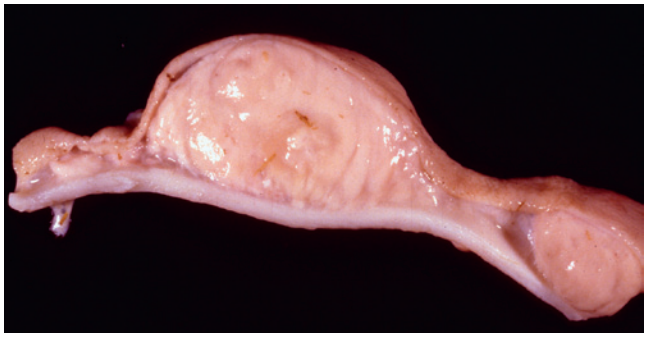


Figure 8-18 Transverse section demonstrating submucosal thickening by pale tissue characteristic of abomasal lymphoma in a cow. (Courtesy of Dr. Barry Cooper.)

nests of neoplastic epithelial cells are embedded in dense stroma. Mucin can be prominent in adenocarcinomas. Because of the sclerotic nature of this tumor, epithelial cells can be difficult to identify on cytologic preparations.

Lymphoma is often an insidious disorder with gradual onset of organ dysfunction and cachexia. In most cases of abomasal (most commonly at the pylorus) lymphoma, tumor is also found at other sites. In cattle involvement of the right heart, retrobulbar, peripheral lymph nodes, and uterus as well as abomasum is common. Adenocarcinoma can be localized or can exhibit marked invasion. Adenocarcinoma can undergo widespread metastasis through lymphatics to the abdominal and thoracic cavities. Spread to peritoneum and pleura results in carcinomatosis. The pot-bellied pig with gastric carcinoma was alive and well 2 years after surgical excision, despite evidence of vascular invasion by tumor cells in histopathologic sections.



Figure 8-19 Multifocal lymphoma of the wall of the small intestine in a cow.

Intestine

Small intestinal adenocarcinoma is diagnosed with some frequency in sheep, usually affecting those 4 years of age or older. In a New Zealand study, approximately 7% of old sheep with poor body condition had intestinal adenocarcinoma. Primary intestinal tumors are uncommon in other farm animal species. Intestinal adenocarcinoma occurs sporadically in older cattle, goats, and pigs, including pot-bellied pigs. Three intestinal adenocarcinomas have been reported in goats, two at the ileocecal junction. Carcinoma of the spiral colon have been reported in three different pot-bellied pigs. Papillomas occasionally occur in the small intestine of cattle. Lymphoma can involve the intestine of older cattle as part of a more generalized neoplastic process. Ileal lymphoma occurs in pigs and is most common in animals less than 1 year of age. Leiomyoma and leiomyosarcoma are sporadic intestinal tumors of cattle, goats, and pigs. Ganglioneuromatosis involving the colon has been seen in a steer, and a carcinoid tumor can involve the small intestine, colon, or rectum of cattle.

Most cases of small intestinal adenocarcinoma in sheep are only detected at necropsy or at slaughter. In addition to poor body condition, ascites caused by tumor metastasis is a common clinical sign before death. Carcinoma cells may be visible in cytologic preparations of ascites fluid. Diarrhea and weight loss occur in cattle with carcinoid tumors. Large tumors of any type within the intestinal tract can result in signs of intestinal obstruction or recurrent bloat. Involvement of the intestinal wall by neoplasms of any type often results in extensive adhesions. Clinical signs have not been reported in pigs with ileal lymphoma.

Thickening of the involved intestinal segment is characteristic of neoplasia (Figure 8-19). Lymphoma and carcinoid tumors in the intestinal wall are relatively soft, whereas adenocarcinoma and carcinoma are typically firm. Adenocarcinoma and carcinoid tumors arise in the mucosa, thus resulting in extensive mucosal involvement and often ulceration. Transmural growth to involve the serosa is common. Adenocarcinoma often causes annular intestinal stenosis and is characterized by invasive nests of glandular epithelium with marked associated sclerosis. Carcinoid tumors are composed of closely packed nests of round cells often with fine cytoplasmic granules. Carcinoid tumors in cattle can be multiple and can metastasize to mesenteric lymph nodes. Leiomyoma, leiomyosarcoma, and ganglioneuromatosis arise within the outer intestinal wall and involve mucosa only by extension. These tumors are firm and smooth and may become quite large before clinical signs are apparent. Smooth

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muscle tumors form nodular masses formed by interlacing bundles of elongated smooth muscle cells. Ganglioneuromatosis is a more diffuse lesion that causes locally extensive mural thickening without a focal mass lesion. Nerve fibers admixed with ganglion cells are characteristic histopathologic features. Solitary intramural nodular masses within the terminal ileum are typical of intestinal lymphoma in pigs. These tumors arise within Peyer's patches and consist of sheets of small to large lymphocytes effacing architecture. Metastasis of ileal lymphoma to mesenteric lymph nodes or to serosal surfaces is common in pigs. Metastasis of intestinal adenocarcinoma in sheep to mesenteric lymph nodes and serosal surfaces is common. In cattle, metastasis of intestinal adenocarcinoma is most often to mesenteric lymph nodes and liver.

If detected at an early stage, surgical excision of intestinal adenocarcinoma could be curative. A pot-bellied pig was alive and well 9 months following surgical excision of a carcinoma involving the spiral colon. Given the high metastatic rate of intestinal carcinoma and adenocarcinoma in most species, however, a guarded prognosis following surgery would be warranted. Similarly, excision of a solitary intestinal carcinoid might be successful, but the potential for metastasis would warrant a guarded prognosis. Surgical excision of intestinal leiomyoma, leiomyosarcoma, and ganglioneuromatosis is more likely to be successful, as these tumors rarely metastasize. Resection of intestinal lymphoma is unlikely to be curative, as the neoplastic process is likely to be either multicentric or to have metastasized. Chemotherapy may be an option in the future.

Pancreas

Pancreatic exocrine tumors are rare. All reported pancreatic exocrine tumors have been in adult to aged cattle and were identified at slaughter. Proliferative lesions of the exocrine pancreas include nodular hyperplasia, adenoma, carcinoma, neural tumors (neurofibroma and neurofibrosarcoma), and fibrosarcoma.

Clinical signs in cattle with pancreatic carcinoma may be inapparent, or affected cattle may present as downer cattle. Exocrine pancreatic carcinoma is associated with peripancreatic and intraabdominal fat necrosis and mineralization and with mesenteric thickening due to fibrosis. Tumors are very firm, pale, tan, and nodular. Metastatic lesions may be more obvious than the primary tumor. Exocrine pancreatic tumors are often poorly differentiated, with a high mitotic index and extensive sclerosis. Metastasis to mesenteric lymph nodes, liver, and other abdominal organs is common.

Neurofibroma, neurofibrosarcoma, and fibrosarcoma are not associated with clinical signs. These tumors form discrete nodular masses of firm, pale, tan to white tissue. Characteristic interlacing fascicles and whorls of spindle cells are seen histopathologically. Metastasis of neural tumors or of pancreatic fibrosarcoma has not been reported.

Salivary Gland

Salivary gland tumors in farm animals are rare. Adenoma and carcinoma occur occasionally in cattle. Salivary gland tumors are rare in sheep and are not reported in goats or pigs. Tumors result in firm swelling of the affected gland. Neoplastic proliferation of epithelial cells with a variable amount of associated fibrous stroma is seen histopathologically. In cattle, metastasis to local lymph nodes can occur.

TUMORS OF THE RESPIRATORY TRACT

Tumors of the respiratory tract occur in the nasal passages and sinuses, the ethmoid region, and the lung. Respiratory tumors are most common in cattle, sheep, and goats and are much less common in pigs. A necropsy study of Brazilian cattle found that respiratory tract tumors comprised 1% of total neoplasms detected.

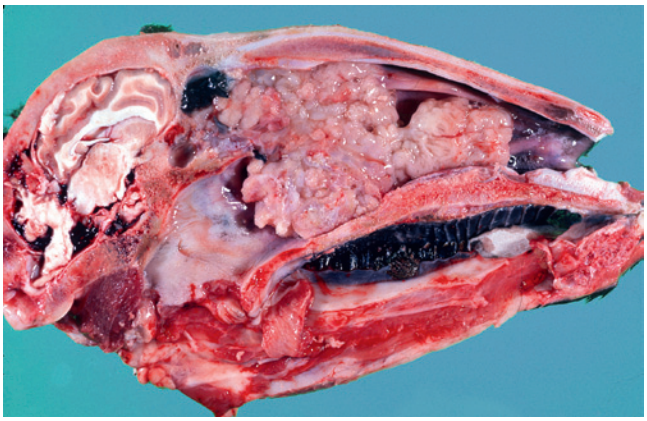


Figure 8-20 Nasal adenocarcinoma in an adult sheep. (Courtesy of Dr. John Schmitz.)



Figure 8-21 Multiple fleshy inflammatory polyps arising in the nasal mucosa in a sheep. The *arrow* points to one of the larger polyps.

Tumors of the Nasal Passages and Sinuses

Papillomavirus can cause proliferative lesions in the nasal skin at sites of bull rings in cattle. Apparently infective nasal papillomas also occur in goats. Nasal adenocarcinoma occurs most commonly in sheep and goats as an enzootic retroviral-induced tumor. Nasal adenocarcinoma can also occur sporadically in cattle and pigs, including pot-bellied pigs. Squamous cell carcinoma of the horn core in adult cattle, sheep, and goats often presents as a cutaneous tumor, but origin from sinus epithelium is suspected. Osteoma and chondrosarcoma of the nasal/sinus bone occur in adult cattle, and osteoma involving the nasal cavity has been reported in an adult sheep. A malignant mesenchymoma occurred in the nasal cavity of a bull. Ethmoid tumors associated with retroviral infection, including epithelial, mesenchymal, and mixed tumors, occur endemically in cattle and sheep in various areas worldwide (Figure 8-20). These viral-associated tumors can involve young adult animals as well as older animals. Nasal polyps are nonneoplastic proliferative lesions arising within nasal mucosa. Nasal polyps are most common in sheep (Figure 8-21), likely related to mucosal irritation by

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nasal bots (*Oestrus ovis*), but nasal polyps can also occur in cattle and goats.

Clinical signs of tumors and polyps within nasal passages and sinuses include nasal discharge and respiratory stridor and dyspnea. Tumors and polyps can involve one or both nasal cavities. Large tumors can result in expansion of overlying bone to form an externally visible lesion. Squamous cell carcinoma of the horn core often results in loosening and/or distortion of the horn. Tumors of the ethmoid region can result in exophthalmos.

Histologic evaluation will distinguish the various types of tumors. Cytologic evaluation of material collected during nasal flushing can differentiate the atypical epithelial cells of carcinoma from reactive cells caused by inflammatory lesions. Papillomavirus infection at the site of a nasal ring in bulls can mimic fibrosarcoma due to abundant mesenchymal proliferation.

Papillomas are benign lesions that often regress spontaneously. Surgical excision is also curative. Osteoma of the nasal/sinus bone is a benign lesion, but surgical excision is not often possible. Carcinomas, sarcomas, and mixed tumors of the nasal passage, sinus, and ethmoid region are locally invasive malignant tumors. Curiously, metastasis to lymph nodes and lung has been reported in cattle with nasal tumors but not in sheep or goats. Surgical excision of these tumors may not be an option because of the extent of the lesion and cost of surgery. But as most of these tumors are low-grade malignancies, debulking to alleviate clinical signs could be considered. Nasal polyps could be cured by excision, although therapy for underlying rhinitis may also be needed.

Tumors of the Lung

Lung tumors are uncommon in farm animals. Tumors and tumor-like lesions occur most often in the lungs of sheep and goats due to retroviral infection. Pulmonary carcinoma and adenocarcinoma occur sporadically in adult cattle. Pulmonary tumors have not been reported in pigs. Tumors of pulmonary epithelium are most common, although rare cases of rhabdomyosarcoma of the lung have occurred in lambs and calves and pulmonary myxomas occurred in adult sheep. Multiple pulmonary papillomas have been described in the diaphragmatic lobes of Angora goats. An outbreak of pulmonary carcinoma occurred in young calves in Bulgaria.

Pulmonary adenocarcinoma (Jaagsiekte disease) is a retroviral-associated neoplastic disorder that affects adult sheep and occurs endemically in many parts of the world. Pulmonary adenocarcinoma must be distinguished from ovine progressive pneumonia (Maedi), also a retroviral-associated disorder that results in nonneoplastic proliferative lung lesions. Proliferative pulmonary tumor-like lesions similar to those in ovine progressive pneumonia occur in goats with caprine arthritis-encephalitis virus (CAEV). Goats can also develop pulmonary carcinoma unrelated to Jaagsiekte sheep retrovirus infection.

Most lung tumors in cattle and goats have been found incidentally at necropsy or slaughter. Rhabdomyosarcoma in lambs can cause severe dyspnea and death. Pulmonary adenomatosis, ovine progressive pneumonia, and caprine interstitial pneumonia caused by caprine arthritis-encephalitis virus result in progressive dyspnea and cachexia. Metastasis of pulmonary carcinomas and of ovine pulmonary adenocarcinoma is possible. Metastatic ovine pulmonary adenocarcinoma can be extrathoracic as well as intrathoracic. Intrathoracic metastatic sites reported are chest wall, lymph nodes, diaphragm, and heart. Reported extrathoracic metastatic sites are, in decreasing order of frequency, liver, kidney, skeletal muscle, gastrointestinal tract, spleen, skin, and adrenal glands.

Tumors are fleshy to firm, depending on the degree of associated sclerosis. Solitary, discrete adenomas and invasive carcinomas occur. Multiple coalescing zones of pulmonary consolidation by pale slightly firm tissue are typical of ovine pulmonary adenocarcinoma, ovine progressive pneumonia, and interstitial pneumonia due to caprine arthritis-encephalitis virus. Histologic evaluation will distinguish benign and malignant epithelial proliferative lesions based on cell morphology and degree of invasion. Rhabdomyosarcoma consisting of interlacing bundles of striated muscle cells and invasion of adjacent parenchyma is typical. Myxomas are well demarcated, multilobular, soft, white tumors composed of spindloid to stellate cells in a myxoid matrix. Pulmonary adenocarcinoma in sheep is characterized by proliferation of type 2 alveolar lining cells forming invasive masses. Ovine progressive pneumonia and pulmonary lesions in goats with caprine arthritis-encephalitis virus result in profound interstitial thickening with type 2 alveolar cell hyperplasia that can mimic neoplasia, but associated chronic inflammation, most often with many lymphocytes, is a distinguishing feature.

TUMORS OF THE THORACIC CAVITY

Tumors of the thoracic cavity have been reported in farm animals. Thymic lymphoma occurs in calves 3 months to 2 years of age as a form of sporadic bovine leukosis and also occurs in sheep and pigs. A mediastinal plasma cell tumor has been reported in an adult sheep. Mediastinal lymphoma has been reported in goats, but it is not clear whether these tumors were true lymphoma or lymphocyte-rich thymomas. Mediastinal thymoma is a common tumor in goats, occurring in 9% of goats with neoplasms in one study. It has been suggested that Saanen goats may be predisposed to development of thymoma, but a study of 100 goats found that thymomas occurred in multiple breeds, none of which were Saanen. Thymoma occurred in goats from 2 to 13 years of age. Thymoma has also been reported in adult cattle, sheep, and pigs. Congenital mesothelioma in calves can be confined to the thoracic cavity or can involve both thoracic and abdominal cavities, but localization with the abdomen is most common (see Tumors of the Abdominal Cavity). Mesothelioma occurs within the thoracic cavity of adult cattle and pigs. Rhabdomyosarcoma arising within the internal thoracic wall causing megaesophagus and infiltrating the thoracic spinal cord occurred in a 7-month-old heifer. An extraskeletal osteosarcoma has been described in the mediastinum of an aged goat, and a malignant peripheral nerve sheath tumor within the thoracic side of the diaphragm occurred in a 2-year-old goat.

Clinical signs are most often progressive respiratory difficulty associated with both growth of the tumor and frequent associated pleural effusion. Progressive cachexia is common. Palpable enlargement of the brisket region can occur in cases of thymic lymphoma and intrathoracic mesothelioma. Enlargement of peripheral lymph nodes can accompany thymic lymphoma. Thymoma in goats has caused megaesophagus and was thought to be the cause of congestive heart failure in two goats.

Cytologic evaluation of pleural fluid or of mass aspirates can distinguish the atypical lymphocytic proliferation of lymphoma from the mesothelial proliferation of mesothelioma. Thymoma can be more difficult to diagnose on cytologic preparations, as the thymic epithelial cells that are the neoplastic population may be obscured by large numbers of associated nonneoplastic small lymphocytes. Histologic evaluation is often necessary for definitive diagnosis of thymic lymphoma, thymoma, and mesothelioma.

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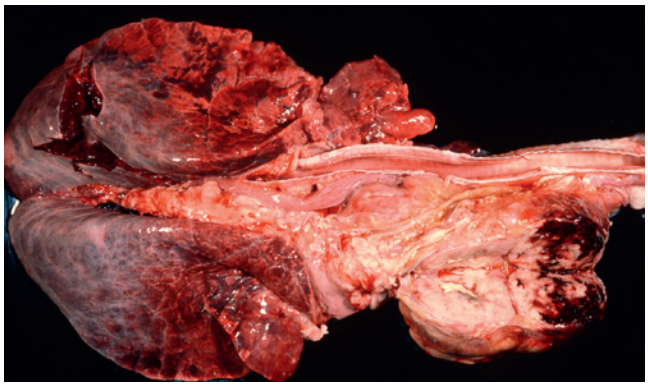


Figure 8-22 Mediastinal lymphoma in a calf. (Courtesy of Dr. Barry Cooper.)

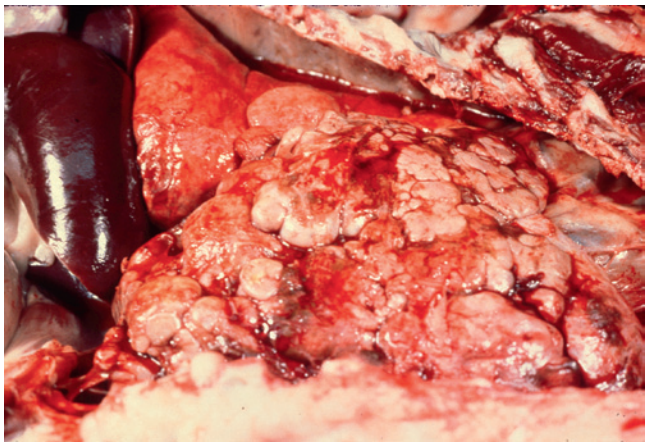


Figure 8-23 Large multilobular mediastinal mass typical of thymoma in a goat. (Courtesy of Dr. Barry Cooper.)

Surgical excision of thymic lymphoma in calves (Figure 8-22) is unlikely to be curative, because involvement of other thoracic organs is possible. Chemotherapy may be an option in the future. Intrathoracic mesothelioma is generally widespread on pleural surfaces, and surgical excision is not possible. Thymoma can get quite large but is typically still localized to the mediastinum (Figure 8-23). Although no reports of surgical excision of thymoma in farm animals were found, extrapolation from results of thymoma surgery in dogs and cats would suggest that surgical excision could be curative.

TUMORS OF THE UDDER AND MAMMARY GLAND

Udder skin tumors are relatively common in farm animals. Mammary gland neoplasia, however, is uncommon. Inflammatory and hyperplastic lesions and benign and malignant tumors of epithelial or mesenchymal cells are possible.

Udder

Papillomas can involve the skin of the udder and teats. Papillomavirus has been shown to cause skin growths in cattle and a viral etiology is suspected in sheep, goats, and pigs. In cattle, papillomas occur in young animals, usually less than 2 years of age, and involvement of the teat is common. A



Figure 8-24 Multiple papillomas on the udder of a goat. (Courtesy of Dr. Mary Smith.)

syndrome of papillomatosis that involves teats and nonpigmented skin of the udder occurs in goats of any age (Figure 8-24), especially white Saanen or Saanen cross goats, and these lesions are prone to malignant transformation to squamous cell carcinoma. The growths appear to be infective, at least to other Saanen goats, with appearance of multiple affected animals within 4 to 6 months of introduction of an infected animal. Exposure to sunlight may also be an etiologic factor. A similar syndrome occurs less commonly in sheep. Papillomas on the teats are often secondarily infected and can interfere with nursing or milking.

Papillomas are exophytic and often pedunculated skin growths that are often multinodular or multilobular. Surface ulceration can result from mechanical trauma. In cattle, viral-induced skin growths can be composed entirely of proliferative epithelium (papilloma) or can contain both epithelial and fibrous proliferation (fibropapilloma). Papillomas in goats are characterized by epithelial proliferation without a fibrous component.

Bovine cutaneous papillomas typically undergo spontaneous regression. Udder papillomas in goats can undergo spontaneous regression without recurrence, can regress in winter and reoccur in summer, or can be persistent. The latter tumors are prone to malignant transformation to squamous cell carcinoma and can result in squamous cell carcinoma of udder skin that can be multicentric. Squamous cell carcinoma of the skin of the udder occurs less commonly in sheep. Squamous cell carcinoma is a spreading ulcerative lesion that is often firm because of associated sclerosis. Invasive cords and nests of neoplastic squamous epithelium are seen on histopathologic evaluation. Neoplastic cells can be difficult to obtain on cytologic preparations in cases with extensive tumor sclerosis.

Given the high incidence of malignant transformation of persistent udder papillomas in goats, wide surgical excision of these growths, when possible, is the treatment of choice. Metastasis of squamous cell carcinoma to local lymph nodes can occur, but early and wide resection of squamous cell carcinoma could be curative.

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Mammary Gland

Tumors of the mammary gland are uncommon in farm animals. In cattle, fibroma and fibrosarcoma of the teat occur in yearlings. Inflammatory polyps that mimic neoplasia occur in the teat canal of cattle of any age. Mammary glandular tumors occur most often in cows 3 years of age or older and are most often adenocarcinoma or carcinoma. Malignant epithelial tumors with extensive squamous differentiation resulting in a diagnosis of squamous cell carcinoma can also occur. Fibroadenoma, a benign mammary tumor, was reported in a 7-month-old heifer and a mammary fibrosarcoma occurred in an aged cow. Adenomas are the most common mammary neoplasia in sheep and occur most often in adults, although adenoma has occurred in a lamb. A low-grade mammary carcinoma occurred in an adult ewe. Mammary gland proliferative lesions in the goat include adenocarcinoma, cystic hyperplasia (fibrocystic change), and fibroepithelial hyperplasia. Nubian goats may be predisposed to fibroepithelial hyperplasia, which occurs in young goats, often less than 1 year of age. Mammary adenocarcinoma comprised 7% of tumors in a study of goat neoplasms and occurred in goats from 4 to 12 years of age. Mammary tumors are very rare in older sows, and reported cases have been carcinomas. A mammary adenoma was reported in a 10-year-old pot-bellied pig.

Teat fibroma and fibrosarcoma are smooth firm nodules covered by intact skin that occur at the base of the teat. Intramammary tumors and hyperplastic lesions cause firm localized to diffuse areas of mammary gland that may or may not result in overall enlargement of the affected gland. Mastitis and fistulation can occur secondary to malignant tumors. Milk production in nonpregnant animals and mastitis can be seen in goats with fibroepithelial hyperplasia.

Fibroma and fibrosarcoma consist of proliferating fibroblasts with admixed collagen and variable mitotic activity. Fibroma and fibrosarcoma at the base of the teat are typically localized lesions, whereas the fibrosarcoma of the mammary gland was invasive. Adenomas are localized tumors formed by relatively well-differentiated and orderly epithelial cells forming glands. Fibroadenoma is a localized mass with relatively well-differentiated and orderly glandular elements admixed with collagen. Adenocarcinoma and carcinoma are invasive tumors that can involve a large portion of the gland and are composed of pleomorphic neoplastic epithelial cells that form glands or sheets of cells with a variable amount of collagenous stroma. Pleomorphic and atypical epithelial cells can be seen on cytologic preparations, but if the tumor contains areas of necrosis or secondary inflammation it can be difficult to make a cytologic diagnosis of a malignant neoplasm. Cystic hyperplasia in goats, also called *fibrocystic change*, consists of localized zones of dilated mammary ducts lined by epithelial cells lacking features of neoplasia. Fibroepithelial hyperplasia of goats consists of proliferation of ductal elements in a prominent loose to dense stroma and is similar to the mammary fibroepithelial hyperplasia seen in young female cats.

Surgical excision of teat fibromas and fibrosarcomas is apparently curative. Surgical excision of hyperplastic lesions and adenomas, which may necessitate removal of the entire affected gland, is also curative. Careful evaluation of cows with mammary neoplasia before surgery is warranted because metastasis of adenocarcinoma and carcinoma to local lymph nodes, internal organs, and the peritoneum is common. Mammary carcinoma can also metastasize in goats.

TUMORS OF THE FEMALE GENITAL TRACT

Tumors of the female genital tract of farm animals are seen quite often and are probably second only to skin tumors in incidence in most parts of the world. Various benign and malignant tumors occur. Although few clinical reports of surgical excision of genital tract tumors in farm animals were found, the behavior of many of these tumors suggests that ovariectomy, tumor excision, or hysterectomy could be curative.

Tumors of the Vulva

Vulvar papillomas and fibropapillomas occur in cattle as a sexually transmitted papillomavirus disease. Squamous cell carcinoma of the vulva occurs in older cattle, sheep, and goats and may occur de novo or as the result of malignant transformation of viral papilloma. Poor pigmentation of vulvar skin and high solar exposure are predisposing factors. Smooth muscle tumors (leiomyoma and leiomyosarcoma) occur in the vulva of cattle. Ectopic mammary tissue in the vulva of goats will cause swelling during lactation and can be mistaken for neoplasia.

Papillomas and fibropapillomas are multinodular to multilobular tumors typically with a broad base of attachment and no evidence of invasion. Large tumors can be ulcerated. Squamous cell carcinoma is an invasive, ulcerated, spreading lesion of the vulvar skin. Ectopic mammary tissue in goats results in bilaterally symmetric nonulcerated vulvar swelling that occurs at parturition. Histologic evaluation will differentiate the relatively orderly epithelial proliferation, often with an associated fibrous component, of papilloma and fibropapilloma from the disorganized, pleomorphic, and invasive squamous epithelium of squamous cell carcinoma. Cytologic diagnosis of squamous cell carcinoma is possible, although frequent secondary infection and sclerosis can make interpretation of cytologic preparations difficult. Aspiration of ectopic mammary tissue in goats reveals milk and fat globules.

Papillomas and fibropapillomas often undergo spontaneous regression. Surgical excision or debulking may be desirable when tumors are large and/or ulcerated. Metastasis of vulvar squamous cell carcinoma to regional lymph nodes and lung is possible. Vulvar squamous cell carcinoma is also often a multicentric tumor, thus making wide surgical excision of this tumor difficult. The swelling of ectopic mammary tissue regresses spontaneously following lactation.

Tumors of the Vagina and Cervix

Smooth muscle tumors are the most common tumors of the vagina and cervix of farm animals and occur in adult cattle, goats and pigs, including pot-bellied pigs. These tumors are rare in sheep. In goats, smooth muscle tumors may be multiple, especially in aged goats (greater than 10 years of age). Saanen goats may be predisposed to development of multiple genital smooth muscle tumors. Papilloma, fibropapilloma, and lymphoma can also involve the vagina and cervix, especially in cattle. Fibroma also occurs in the vagina of sheep and pigs. Squamous cell carcinoma of the vagina and cervix occurred in an adult ewe. A diagnosis of leiomyofibromatosis and a diagnosis of adenomatous hyperplasia were made in the cervices of two goats.

Smooth muscle tumors and fibromas most often occur as nonulcerated nodular masses within the wall of the vagina (Figure 8-25) or cervix (Figure 8-26). Leiomyosarcoma, and large tumors of any type, can become ulcerated and cause bleeding that can be fatal. Goats with multiple smooth muscle tumors often present with vulvar bleeding, recurrent pseudopregnancy, and spontaneous expulsion of uterine fluid (*cloud burst*). Straining, anorexia, depression, and weight loss can also be seen. Histologic evaluation is necessary to distinguish tumor types and to distinguish benign from malignant smooth muscle tumors. Genital papillomas and fibropapillomas have histologic features identical to

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Figure 8-25 Multiple (2) vaginal leiomyomas in a cow. (Courtesy of Cornell University.)

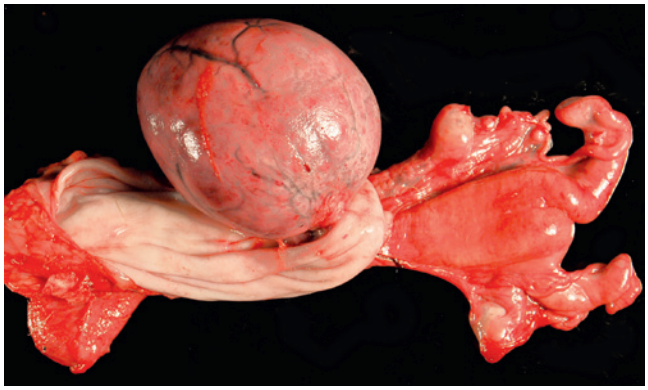


Figure 8-26 Cervical leiomyoma extending into the vagina of a goat. (Courtesy of Dr. Christiane Löhr.)

those at other sites. Smooth muscle tumors consist of interlacing bundles of elongated cells. Leiomyoma consists of well-differentiated and noninvasive cells that resemble normal smooth muscle. Mitoses are not usually seen. Leiomyosarcoma is characterized by mildly to markedly pleomorphic spindle cells with variable mitotic activity and evidence of local invasion.

Surgical excision of papillomas, fibropapillomas, and fibromas is possible and can be curative, although viral-induced lesions may recur. Isolated leiomyoma or leiomyosarcoma can also be surgically excised, although recurrence of leiomyosarcoma caused by local invasion is common. Peritoneal metastasis of leiomyosarcoma is also possible. A 4.5-kg cervical leiomyoma was successfully excised from a pregnant cow during parturition. Surgical removal is more challenging in goats with multiple genital smooth muscle tumors. Interestingly, this syndrome in goats is associated with ovarian cysts and is likely to be hormonally related. In one case, removal of the ovaries resulted in resolution of the vaginal tumors, and ovariectomy should be considered in goats with multiple genital smooth muscle tumors.

Tumors of the Uterus

Primary uterine tumors in farm animals include smooth muscle tumors (leiomyoma and leiomyosarcoma), epithelial tumors (adenoma and adenocarcinoma), and mixed tumors (carcinosarcoma). Uterine fibroma and hemangioma are uncommon tumors of cows. Uterine neoplasms are particularly common in pot-bellied pigs and miniature pet pigs, and multiple uterine tumor types can occur in the same pig. The

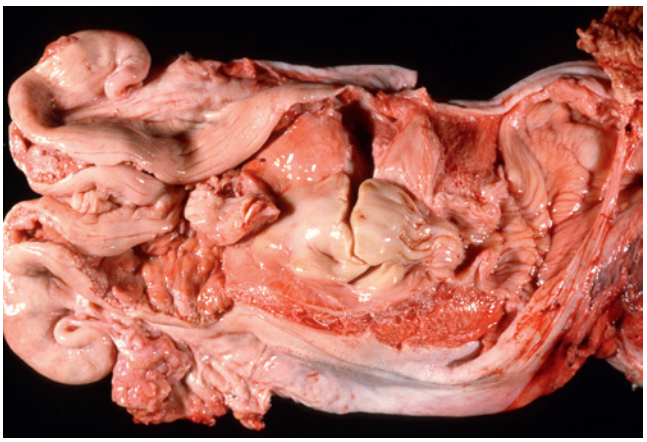


Figure 8-27 Localized thickening of the uterus of an adult cow by pale tissue typical of lymphoma.

uterus is also a common site of infiltration in cattle with multicentric lymphoma caused by BLV infection. Uterine smooth muscle tumors are most commonly reported in cattle but also occur in sheep, goats, and pigs. Multiple leiomyosarcomas were found in the uterus of a sheep, and uterine leiomyoma was reported in two adult goats. Four cases of uterine smooth muscle tumors, leiomyoma and leiomyosarcoma, were found in a study of tumors in 21 pot-bellied pigs and occurred in pigs from 6 to 14 years of age. Endometrial adenocarcinoma is most common in the cow and not uncommon in pigs, especially pot-bellied pigs and miniature pet pigs. Endometrial adenocarcinoma is rare in sheep and goats. Benign epithelial tumors of the uterus (adenomas) are rare in all species but have been reported in pigs, especially miniature pet pigs. Endometrial carcinosarcoma has been reported in an aged pig.

Clinical signs in animals with uterine tumors may be inapparent, even when tumors have achieved an extremely large size. Uterine masses are palpable during rectal examination of cattle. In other species, tumors may not be detected until systemic signs of anorexia and cachexia are apparent. Large uterine tumors in pigs can result in abdominal distention.

Leiomyoma is a smooth-surfaced, discrete mass within the uterine wall that closely resembles normal smooth muscle in appearance. Leiomyosarcoma is invasive and often contains areas of necrosis and hemorrhage. Uterine adenocarcinoma in cattle occurs most often in the horns and less commonly in the body of the uterus. Uterine adenocarcinoma arises within the uterine wall and does not generally extend to the mucosal or serosal surface. Diffuse thickening of the uterine wall as a result of adenocarcinoma can mimic pregnancy. Adenocarcinoma is sclerotic and can cause annular constriction of the uterus. Lymphoma causes diffuse thickening of the uterine wall by characteristic soft to slightly firm tan tissue with minimal to no sclerosis and no evidence of constriction (Figure 8-27).

Cytologic evaluation can help to distinguish smooth muscle and other mesenchymal tumors from epithelial and lymphoid neoplasia. Histopathologic evaluation is necessary to distinguish benign and malignant smooth muscle tumors; cellular pleomorphism, mitotic activity, and evidence of invasion indicate malignancy. Adenocarcinoma forms nests and glands composed of pleomorphic neoplastic epithelial cells. Carcinosarcoma is characterized by neoplastic proliferation of both epithelial and mesenchymal elements. Lymphoma is characterized by invasive sheets of neoplastic lymphocytes that obliterate normal architecture.

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Leiomyoma is a benign neoplasm that could be cured by hysterectomy. Leiomyosarcoma in early stages might also be cured by surgical excision; however, widespread metastases within the abdominal cavity are possible. Uterine adenocarcinoma typically metastasizes to lungs as well as abdominal organs, and surgical excision is not likely to be curative. In one study over half of bovine uterine adenocarcinomas diagnosed at necropsy had metastasized. Endometrial adenocarcinoma with metastasis also occurred in a 16-year-old pot-bellied pig and in a 10-year-old miniature pig. Similarly, metastasis of carcinosarcoma to thoracic and abdominal viscera is likely. Cows with uterine lymphoma will also have lymphoid neoplasia within other organs.

Tumors of the Accessory Sex Glands

Tumors of accessory sex glands are very rare in all animals. An adenocarcinoma of the major vestibular gland (Bartholin's gland) has been reported in a 9-year-old Japanese Brown cow. Clinical signs were of persistent vulvovaginitis and hemorrhage. A large solitary invasive mass was found in the vestibule near the urethral opening. Histologic evaluation after slaughter revealed invasive, pleomorphic neoplastic epithelial cells that formed irregular tubules and glands with marked associated fibrous stroma and inflammation. Metastasis was not found; therefore treatment by surgical excision of this type of tumor may be possible.

Tumors of the Ovary

Ovarian neoplasms are unusual in farm animals. Granulosa cell/stromal tumors are most common in cattle and have been reported in fetuses, neonates, and heifers as well as adults. Granulosa cell/stromal tumors occur rarely in pigs and sheep. Other ovarian tumors typically occur only in older animals. Adenoma, adenocarcinoma, and dysgerminoma occur rarely in cattle and pigs. Vasoproliferative lesions, classified as hamartoma, hemangioma, or hemangiosarcoma, occur most commonly in sows and less frequently in cows. Ovarian teratoma is a rare neoplasm of cattle and sheep. Ovarian infiltration by lymphoma in cows with BLV infection can also occur. No reports of ovarian neoplasia in goats were found.

Granulosa cell/stromal tumors of cattle can result in signs of nymphomania. Clinical signs of masculine behavior are less common. Lactation can occur in virgin heifers with ovarian granulosa cell/stromal tumor. Rupture of ovarian granuloma cell tumor can cause hemoperitoneum. Ovarian tumors of all types in cattle typically result in palpable enlargement of the affected ovary on rectal examination. Ovarian tumors in sheep and pigs have most often been described in surveys of animals examined at slaughter, and no clinical information is available. It is possible that affected animals were culled because of poor reproductive performance.

Gross examination reveals enlargement of one or both ovaries. Bilateral involvement is common in sows with vasoproliferative lesions. Adenoma, adenocarcinoma, and dysgerminoma often present as solid tissue tumors. Granulosa/stromal tumors often have multiple cystic spaces, which can be hemorrhagic, admixed with solid tissue (Figure 8-28). Teratomas contain multiple tissue types—including hair, bone, cartilage, and teeth—and a vascular nature is exhibited by the various vasoproliferative lesions. Histologic examination will distinguish the glandular pattern of adenoma and adenocarcinoma, the sheets of germ cells typical of dysgerminoma, the nests of plump granulosa cells often admixed with stromal cells typical of granulosa/stromal cell tumors, the multiplicity of tissue types in teratoma, and the vascular channels typical of vasoproliferative lesions.

Metastasis of ovarian neoplasia in farm animals is rare. Surgical excision of the affected ovary should be curative in most cases. Excision of unilateral ovarian granulosa/stromal tumors in two dairy heifers did not interfere with subsequent pregnancy or milk yields.

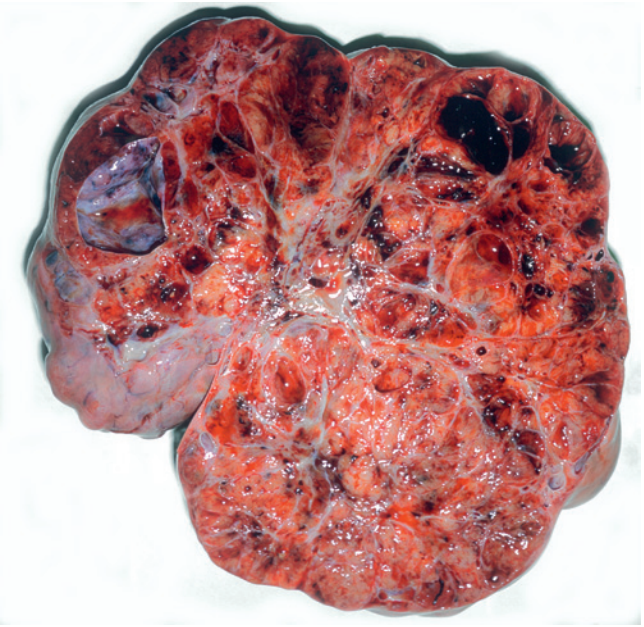


Figure 8-28 Granulosa cell/stromal tumor of the ovary of a cow. (Courtesy of Dr. Barry Cooper.)

TUMORS OF THE MALE GENITAL TRACT

Tumors involving the male genital tract occur in all farm animal species. Penile and preputial papillomas and fibropapillomas are most common and occur most often in cattle. Various testicular tumors occur but are uncommon, likely related to the fact that so many male farm animals are castrated. Sperm granulomas, especially in polled cattle and goats, can mimic testicular neoplasia (Figure 8-29). A localized swelling within the testis or epididymis of cattle, sheep, or goats is more likely to be a sperm granuloma than a testicular tumor.

Tumors of the Penis, Prepuce, and Scrotum

Papilloma and fibropapilloma as the result of papillomavirus involving the penis and/or prepuce are common in bulls up to 4 years of age and have also been seen in mature boars. A bovine tubular adenoma involving the prepuce has been reported. Mesothelioma is relatively common in the scrotum of adult bulls.

Papillomas and fibropapillomas of the penis can cause bleeding associated with breeding, and because of pain affected bulls are often reluctant to breed. Large tumors can interfere with retraction of the penis. Tumors in the area of the urethral opening will cause dysuria. Tumors are single or multiple and most often appear as multinodular to multilobular masses with a broad base of attachment. These tumors in cattle can also be cylindrical and surround the penis (Figure 8-30). Fibrous proliferation is typical of genital tumors in cattle, whereas epithelial proliferation is characteristic of genital tumors in boars. Tubular adenoma occurs as a circumscribed tumor composed of well-differentiated glands. Mesothelioma presents as diffuse scrotal swelling with multiple soft granulomatous-appearing growths in the vaginal tunics. Scrotal mesothelioma in bulls can be

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Figure 8-29 Multinodular yellow-tan epididymal mass characteristic of sperm granuloma in a goat. (Courtesy of Dr. Barry Cooper.)



Figure 8-30 Fibropapilloma forming a cylindrical mass on the penis of a bull. This sample has been fixed in formalin. (Courtesy of Cornell University.)

unilateral or bilateral. Variable cell patterns are seen on histopathologic evaluation, and differentiating reactive from neoplastic mesothelium in cytologic and histopathologic preparations can be difficult.

Viral papillomas and fibropapillomas regress spontaneously. Surgical removal or debulking of larger tumors can be achieved, although tumors may recur in young bulls. Surgical excision of genital fibropapilloma in older bulls is often curative. Surgical excision of the testis and associated tunics of bulls with unilateral mesothelioma can be curative. Internal metastasis of mesothelioma to the abdominal and/or thoracic cavities is, however, also possible, and the prognosis for bulls with bilateral scrotal mesothelioma is poor. Surgical excision of adenoma would be curative.

Tumors of the Testis

Various testicular tumors occur in older farm animals, although the incidence is low. Sertoli cell tumor, interstitial cell tumor, and germ cell tumors—teratoma and yolk sac tumor—occur in bulls. Shorthorn cattle may be predisposed to development of Sertoli cell tumors. Sertoli cell tumors can be a congenital lesion in calves, usually within descended testes. A Sertoli cell tumor was found in a descended testis of an 11.5-year-old bull that had been fertile until 11 years of age. Testicular yolk sac tumors are rare congenital tumors in calves. An interstitial cell tumor was found within a retained testis in a calf and a fibrolipoma was reported in a retained testis in a 6-month-old bull. Seminoma, rete testis tumors, and leiomyoma of the testis occur in rams. Bilateral lymphangiomatous lesions occurred in testes from a young lamb and were thought to represent hamartomas, benign neoplasia, or reaction to lymphatic obstruction. No follow-up was available following castration of this lamb, but castration would likely have been curative. Teratomas and interstitial cell tumors are rare in boars; two interstitial cell tumors were found in a study of 21 pot-bellied pigs with neoplasms and occurred in boars 7 and 14 years of age. Testicular tumors are rare in buck goats. A testicular rhabdomyosarcoma occurred in a goat, and bilateral interstitial cell tumors were found within retained testicle-like tissue in a polled intersex syndrome goat (phenotypic female).

Testicular tumors cause palpable nodules or overall enlargement of the affected testis. Large tumors or Sertoli cell tumors with estrogen production can be associated with poor sperm production as a result of atrophy of testicular cords. Testicular tumors vary in gross appearance. Solid pale tan tumor tissue is typical of Sertoli cell, seminoma, and rete testis tumors. Sertoli and rete testis tumors are often associated with fibrous stroma, whereas seminoma is commonly soft and meaty. Interstitial cell tumors are typically a soft, pink to red tumor that often contains areas of hemorrhage. Leiomyoma is most often pale tan to pink and slightly firm. Teratomas vary in appearance depending on the tissue types present. Hair, teeth, bone, and cartilage can be found in well-differentiated testicular teratomas. Histologic evaluation will differentiate the sheets of germ cells characteristic of seminoma, the sheets and nests of plump eosinophilic cells typical of interstitial cell tumors, the cords of often vacuolated columnar cells in fibrous stroma seen in Sertoli cell tumors, the embryonal cells forming various histologic patterns characteristic of yolk sac tumors, the glandular pattern of rete testis tumors, the admixture of adipocytes and fibrous tissue typical of fibrolipoma, and the mixture of differentiated epithelial and mesenchymal tissue indicative of teratomas.

The majority of testicular tumors in farm animals are benign and cured by surgical removal of the affected testis. Seminoma can be invasive into testicular tunics, epididymis, and spermatic cords in sheep, although no reports of metastasis were found.

TUMORS OF THE KIDNEY AND URINARY BLADDER

Tumors involving the kidney or urinary bladder occur most often in pigs, cattle, and sheep. A necropsy study of tumors in Brazilian cattle found that 22% of tumors involved the urinary system and most were in the urinary bladder. Renal cell tumors (adenomas and adenocarcinomas) and lymphomas involving the kidney occur most often in cattle and are much less common in sheep and pigs. Nephroblastoma occurs most often in pigs, less commonly in cattle, and rarely in sheep. Urinary bladder tumors—including papillomas, adenomas, and vascular tumors—are more common than renal tumors and occur most often in cattle and sheep, especially those grazing on bracken fern, such as in Brazil. Tumors that involve the kidneys or urinary bladder are rare in goats.

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Kidney

Renal cell tumors are found most often in adult to aged cattle and are described most often in females. Tumors can be single to multiple and can involve one or both kidneys. Lymphoma in cattle can involve one or both kidneys. Nephroblastoma (embryonal nephroma) occurs most often in pigs, including pot-bellied pigs, and is the most common neoplasm encountered in domestic pigs. Nephroblastoma is less common in cattle and is rare in sheep. Nephroblastoma is a tumor of young animals seen most often in animals up to 1 to 2 years of age, and it can be seen in fetal animals. Occasionally nephroblastoma is found in older animals. Nephroblastoma in children, also known as Wilms' tumor, is associated with mutation of the Wilms' tumor gene, but it is not known if a similar mutation occurs in animals. Renal tumors have not been described in goats.

Renal epithelial tumors in cattle have been found at necropsy, and antemortem clinical signs have not been described. Clinical signs in animals with renal lymphoma are variable and include cachexia and peripheral lymphadenopathy. The signs may or may not indicate renal dysfunction. Enlargement of one or both kidneys palpable on rectal examination is typical of renal lymphoma. Nephroblastoma rarely results in clinical signs of renal dysfunction, although abdominal distention caused by large tumors is possible. Nephroblastoma with pulmonary metastasis in a 2-year-old sheep caused abdominal distention, emaciation, and death.

Renal cell adenomas and adenocarcinomas are firm, irregular, yellow-orange, tan, or brown well-circumscribed cortical tumors that often protrude on the capsular surface and can also extend into the renal pelvis. Histologic features are similar for adenomas and adenocarcinomas, and size is not a good criterion for malignancy as even small (less than 2-3 cm in diameter) tumors have exhibited metastatic behavior. A variety of patterns from solid to papillary is seen, and a variant composed of renal cells with prominent clear cytoplasm (clear cells) occurs in cattle. Lymphoma results in locally extensive to diffuse enlargement and thickening of the affected kidney by pale tan tissue. Histologic and cytologic preparations reveal sheets of neoplastic lymphocytes with marked infiltration and architectural effacement in tissue sections. Nephroblastoma is a firm, nodular, often multilobular tumor that typically arises in the cortex of one pole of the kidney. Nephroblastoma can be quite large and can cause massive enlargement of the affected kidney (Figure 8-31). The tumor tissue is firm and pale and often contains cystic and necrotic zones. Foci of bone and cartilage are also possible. Nephroblastoma has a unique histologic pattern of admixed embryonal epithelial and mesenchymal elements.

Renal cell tumors can be multicentric within the kidneys, but extrarenal metastasis is uncommon. When present, metastasis of renal cell tumors is most often to peritoneum and abdominal lymph nodes, although metastasis to the lung, liver, and the other kidney is possible. If metastasis is not evident, surgery to remove the affected kidney might be curative, but the prognosis should still be guarded. Lymphoma involving the kidney occurs in cattle in association with multicentric lymphoid neoplasia caused by BLV infection, and surgical intervention would not alter the progressive course of this disease. Nephroblastoma can achieve an extremely large size but metastasis is rare. Therefore surgical excision of the affected kidney would likely be curative.



Figure 8-31 Massive enlargement of the kidney in a young pig with nephroblastoma. (Courtesy of Cornell University.)

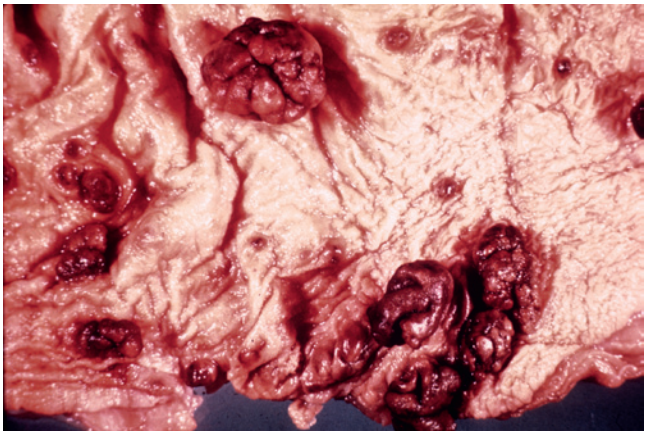


Figure 8-32 Multiple hemorrhagic tumors of the urinary bladder mucosa in a cow with enzootic hematuria. (Courtesy of Cornell University.)

Urinary Bladder

Tumors of the urinary bladder are most common in cattle, in large part due to induction of an array of epithelial and mesenchymal tumors by bovine papillomavirus infection of urinary bladder tissue and by ingestion of bracken fern. Tumors of the urinary bladder are also common in sheep and are also often associated with bracken fern ingestion. Enzootic hematuria is a syndrome in cattle and sheep that have access to brackern fern in which multiple animals are affected with a variety of urinary bladder tumors. In cattle, bovine papillomavirus and bracken fern can act synergistically to cause tumors of the urinary bladder. Types of tumors that occur in the urinary bladder include transitional cell papillomas, transitional cell adenomas, other carcinomas, vascular tumors (hemangioma and hemangiosarcoma), smooth muscle tumors (most often leiomyoma), and glomus tumors (tumors containing smooth muscle and vascular elements). Urinary bladder tumors in goats are uncommon and usually benign. Leiomyoma of the urinary bladder can be multiple in goats. Urinary bladder tumors are rare in pigs. The most common clinical sign of tumors within the urinary bladder in all species is hematuria. Weight loss and nonregenerative anemia are also possible.

Tumors appear as single to multiple polypoid masses within the mucosa of the bladder (Figure 8-32). Multiple tumors are most often associated with bovine papillomavirus infection and/or bracken fern exposure. Papillomas and adenomas form noninvasive solitary masses that are typically

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exophytic or papillary, whereas carcinomas are invasive. A hemorrhagic appearance is typical of vascular tumors (hemangioma and hemangiosarcoma) and of glomus tumor. Histologic evaluation will differentiate epithelial, smooth muscle, and endothelial tumors, and the degree of cellular pleomorphism, mitotic activity, and tumor invasion will differentiate benign from malignant tumors. Cytologic evaluation of urine sediment can help to differentiate reactive from neoplastic processes within the urinary bladder, but differentiating reactive transitional cells from neoplastic transitional cells can be difficult. Moreover, neoplastic endothelial cells and smooth muscle cells are rarely seen in urine.

Metastasis of urinary bladder tumors in farm animals is rare. Surgical excision of benign tumors should be curative. Most malignant tumors are in an advanced stage at the time of clinical diagnosis, thus making complete surgical excision difficult or impossible. Tumors caused by papillomavirus infection and/or bracken fern exposure are generally multiple, and surgical excision is not an option. As most urinary bladder tumors in goats are benign, if a tumor is detected surgical excision should be considered, because it could be curative.

TUMORS OF THE LIVER AND GALLBLADDER

Hepatocellular, biliary, and gallbladder epithelial tumors are found in many farm animal species, and carcinoma is more common than adenoma. Tumors of the liver and gallbladder occur most commonly in cattle, sheep, and pot-bellied pigs and are uncommon in domestic pigs. Tumors of the liver and gallbladder are rare in goats; only two reports of hepatocellular carcinoma in a goat were found. Biliary and gallbladder tumors are most often found in older animals, whereas hepatocellular carcinoma can also occur in cattle less than 3 years of age, in sheep less than 1 year of age, and in domestic pigs less than 6 months of age. Both biliary carcinoma and hepatocellular carcinoma occur in aged pot-bellied pigs, and nine reported cases—six hepatocellular carcinomas and three gallbladder carcinomas—occurred in pigs 11 to 18 years of age. Hepatocellular carcinoma has been associated with carcinogens such as aflatoxin and nitrosamines, especially in pigs. In cattle, sheep, and goats, an association between liver fluke infestation and biliary carcinoma has been proposed but not proven. Lymphoma can involve the liver of cattle and goats with multicentric lymphoid neoplasia. Benign vascular lesions that may be hamartomatous rather than neoplastic occur in the liver of adult cattle as incidental findings. Cholangioma occurs in older pigs, and nodular hyperplasia occurs in the liver of pigs of all ages. Neuroendocrine tumors of the liver and gallbladder and leiomyoma are rare hepatic tumors in cattle.

Few clinical signs have been reported in farm animals with hepatic tumors, and many reports are of incidental lesions detected at necropsy or slaughter. Anorexia, progressive weight loss, and abdominal effusion are possible. Tumors of the gallbladder and biliary tree can result in icterus and photodermatitis. Increased serum levels of liver enzymes (glutamate dehydrogenase, sorbitol dehydrogenase, and gamma glutamyltransferase) were consistent findings in a study of four cows with liver tumors, and an increase in bilirubin was found in three of four affected cattle. Ultrasonography proved useful in distinguishing hepatic neoplasia from other forms of hepatic disease in these cows, revealing mass lesions or diffuse enlargement with a very heterogeneous appearance.

Hepatocellular and biliary adenomas are generally small and discrete, whereas carcinomas are often quite large at the time of diagnosis and can involve entire liver lobes. Hepatocellular carcinomas are composed of tissue that closely resembles normal hepatic parenchyma. Most hepatocellular tumors are confined to one liver lobe, although metastasis within the liver is possible. Biliary tumors are often pale and firm because of the presence of connective tissue stroma and may be seen to follow the tracts of the biliary tree (Figure 8-33). Biliary carcinoma commonly involves multiple liver lobes, most likely because of intrahepatic metastasis. Lymphoma can be a diffuse or a multifocal tumor composed of pale tan, soft to slightly firm tissue. Vascular hamartomas in cattle can be single or multiple and are pale to red firm lesions that can be either depressed or pedunculated. Thrombi can be present within dilated vascular spaces. Neuroendocrine tumors are typically discrete, pale, and soft to slightly firm. Leiomyomas form a smooth firm to fibrous tan nodular mass.

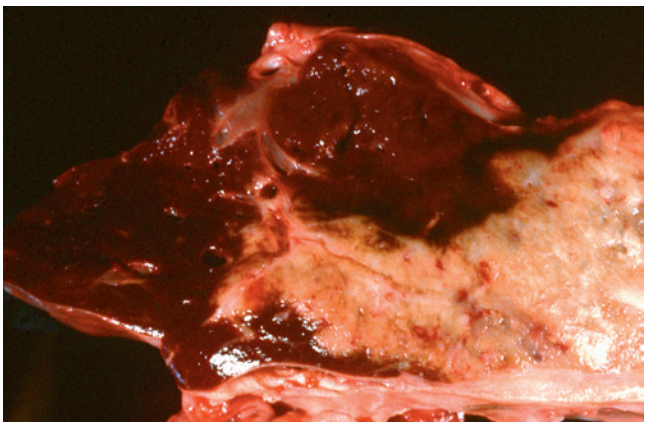


Figure 8-33 Pale zones with linear growth along biliary tracts characteristic of biliary carcinoma in the liver of a sheep.

Examination of histologic and cytologic preparations aids in the differentiation of hepatocellular from biliary tumors and of benign from malignant lesions and will identify neoplastic lymphocytes in cases of lymphoma, bland endocrine-type cells characteristic of neuroendocrine neoplasia, and spindle cells in cases of leiomyoma. Hepatocellular tumors closely mimic normal hepatic parenchyma but lack portal zones and bile ducts, which differentiates them from hyperplastic nodules. Well-differentiated hepatocellular carcinoma can be difficult to distinguish from hepatocellular adenoma, although carcinoma is generally a larger and more extensive tumor than adenoma. Biliary adenomas are composed of well-differentiated biliary epithelium lining dilated spaces, whereas biliary carcinomas contain pleomorphic epithelial cells forming irregular ducts that are most often admixed in a dense fibrous stroma. Lymphoma is characterized by sheets of neoplastic lymphocytes effacing architecture. Vascular hamartomas consist of stromal and vascular proliferation, often with prominent thick-walled arterioles. Neuroendocrine tumors have nests of characteristic round cells in fine reticular stroma. Silver stains (argentaffin and argyrophil stains) can reveal cytoplasmic neurosecretory granules. Leiomyoma is composed of interlacing bundles of spindle cells with abundant eosinophilic cytoplasm.

Metastasis of biliary carcinoma is more common than is metastasis of hepatocellular carcinoma. Intrahepatic metastasis of biliary carcinoma often precedes spread to abdominal lymph nodes and lung. Hepatocellular carcinoma may be more likely to metastasize in pot-bellied pigs; three of six reported cases had metastasized. Lymphoma of the liver of

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cattle and goats will be part of a generalized neoplastic process. Surgical excision of biliary adenomas, hyperplastic nodules, vascular hamartomas, and leiomyoma would be curative, although surgery would rarely be practical. The behavior of neuroendocrine tumors is often unpredictable, but some can be cured by excision.

TUMORS OF THE SPLEEN

Tumors of the spleen are rare in farm animals. Mast cell tumors in cattle and lymphoma in cattle and goats are most common. The spleen is often involved in calves with lymphoma. Splenic tumors can cause diffuse organ enlargement or form multifocal nodules throughout the splenic parenchyma. Cytologic and histologic examination will differentiate mast cell neoplasia from lymphoid neoplasia. Mast cell neoplasia confined to the spleen occurs in cattle, and splenectomy might be curative. Splenectomy in cases of lymphoma is not advised.

TUMORS OF THE ABDOMINAL CAVITY

Primary tumors of abdominal tissue (omentum, peritoneum) include mesothelioma, lymphoma, rhabdomyosarcoma, mast cell tumor, myxosarcoma, leiomyoma, and mesenteric lipoma. Most tumors of the abdominal cavity occur in older cattle, although mesothelioma occurs in young and old cattle, including fetuses. Nephroblastoma can be extrarenal within the abdomen in cattle and pigs but this is rare. Embryonal carcinoma, a primitive germ cell tumor, has been reported in the abdomen of a calf. Secondary neoplasia is most often metastatic spread of carcinoma (carcinomatosis). Abdominal mesothelioma in bulls can occur as an extension of scrotal mesothelioma (see Tumors of the Male Genital Tract). Mesothelioma occurs rarely in sheep and pigs. Disseminated abdominal rhabdomyosarcoma, disseminated peritoneal mast cell tumors, and widespread abdominal lipomatosis occur in older cattle. Discrete focal mesenteric lipomas occur in adult cattle, sheep, and pigs. Mesenteric leiomyoma and omental myxosarcoma are rare tumors in the abdomen of farm animals.

Progressive weight loss accompanied by abdominal distention is the most common clinical sign of widespread abdominal neoplasia. Fetal mesothelioma can cause dystocia. Intraabdominal masses are often felt upon rectal examination. Cytologic evaluation of abdominal fluid most often reveals a modified transudate that may contain neoplastic lymphocytes or mast cells. Neoplastic mesothelial cells can also be seen, but the differentiation of reactive mesothelial cells from neoplastic mesothelium is often extremely difficult. Atypical epithelial cells can be detected in abdominal fluid from animals with carcinomatosis, and primitive germ cells characterize embryonal carcinoma. Spread of abdominal mesothelioma to the thoracic cavity results in pleural effusion and can cause brisket edema and respiratory distress. Focal mesenteric lipoma is most often found as an incidental finding. Multiple mesenteric lipomas (lipomatosis) occur in older cattle and can result in signs of large intestinal obstruction.

Widespread soft to firm nodular to infiltrative growths typify mesothelioma, lymphoma, and rhabdomyosarcoma. Mesothelioma is often a soft and granulomatous-appearing lesion of the peritoneum that can have a multinodular to shaggy surface (Figure 8-34). Widespread abdominal mesothelioma, carcinomatosis, and embryonal carcinoma can have a similar gross appearance. Lymphoma is typically firmer, tan to white, and infiltrative into adjacent organs.



Figure 8-34 Multinodular fleshy growth characteristic of mesothelioma in the abdomen of a goat. (Courtesy of Dr. Christiane Löhr.)

Lipomas are fatty masses within the mesentery or on serosal surfaces.

Rhabdomyosarcoma, lymphoma, mast cell tumors, myxosarcoma, and leiomyoma can appear similar on gross examination. Cytologic and histologic preparations will usually distinguish the sheets of neoplastic round cells typical of lymphoma; the granulated mast cells of mast cell tumors; the oval to spindle-shaped cells of rhabdomyosarcoma, myxosarcoma, and leiomyoma; poorly differentiated cells in embryonal carcinoma; typical primitive epithelial and mesenchymal elements in nephroblastoma; and the clusters and individual large round cells characteristic of mesothelioma. Poorly differentiated tumors, however, may require stains for mast cell granules and/or immunohistochemistry for identification of the tumor cell type. Lipomas are composed of mature adipocytes.

Abdominal lymphoma in cattle occurs as part of a more generalized neoplastic process associated with BLV infection. Abdominal mesothelioma and rhabdomyosarcoma metastasize widely within the abdominal cavity and can also spread to involve the thoracic cavity. A case of peritoneal mast cell neoplasia in a cow exhibited metastasis to lungs and lymph nodes. Isolated mesenteric lipomas are benign lesions for which surgical excision is curative. Focal leiomyoma or myxosarcoma and extrarenal nephroblastoma are tumors that might be cured by surgical excision.

TUMORS OF ENDOCRINE GLANDS

Adrenal tumors are the most common endocrine tumors in farm animals and occur most often in cattle and goats. Adrenal tumors can be unilateral or bilateral and can arise within the cortex (adenoma and carcinoma) or within the medulla (pheochromocytoma). Adrenal cortical adenoma, adrenal cortical carcinoma, and pheochromocytoma are all common in bovine adrenal glands. Neural tumors (schwannoma and ganglioneuroma) can also occur in adrenal glands of cattle but are rare. Adrenal cortical adenoma and pheochromocytoma occur in goats. Other endocrine tumors of farm animals include thyroid C-cell tumors and pancreatic islet cell tumors. In cattle, multiple endocrine tumors can occur in the same animal. In particular, C-cell tumors and islet cell tumors can be seen associated with pheochromocytoma. This concurrence of tumors in multiple

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endocrine glands has been compared with the syndromes of multiple endocrine neoplasias in humans. Thyroid tumors are much less common in other farm animals, although thyroid carcinoma can occur in goats. Endocrine tumors are rarely reported in sheep or pigs.

Endocrine tumors in farm animals occur in adult to aged animals. Most occur in both sexes, but most reports of thyroid (C-cell tumors, also called *ultimobranchial tumors*) are in aged dairy bulls. Adrenal gland tumors are most common in cattle over 3 years of age. Pheochromocytoma occurred in goats from 7 to 19 years of age. Adrenal cortical tumors occur in adult goats and may be more common in castrated male goats than in intact male goats. There are sporadic reports of adrenal cortical tumors and of pheochromocytoma in adult sheep and of adrenal cortical tumors in adult pigs.

Thyroid tumors can result in palpable enlargement of the thyroid gland. Thyroid tumors in aged bulls are often associated with degenerative changes in vertebrae and lameness, although the exact relationship between the thyroid C-cell tumors and the bony changes is not clear. Blood calcium levels in cattle with C-cell tumors are typically normal. Adrenal tumors in farm animals are most often incidental findings at necropsy, although cattle with pheochromocytoma excrete increased levels of catecholamines in urine. Malignant pheochromocytoma with metastasis was a likely cause of death or euthanasia in affected goats. Pancreatic islet cell tumors in cattle can be found as an apparently incidental finding or are associated with recumbency (downer cows).

Thyroid C-cell tumors form single to multiple firm, pale tan nodular masses within one or both lobes of the thyroid. Adenomas are smaller than carcinomas and average approximately 1 to 3 cm in diameter. Adrenal cortical adenomas are discrete soft yellow to red nodular masses that often bulge from the adrenal surface. Pheochromocytoma causes overall enlargement of the adrenal gland and can become quite large and replace large portions of the affected gland. Malignant pheochromocytoma can invade the vena cava. Pheochromocytomas are soft and dark tan to red and arise within the adrenal medulla. Pancreatic islet cell tumors occur as single to multiple firm, pale creamy white to yellow nodular masses within the pancreas.

Cytologic and histologic evaluation of endocrine tumors reveal sheets of relatively homogeneous and bland round cells with a thin rim of clear to finely granular cytoplasm. Nesting of tumor cells by fine reticular strands is a histopathologic characteristic of endocrine tumors. Positive staining of cytoplasmic granules with argyrophilic silver stains is characteristic of pheochromocytoma and distinguishes this tumor from adrenal cortical tumors. Immunocytochemical procedures to identify cellular specific proteins, including hormones and hormone-related compounds, may be necessary to classify some endocrine tumors. Mitoses and cellular pleomorphism can be inapparent, and distinguishing benign and malignant endocrine tumors on the basis of histologic and cytologic cell features is often difficult. Mitotic activity and nuclear pleomorphism can be features of malignancy, but evidence of invasion is the best indication of malignancy in most endocrine tumors.

Thyroid adenomas are localized tumors cured by surgical excision of the affected thyroid gland. Thyroid carcinomas invade adjacent tissue, often metastasize to local lymph nodes, and can spread to the lung. Pancreatic islet cell tumors in cattle are often malignant and exhibit multiple metastases throughout the abdominal cavity and also to lymph nodes within the thorax. Excision of adrenal tumors in animals with no evidence of metastatic disease could be curative.

TUMORS OF BONE AND JOINT

Neoplasia of bones and joints is uncommon in farm animal species. No tumors of bone or joint were found in a necropsy study of 586 neoplasms in cattle or in a necropsy study of 100 goats with neoplasms. Osteoma, osteosarcoma, chondroma, chondrosarcoma, and synovial cell sarcoma are primary tumors that can involve these tissues. Myeloma is a plasma cell tumor that involves bone. Tumors that involve the bones of the jaw are discussed in Tumors of the Oral Cavity and Jaw. Bone tumors of nasal bones and sinuses are discussed in Tumors of the Respiratory Tract. Lymphoma in cattle can involve multiple bones, but clinical signs are usually related to dysfunction of other organs.

Osteoma and osteosarcoma occur in older cattle and most commonly involve flat bones such as the skull at the base of the horn, the frontal bone, and the pelvis. Chondroma is a rare tumor in farm animals. Chondrosarcoma in cattle also occurs primarily in flat bones; most reported cases occur in the scapula and in the costal cartilage of the costosternal region. Chondrosarcoma in cattle can occur in animals under 1 year of age and in aged animals. Synovial sarcoma is rare and has been reported in a small number of cattle that were at least 3 years old. Sarcoma involving the joint in cattle may occur at sites of chronic joint inflammation. In sheep, chondrosarcoma is more common than osteosarcoma. Chondrosarcoma in sheep most often affects flat bones such as the rib, scapula, and pelvis, but long-bone chondrosarcoma also occurs. Chondrosarcoma can occur in sheep as young as 2 years of age. Chondrosarcoma of the costosternal region occurs rarely in goats, and bone and joint tumors of goats and pigs are extremely rare. Myeloma (plasma cell tumor) involving vertebrae have been seen in adult pot-bellied pigs.

Long-bone tumors and joint tumors result in lameness. Tumors involving the ribs or sternum may be mistaken for healing fractures. Tumors involving the pelvis can compress structures in the pelvic canal and interfere with parturition and defecation and can also cause signs of pelvic limb lameness.

Progressive swelling of affected bones and joints is typical. Radiographic findings of concurrent osteolysis and irregular mineralization can help to confirm the diagnosis of bone neoplasia, but differentiation of osteosarcoma from chondrosarcoma cannot be reliably achieved by radiographic evaluation. Synovial sarcoma results in increased soft tissue density within the joint and often lytic lesions within the adjacent bones. Myeloma (plasma cell tumor) causes lytic lesions within the bone and may involve multiple bones.

Gross examination of bone tumors most often reveals expansion of the medullary cavity by tissue that may be soft, firm, bony, or cartilaginous and expansion and often disruption of the overlying cortex. Myelomas (plasma cell tumors) are soft and fleshy masses causing bone lysis. Histologic evaluation reveals osteoblastic differentiation (osteosarcoma), chondrocytic differentiation (chondrosarcoma), a mixture of these cell types (osteochondrosarcoma), or sheets of pleomorphic round cells with plasmacytoid features (myeloma/plasma cell tumor). Antemortem diagnosis of bone neoplasia often relies on evaluation of bone biopsies. Submission of multiple samples, including tissue from deep in the bone, is recommended because bone tumors are often associated with large areas of reactive bone and of necrosis. Evaluation of cytologic preparations for atypical osteoblasts, chondrocytes, plasma cells, or other neoplastic cell types can also be useful. Synovial tumors are characterized by marked and irregular proliferation of synovial tissue that may mimic synovitis or synovial hyperplasia but that can extend through the joint capsule into adjacent muscle following fascial planes. Histologic features primarily include a spindle cell

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component or an admixed spindle cell and polygonal cell population. Atypical cells indicative of neoplasia are seen in cytologic preparations and in biopsy samples. Immunohistochemistry can be a valuable procedure in the workup of synovial tumors. Histiocytic markers can be particularly useful, as many synovial tumors in animals have been found to be of histiocytic origin.

Extensive local invasion and widespread metastasis of osteosarcoma and chondrosarcoma in farm animal species is often reported, which may reflect the advanced stage of the tumor at the time of diagnosis. Extrapolation from other species, however, would suggest that early detection and wide surgical excision might be curative. In sheep and goats, limb amputation could result in a viable animal and could be considered in cases of bone or joint neoplasia where internal metastases are not apparent. Synovial cell sarcoma in cattle is capable of metastasis to local lymph nodes and to the lungs.

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AUXILIARY TREATMENT OF NEOPLASIA IN FARM ANIMALS

Emily E. Barrell

As described in the preceding chapter, tumors affecting all body systems have been documented in farm animal species. Surgical excision to remove these neoplasms, in some cases, may be curative. However, a large number of neoplastic conditions cannot be managed with surgery alone, and ancillary treatments may be considered. Although farm animals kept as pets or in rescues or sanctuaries are the most likely to be considered as candidates for such adjunctive therapies, indications may also exist in certain cases of genetically valuable production animals. This chapter will review the basic principles of surgical oncology and some of the few available case reports of nonsurgical or adjunctive treatments of neoplasia in the literature. It will also serve to document several unique and innovative cases we have seen in our clinic.

Surgery remains the most common treatment of solid tumors in small animal veterinary medicine and has been performed in many large animal species as well. Whether used as a solitary treatment or in concert with radiation or chemotherapy, it is imperative that the veterinary surgeon have an understanding of the principles of surgical oncology. Before endeavoring to remove a tumor, histologic diagnosis is encouraged. In some cases, this may be achieved with fine needle aspirate or biopsy of the tumor or cytologic examination of fluid from the thorax, abdomen, or pericardium. However, in many cases, either it is not possible to acquire a sample or that sample may be nondiagnostic. It is then necessary to construct a list of the most common tumor types that may occur in that location and proceed with treatment. Advanced imaging of a solid tumor is also recommended before removal. Computed tomography (CT) and/or magnetic resonance imaging can facilitate surgical planning to determine the approach and margins necessary for successful removal. These imaging modalities may be accomplished in smaller species such as goats, sheep, camelids, and small swine but would not be possible in adult cattle or large swine. In those animals, ultrasound examination or radiography may be the only imaging available preoperatively, and even those studies may be unrewarding based on the large size of the animal. Once surgery has been elected, it is important to remember that infiltrative, microscopic cells from the tumor may spread to include surrounding tissues, and for this reason wide margins of 2 to 3 cm are recommended. The fascia underneath the tumor serves as the deep margin because most tumor types, at least in small animals, will extend to but not penetrate the fascia under the tumor. Tumor pseudocapsule, subcutaneous tissue, and fat should not be considered suitable planes and should not be the designated deep layer if complete excision is the goal. To reduce the risk of seeding unaffected areas with tumor cells, gloves and instruments should be changed if multiple sites are addressed in the same surgery, if a skin graft or flap is harvested, or if the tumor pseudocapsule is entered mistakenly during surgery. Penrose drains may promote the spread of tumor cells to distant sites, and thus closed suction drains are advocated instead whenever possible. Once the tumor has been resected, it is the surgeon's responsibility to accurately mark the tissue for submission to a pathologist. Margins should be inked and a key provided in the sample request, with different colors representing various margins (i.e., cranial, caudal, ventral, dorsal, and deep). A thorough history and description of the tumor's appearance in situ are also vital pieces of information for the pathologist to more accurately assess the tumor and the resection. If chemotherapy is to be used in addition to surgery, tissue healing and secondary effects must be considered. Corticosteroids, a mainstay of chemotherapeutic treatment, may delay wound healing, and thus a nonabsorbable or slowly absorbable suture may be recommended if surgery is to be performed in the face of steroids. Studies in rats suggest that doxorubicin may compromise wound healing when administered up to 7 days before or 21 days after surgery. Additionally, one must consider the nadir, the lowest blood cell count (neutrophils and platelets), of a particular chemotherapeutic. Nadir is not

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known for chemotherapeutics in large animals due to their infrequent use and therefore must be extrapolated from dogs and cats, where it ranges from 7 to 21 days postadministration depending on the agent used. Complete blood counts should be utilized before surgery in an animal that has received chemotherapy to ensure adequate immune function and minimize postoperative complications.

Once it has been determined by the surgeon that clean margins with surgical excision cannot be achieved, or that surgery is not possible to begin with, ancillary treatment with radiation can be considered in some cases. Surgical debulking often occurs before radiation because this modality is most effective when neoplastic cells are small in volume, are in active cell division, or have a sufficient supply of oxygen and when adjacent tissue can be protected. A radiation oncologist can then devise the best possible plan forward for the patient, using information gained from histology, previous imaging, and the surgeon. With a variety of radiation types and new technologies, establishing a relationship with a trained oncologist is critical. Although manual treatment plans can be made by calculating the size of the field, depth of the treatment, and characteristics of the radiation unit, radiation planning is best accomplished with CT studies and computer programs. In addition to the size limitations of the imaging equipment, radiation equipment is also limited by the size of the animal, restricting this ancillary treatment to small farm animals such as sheep, goats, camelids, small pigs, and possibly young cattle.

In our clinic, the most notable example of combining radiotherapy with surgery in a farm animal involved a 10-year-old, hermaphrodite, mixed breed goat that was presented for 1 month of weight loss and coughing. Physical examination revealed the goat to be thin with a body condition score of 1.5/5, and a firm, nonmoveable, soft tissue mass measuring 7 cm × 7 cm × 6 cm was palpable in the thoracic inlet. Fine needle aspirate of the mass revealed only blood, and the sample was deemed nondiagnostic. Thoracic radiographs and ultrasonographic examination revealed the presence of abnormal gas-filled areas in the cranioventral lung fields bilaterally, but these modalities could not distinguish between mass and consolidated lung tissue. Transtracheal wash revealed septic suppurative inflammation, and the goat was diagnosed with presumptive bacterial pneumonia. He was discharged on antimicrobial therapy with instructions to monitor the thoracic inlet mass. The goat re-presented 3 weeks later for a recheck examination with no improvement in clinical signs and a mild increase in the size of the external mass. Repeat radiographs showed a now clearly delineated intrathoracic mass in the cranioventral lung fields. Repeat fine needle aspirate and cytology of the extrathoracic mass was of low cellularity, but cells that were present were mostly lymphocytes and were in numbers larger than those of peripheral circulation, making the top differentials lymph node or thymoma. A wedge biopsy was performed and histopathology confirmed the extrathoracic mass to be a thymoma. To better characterize both the intra- and extrathoracic masses, CT both with and without contrast was performed. The intrathoracic mass measured 9 cm × 9 cm × 7 cm and was located cranial to the heart, likely in the mediastinum, and to the left of midline in the location typical for the thymus. The subcutaneous, extrathoracic thymoma at the thoracic inlet was also visible on CT but did not appear to connect to the intrathoracic mass. Finally, consolidation in the cranioventral lung adjacent to the mass was identified and was supportive of pneumonic lung tissue. After discussion with the farm managers from the sanctuary from which the goat originated, options included surgical removal of both masses, surgical removal of the extrathoracic mass only, and radiation in addition to either of these previous options. The farm elected surgical excision of the external thymoma and external radiation of the intrathoracic mass. With supervision by a board-certified radiation oncologist, a total of six treatments of external beam radiation therapy using 6-MV photons in parallel opposed fields with 4 Gy/fraction was planned, for a total of 24 Gy. The goat was anesthetized and positioned in dorsal recumbency. A ventral, midline incision was made centered over the mass. The mass was bluntly dissected, and the right jugular vein was identified and delicately dissected away from the mass. Once the mass was excised, the incision was closed in layers, with tacking of layers utilized to minimize dead space. The goat was then positioned for CT planning and received radiation. The goat recovered well from anesthesia and subsequently underwent five more sessions of general anesthesia and external beam radiation therapy. Following the sixth session, CT was performed to assess the size of the intrathoracic mass, and because it appeared to have slightly decreased in size an additional two sessions were performed, for a total of eight treatments over the course of 24 days. At the time of this writing, 16 months had passed since surgical excision of the thoracic inlet mass and radiation of the internal mass. Serial recheck examinations with radiography revealed persistence of the intrathoracic mass with minimal change in shape or size, as well as continued atelectasis of adjacent lung tissue. However, the goat had gained a significant amount of weight and was active and reportedly doing well at home.

Little is known about the use of antineoplastic drugs in farm animal species, and only a few case reports exist in the literature. This is largely due to the cost-prohibitive nature of chemotherapeutic agents, as well as the restrictions that mandate that these animals never enter the food chain following use of these compounds. However, as more farm animals become pets or find their ways to sanctuaries and rescues, and as the genetic value of production animals increases, the use of chemotherapy may become more frequent. L-asparaginase is perhaps the first antineoplastic drug to have its use documented in livestock. A collection of 73 animals treated with L-asparaginase were described by Hardy and Old in 1970, including three cows diagnosed with lymphosarcoma (LSA). The cattle were treated at the University of Pennsylvania with doses of 100 to 400 IU/kg daily for 7 days. Of those, one cow responded favorably with a decrease in lymph node size, improved appetite, and increased milk yield, whereas the other two cows failed to respond clinically. None of the cows appeared to suffer any adverse effects secondary to the chemotherapeutic. L-asparaginase is an enzyme, produced by microorganisms such as *Escherichia coli*, which hydrolyzes asparagine to aspartic acid. Leukemic cells, unlike normal cells, are unable to produce their own asparagine, an amino acid essential for cell life, and therefore must scavenge circulating asparagine. However, in the presence of L-asparaginase, that circulating asparagine is broken down and the tumor cells deprived of this important amino acid, resulting in cell death. Although the large volume needed to treat a farm animal results in exorbitant price, L-asparaginase carries the benefit of being able to be administered intravenously, subcutaneously, or intramuscularly without the risk of tissue inflammation, alleviating the need for catheterization, which must be performed with other chemotherapeutics. In small animals, it has been shown to provide temporary relief from clinical signs during a crisis or may reinduce remission in some cases of small animal lymphoma. Although generally considered a rescue drug and not typically used as a stand-alone chemotherapeutic, L-asparaginase may alleviate clinical signs and prepare for another chemotherapy protocol, extend the life of a genetically valuable animal, or improve the quality of life in an animal with end-stage neoplasia. The only other

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case report in the literature documenting the use of L-asparaginase in a farm animal describes a 5-months pregnant, 4-year-old Holstein with presenting clinical signs of exophthalmos, hind limb weakness that progressed to ataxia and recumbency, anorexia, and lymphadenopathy. A diagnosis of LSA affecting the spinal cord, peripheral lymph nodes, and retrobulbar space was made, and due to her high genetic value treatment of the cow was undertaken in an effort to prolong her life until parturition. Extrapolating from the standard dose in dogs of 10,000 IU/m^2, the cow received 60,000 IU L-asparaginase intravenously. Clinical signs improved initially, although they recurred within 11 days of the first treatment. She was subsequently administered a total of four doses of L-asparaginase. Due to the short duration in improvement in clinical signs, the pregnancy was terminated on day 20 so that a superovulation protocol could be initiated. The cow came into estrus and was bred on day 50 and was euthanized on day 57. The reproductive tract was collected and the uterus flushed, but no embryos were recovered. Although the end goal was not achieved in this case, the cow's life was prolonged for a total of 57 days, which would be sufficient time to complete superovulation protocols and/or harvest semen. In addition to L-asparaginase, McGuirk describes the use of Adriamycin, *Nocardia rubra* cell wall skeleton, suramin, cyclophosphamide, chlorambucil, alkylating agents, corticosteroids, and vincristine to treat cardiac LSA in cattle, although remission has never been documented in any case. Descriptions of using doxorubicin in weaned pigs to simulate chemotherapy-induced mucositis, a complication seen in humans following treatment, are available but represent only a research model and not the use of the agent to treat clinical disease. To the author's knowledge, these represent the only documented cases of use of a chemotherapeutic to treat systemic neoplasia in a livestock species.

In addition to the financial constraints that limit the use of chemotherapy in farm animals, one of the biggest challenges livestock clinicians face is how to safely administer these agents. The majority of chemotherapeutics used today in human and small animal oncology carry significant risk both to the patient and to the professional administering that drug. Extravasation of these agents can result in profound perivascular inflammation, tissue damage, and necrosis. Risk of exposure of health care personnel to these agents must be minimized in human medicine and is no less important in cases of veterinary use of antineoplastic agents. In our hospital, we recently treated a case of LSA with an innovative approach to these concerns. A 4-year-old, 330-kg, male Hampshire hog kept as a pet in a sanctuary was presented for acute-onset lethargy and inappetence. Thoracic radiographs and abdominal ultrasound were performed under general anesthesia and revealed a suspect mass effect in the thorax and a small amount of peritoneal effusion, respectively. Abdominocentesis and cytologic examination revealed large numbers of large neoplastic lymphocytes, and the pig was diagnosed with lymphoma, although the site of the primary tumor could not be definitively identified. The animal was given a grave prognosis for survival without treatment, and the owner elected to pursue chemotherapy. Initial rescue treatment with L-asparaginase and lomustine provided relief from clinical signs of the lymphoma and allowed for the planning of future chemotherapy.

After much discussion, it was determined that the best chance of safely administering a course of chemotherapy in this case would be to use a vascular access port (VAP) to secure venous access. Vascular access ports, used frequently in human and small animal medicine and in animal research models, are central venous access devices that are surgically implanted under the skin without any portion of the device exiting the skin. The port consists of an injection port with a self-sealing silicone septum covering a metal or plastic reservoir (the body) (Figure 8-35). A catheter connects the port to a central vein so that the port can be used to draw blood, deliver fluids, or administer medications such as chemotherapy. Specialized Huber needles (Figure 8-36) are used to access the port to prevent damage to the septum and coring because repeated coring could result in leakage of caustic chemotherapeutics into surrounding tissues. In this case the VAP would be positioned in an easily accessible location behind the left ear, allowing for the intravenous administration of multiple different chemotherapeutics.

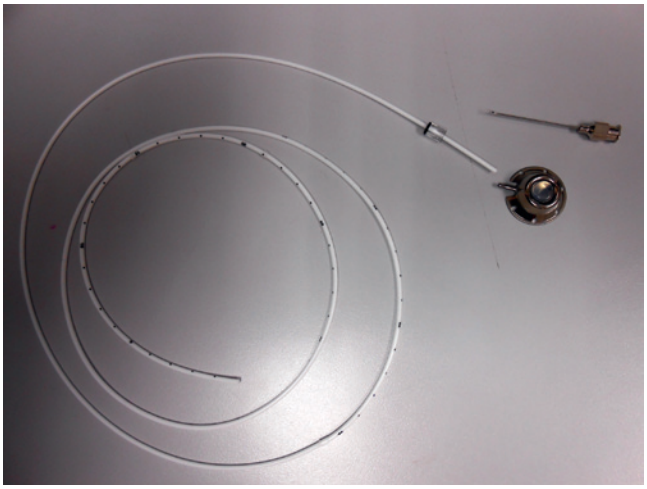


Figure 8-35 Photograph showing all components of the vascular access port (VAP) device. The metal port has a silicone septum covering the body. A catheter connects the body of the VAP to the central vein of choice, and the length of the catheter tubing can be custom ordered to meet the needs of a particular patient. There is a clear adaptor that helps to secure the catheter onto the extension from the port. Specialized Huber needles must be used to access the port (see Figure 8-36).

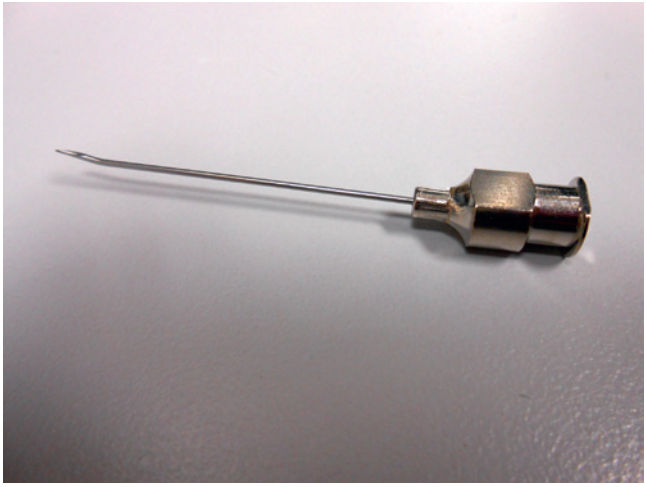


Figure 8-36 Photograph showing the Huber needle used to access the vascular access port. The needle has an angled tip that is designed to penetrate the port without cutting and dislodging any silicone cores or slivers from the port into which it is inserted.

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With the pig under general anesthesia and in dorsal recumbency, an 8-cm skin incision was made over the right jugular furrow using a No. 22 blade. The subcutaneous tissues and fat were bluntly dissected until the external jugular vein was exposed. Two ¼-inch Penrose drains were used to elevate the jugular vein, and a 4-mm-diameter purse-string suture was placed within the wall of the vessel. A small stab incision was made into the jugular vein within the lumen of the purse string, and the tip of the VAP catheter was inserted and threaded approximately 15 cm into the vessel. The purse-string suture was then tightened to fix the catheter within the vessel. Using a long guiding pin with a sharp end, the free end of the catheter was tunneled under the skin and through the subcutaneous fat approximately 10 cm toward the base of the ear, emerging through the skin dorsolateral to the jugular incision. A subcutaneous pocket was made for the catheter line, which was then closed in a simple continuous pattern. The jugular furrow incision was closed in three layers in a simple continuous pattern; the three layers were the deep and superficial subcutaneous tissues and the skin. The patient was then repositioned and placed in left-lateral recumbency. The lateral aspect of the right neck was clipped and prepped, and a 12-cm curvilinear incision was made 5 cm caudal to the right ear. The subcutaneous pocket containing the catheter line was opened, and the guiding pin was used to tunnel the catheter line from the pocket to the incision. The VAP was connected to the catheter line and flushed with heparinized saline and then locked with heparin solution (10 mL, 1000 units/mL). The subcutaneous adipose tissue was dissected away to make a hollow for the VAP. The port was secured and suspended from the dermis using suture, and several additional tension-relieving sutures were placed, putting a loop in the catheter and holding it in place. The subcutaneous tissues and skin were closed using a simple continuous pattern and covered with a dressing, and the pig recovered uneventfully from anesthesia.

Following implantation of the VAP and under the guidance of a board-certified internal medicine diplomate specializing in oncology, the pig began a course of chemotherapy. He received a total of four rounds of traditional CHOP chemotherapy consisting of alternating injections of cyclophosphamide, doxorubicin, and vincristine, and oral prednisolone. With the exception of mild lethargy seen several days following each administration of doxorubicin, the hog experienced few clinical signs secondary to the chemotherapeutics. Five months after admission, the pig relapsed and experienced clinical signs similar to those present on presentation: fever, lethargy, and inappetence. Ultrasound confirmed thoracic effusion, and he was thus treated with a second dose of L-asparaginase and lomustine. Signs resolved, and he was then started on single-agent therapy with doxorubicin, administered via VAP every 2 to 3 weeks for a total of seven treatments. Again, the hog experienced minimal side effects from treatment. He relapsed again 11.5 months after admission. Thoracocentesis was performed and 5 L of serosanguinous, proteinaceous exudate was removed from the thorax. The pig received a single dose of mustargen and was then transitioned to single-agent chemotherapy with vinblastine, administered via VAP every 1 to 4 weeks for a total of nine treatments. He continued to do well clinically, until he relapsed a final time 14 months following admission and succumbed to his disease. With the exception of several days during relapse, he had maintained a normal appetite, attitude, and energy level for the duration of his hospitalization and suffered few adverse effects from the chemotherapy agents. At necropsy, B-cell lymphoma was confirmed with the primary tumor site attributed to mediastinal lymph node. Although a unique situation and a serious financial undertaking, this case represents the long-term management of a case of lymphoma in a farm animal with successful obliteration of clinical signs and extension of life for an additional 14 months.

Lymphosarcoma, as described in this hog, is also the most common form of bovine neoplasia, and tumor sites frequently include the heart (particularly the right atrium), abomasum, uterus, kidney, spinal cord (primarily epidural), retrobulbar space, and forestomach. In cattle with emotional value, treatment may be pursued by an owner or caretaker in an effort to alleviate suffering and prolong life, although to the author's knowledge no report of treatment of LSA in a farm animal resulting in remission of disease exists in the literature. In genetically valuable animals, treatment of LSA may be pursued to prolong the life of a late-pregnant cow, recover oocytes or embryos, or collect semen. However, when the goal of treatment is to have a pregnant cow diagnosed with LSA survive to parturition to preserve the life of the calf, it must be remembered that LSA is associated with bovine leukemia virus (BLV) infection. Because in utero transmission has occurred, fetuses born to BLV-positive dams may be BLV-positive as well. Steroids such as dexamethasone and prednisone serve as the benchmarks of treatment for lymphoma in most species and have been used in cattle diagnosed with LSA as well. However, administration of corticosteroids to cattle undergoing superovulation protocols has both pros and cons. Although steroids can improve the overall health and comfort of the cow and prolong life, these medications also can decrease the quality of the recovered oocytes. If superovulation and oocyte recovery is the goal, this fact must be weighed against the animal's perceived quality of life and benefit of corticosteroid therapy.

Additionally, steroids carry the risk of abortion in pregnant animals. Isoflupredone acetate (Predef 2X) is a glucocorticoid that may be considered as an alternative to traditional corticosteroids. Isoflupredone is the only corticosteroid approved by the U.S. Food and Drug Administration for use exclusively in large animals, including lactating cattle. It carries no milk withhold but does require a 7-day preslaughter withdrawal. As stated on the label, this product will not induce parturition. In 1994 Mohammedsadegh documented that when 48 out of a total of 650 Holstein-type cows in varying stages of pregnancy were treated with 30 to 40 mg of isoflupredone intramuscularly once daily for 3 days, none aborted or had grossly visible birth defects such as cleft palate or harelip. This was postulated to be due to the difference in the chemical structure of isoflupredone; traditional corticosteroids such as dexamethasone, betamethasone, and flumethasone are methylated at the C_{16} position and can induce parturition, whereas isoflupredone lacks this alteration at the C_{16} location. Isoflupredone has been used only once within our clinic in the recent past. In that case, a 3-year-old, second-lactation Holstein cow 7 months pregnant with a valuable embryo transfer calf was presented for decreased appetite and manure of 3 days' duration. Additionally, the cow had recently been dried off when she was noted to be losing weight. On presentation, she was tachycardic, tachypneic, and febrile. Bloodwork revealed anemia, hypoproteinemia, and hyperlactatemia but no lymphocytosis. The cow was, however, positive for BLV on enzyme-linked immunosorbent assay (ELISA). Ultrasonographic examination of the thorax and abdomen revealed marked pleural and peritoneal effusion, and analysis of the fluids in each cavity confirmed a diagnosis of lymphoma. The owner declined hospitalization of the cow and instead elected medical management on the farm in an effort to prolong the cow's life so that full-term pregnancy could be achieved. A chest drain was inserted and sutured in place to relieve pleural effusion,

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and she was discharged with instructions to commence treatment with isoflupredone (20 mg intramuscularly every 24 hours) in addition to antimicrobials, as well as flunixin meglumine for pain and inflammation as needed. Although the cow initially appeared bright and alert with a good appetite following initiation of treatments at the farm, the calf was aborted 5 days after discharge from the hospital and the cow was subsequently euthanized. Although it is possible that the isoflupredone contributed to the abortion of the calf in this case, it is also highly possible that the pregnancy was lost due to the stress and systemic effects of the cow's primary disease.

In some cases, noncurative surgical intervention is the best palliative option available in a case of neoplasia. Buczinski et al documented the case of a 4.5-year-old Holstein cow, 11 days fresh, who was presented for anorexia, decreased milk production, muffled heart sounds, and signs of right-sided heart failure. She was seropositive for BLV, and echocardiography revealed pericardial effusion and thickening of the right atrioventricular junction. Pericardiocentesis resulted in significant reduction in clinical signs and increased milk production, until the cow regressed on day 27. A second pericardiocentesis was performed, and the cow improved until day 34, when her milk production decreased once again and she was euthanized by the producer. In this case palliative care had improved her quality of life and allowed for over a month of additional milking, improving economic gain for the farmer.

In another report, a 5-year-old Holstein cow 7 months pregnant with a valuable embryo transfer calf presented for signs of right-sided congestive heart failure. Echocardiogram revealed extensive pericardial effusion with cardiac tamponade and thickening of the epicardium at the atrioventricular junction of both ventricles, consistent with neoplasia. Pericardiocentesis confirmed the effusion to be neoplastic, and the cow was diagnosed with presumptive LSA of the pericardium. She was seropositive for BLV on ELISA, and due to the high genetic value of the calf she carried, palliative treatment was elected in an attempt to recover the calf at 8 months of gestation. When the pericardial effusion returned 5 days after initial centesis, pericardiotomy to allow drainage into the pleural cavity was performed. With the cow restrained in the standing position, a laparoscopic approach to the thorax was made and the mediastinum was opened. The pericardium was identified and blocked with lidocaine to prevent arrhythmia. The dorsolateral pericardium was then incised in a T shape, allowing pericardial effusion to egress into the thoracic cavity, reducing pressure on the right side of the heart and promoting forward flow of blood. The incisions were closed and pneumothorax corrected, and the cow recovered from the procedure uneventfully. All clinical signs resolved over the next 5 days, and she was discharged to the care of her owners. The cow did well over the next month, but unfortunately aborted the calf 3 weeks after being discharged from the hospital. Despite the loss of the fetus, this case report described a minimally invasive procedure that could effectively improve clinical signs and prolong the life of a valuable animal and/or the offspring they carry.

Recently in our clinic, a 12-year-old Holstein cow was presented for gradually decreasing milk production, recurrent bloat, and inappetence. On examination, the cow was bloated and had an irregularly irregular heart rhythm. Bloodwork revealed hyperproteinemia but no lymphocytosis. The cow was positive for BLV on ELISA. Ultrasound of the abdomen revealed anechoic peritoneal effusion, and examination of the fluid confirmed a diagnosis of lymphoma. Rectal palpation revealed thickening of the right uterine horn, and invasion of the uterus with lymphoma was presumed. Based on the cow's perceived genetic value, she was deemed a satisfactory candidate for transvaginal oocyte recovery. To alleviate her recurrent bloat, a temporary rumen fistula was placed (see Section 14.5), and the cow was discharged the following day. She remained comfortable without bloat at home for several weeks before a superovulation and oocyte recovery protocol was implemented, resulting in the successful recovery and implantation of several embryos in recipient cows.

Although these case examples represent only a handful of experiences with ancillary treatments of neoplasia, they highlight the fact that the way we approach cancer in farm animal species may be changing. By partnering with oncologists with experience in other species, it may be possible to offer more options to clients wishing to prolong life, make an animal more comfortable, or salvage genetic value.

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CHAPTER 9

Dentistry

Allison Dotzel and Jennifer Rawlinson

Historically, the focus of evaluation and care of livestock oral cavities has been mostly limited to accurate aging, caloric conversion, and environmental management concerns. The vast majority of animals in production environments did not live long enough to develop oral and dental conditions common in older animals. With the increased interest in boutique farms, animal sanctuaries, and livestock as family pets, many animals are living longer with owners willing to devote increased time and money to maintaining the systemic health of an individual animal. As a result, pathologic conditions more frequently seen in older animals of other species are being identified and treated in farm animals.

Many common cross-species dental diseases have the potential to affect the oral cavity of farm animals. Although there is little published material on naturally occurring dental pathology and therapeutics in pigs and ruminants, it has long been recognized that pigs are an ideal animal for human dental research because of the similarities in dentition, diet, and pathology development, resulting in a mountain of literature on specific research topics. Ruminants have been used similarly for studies evaluating dental hard tissues and bone. Unfortunately, progress in livestock cross-species, translational dentistry has been slow because of low interest and limited funds, but this is changing with the growth in pet farm animals. Dental pathology can interfere with an animal's ability to prehend and masticate feed, which can significantly contribute to malnutrition, weight loss, decreased quality of life, and loss of production. This chapter will review the oral anatomy of cattle, small ruminants, and pigs, and it will discuss past commonly identified oral conditions as well as applicable cross-species dental topics.

ANATOMIC CONSIDERATIONS

Before discussing the dentition of domestic farm animal species, it is helpful to review dental classification terminology to fully understand dental structure and possible cross-species applications. There are two basic animal groups among the heterodonts, or animals with multiple types of teeth: elodont and anelodont. *Elodont* refers to animals with continuously developing teeth and *anelodont* refers to animals with teeth that develop for a finite period of time although fully developed teeth may continue to erupt for many years. For the most part, farm animals are classified as anelodonts with the exception of the pig because of its continuously developing tusks. Pigs are classified as anterior elodonts. This is significant because it dramatically affects pig tusk maintenance and therapeutic options.

In general, there are two types of teeth, brachydont and hyposodont. Brachydont teeth have relatively short crowns and long roots, whereas hypsodont teeth have long crowns and comparatively short roots. Brachydont teeth are found in carnivores and some omnivores such as the pig. In fact, with the exception of the tusk or canine teeth in pigs, the remainder of porcine teeth are brachydont. A newly erupted adult brachydont tooth will not erupt past the crown-root junction of the tooth. Therefore brachydont teeth remain static within the oral cavity. Grazers typically have hyposodont teeth with long reserve crowns that erupt during a prolonged period of the animal's life. Hypsodont teeth are divided into two subcategories based on root formation, radicular and aradicular. Radicular hypsodont teeth, found in cattle and small ruminants, have well-formed roots that mature completely. These teeth can erupt for a prolonged period, but the root apices eventually close and tooth development ceases. Aradicular hypsodont teeth do not have true roots. The root apices never close, and the crown continues to develop throughout the animal's life. Continual development occurs via dental progenitor cells at the tooth apex, adding complexity to considerations for treatment of endodontically infected or broken teeth needing extraction or endodontic therapy.

CATTLE AND SMALL RUMINANTS

Cattle and small ruminant incisors, premolars, and molars are radicular hypsodont teeth that have a prolonged eruption period over the majority of the life of the animal (Figure 9-1). The premolars and molars have complex infoldings of cementum, enamel, and dentin. Given the different wear rates of these calcified tissues, the occlusal surface is characterized by irregular ridges that aid in mastication of coarse and fibrous feeds. As ruminant cheek teeth wear to their more apical aspects, the complex infolding of cementum, dentin, and enamel on the occlusal surface becomes less pronounced. The cheek teeth cease to erupt when they experience attrition to the point of exposing the junction between the reserve crown and the root. At this point, the cheek teeth of geriatric ruminants become smooth as a result of a lack of the irregular enamel ridges (Figure 9-2). This makes mastication of coarse and fibrous feedstuffs difficult and may contribute to malnutrition and weight loss.

Cattle and small ruminants lack upper incisors and canines. Instead, the rostral maxilla consists of a pair of heavily cornified dental pads. Cattle differ from small ruminants in the way they prehend their food. They rely heavily on the tongue to draw food into the oral cavity. In contrast, small ruminants have very mobile lips that aid in prehension and allow them to crop pasture more closely to the ground than cattle. The incisor and canine teeth of all ruminants have loose implantation and can be moved a couple of millimeters with gentle pressure. This mobility reduces the potential for trauma to the dental pad during prehension.

The deciduous dental formula for the domestic ruminant species is 2(Di 0/3, Dc 0/1, Dp 3/3), and the permanent dental formula is 2(I 0/3, C 0/1, P 3/3, M 3/3), where Di is deciduous incisor, Dc is deciduous canine, Dp is deciduous premolar, I is incisor, P is premolar, and M is molar. Estimation of age in these species is based on eruption dates and wear of the incisors and canines (Table 9-1 and Table 9-2). However, estimation of age can be relatively unreliable

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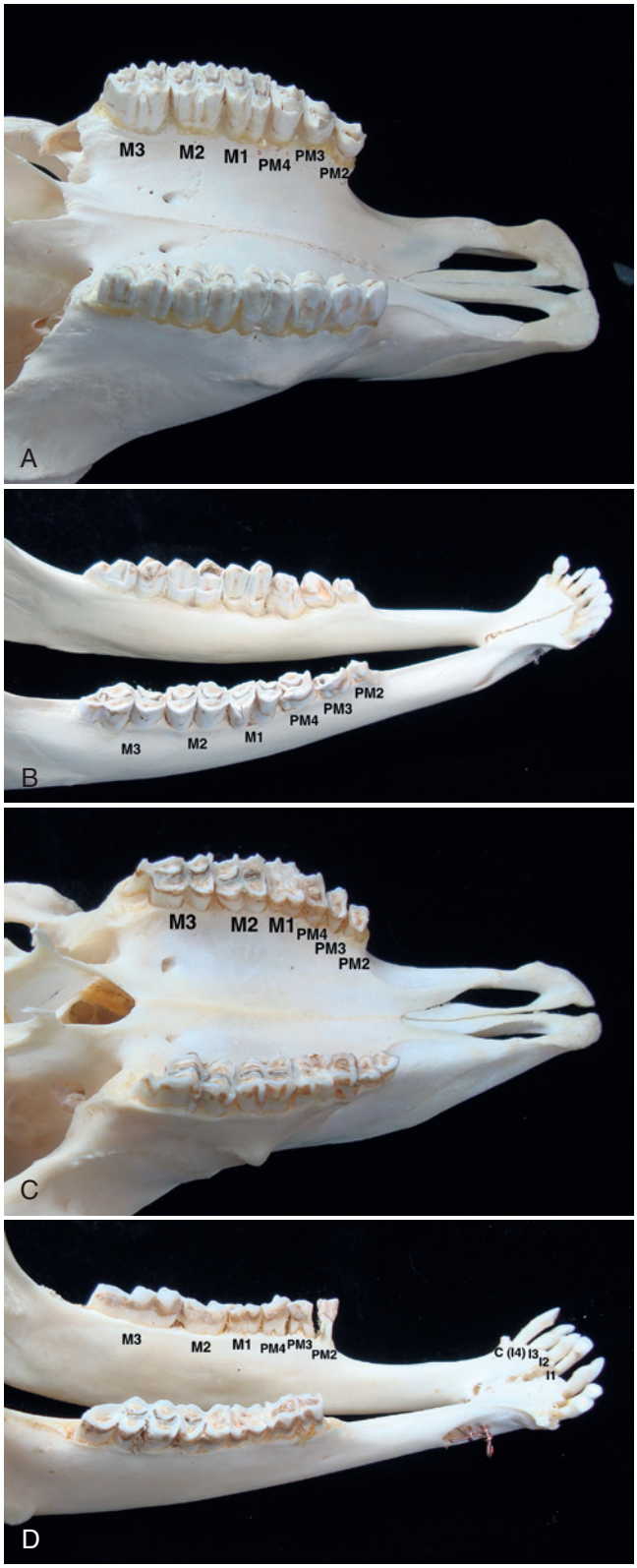


Figure 9-1 Dentition of the maxilla and mandible in a cow (*A*, *B*) and a goat (*C*, *D*).

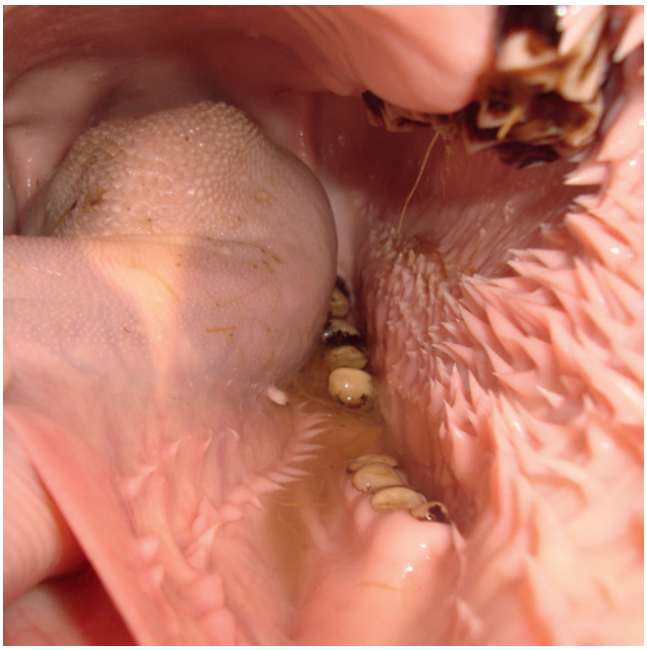


Figure 9-2 Aged teeth in an 18-year-old cow. The occlusal surfaces of the teeth are smooth and worn down to the roots.

Table • 9-1

Eruption Dates in Cattle

	DECIDUOUS	PERMANENT
Incisor 1	Birth to 2 weeks	18-24 months
Incisor 2	Birth to 2 weeks	24-30 months
Incisor 3	Birth to 2 weeks	36-42 months
Canine	Birth to 2 weeks	42-48 months
Premolar 2	Birth to 1 week	24-30 months
Premolar 3	Birth to 1 week	18-30 months
Premolar 4	Birth to 1 week	20-36 months
Molar 1		6 months
Molar 2		12-18 months
Molar 3		24-30 months

Table • 9-2

Eruption Dates in Sheep and Goats

	DECIDUOUS	PERMANENT
Incisor 1	Before birth to 1 week	12-18 months
Incisor 2	Before birth to 1 week	18-24 months
Incisor 3	Before birth to 1 week	30-36 months
Canine	Birth to 1 week	36-48 months
Premolar 2	Birth to 4 weeks	18-24 months
Premolar 3	Birth to 4 weeks	18-24 months
Premolar 4	Birth to 4 weeks	18-24 months
Molar 1		3 months
Molar 2		9 months
Molar 4		18 months

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because eruption dates vary by breed and individual animal and rate of incisor and canine wear varies based on the abrasiveness of the diet and pasture soil composition.

The canine teeth (or in some references the fourth incisor) in both cattle and small ruminants are closely situated to the mandibular incisors and the first premolar fails to develop in these species. The incisor and canine teeth have a wide, paddle-like crown and a narrow peg-like root. The canine tooth looks the same as the incisors, which is why it is sometimes considered a fourth incisor and not a canine tooth. The cheek teeth are separated from the incisors and canines by a large diastema, or gap. The six cheek teeth (premolar 2, 3, 4, and molar 1, 2, 3) in each quadrant of the ruminant jaw are arranged into a tightly apposed arcade. The maxillary premolars and molars have three roots being located mesiobuccal, distobuccal, and palatal; the mandibular premolars and molars have two roots, located mesial and distal, with the third molar having a distal widening of the root nearly doubling its width. The cheek teeth increase in size from mesial to distal, and the table angles on the occlusal surface are transverse, with the buccal aspect being taller on the maxillary arcades and the lingual aspect being taller on the mandibular arcades. Ruminants have an anisognathic skull, with the maxilla being wider than the mandible.

PIGS

Pigs have primarily brachydont dentition, with the exception of the canine teeth or tusks of boars that are aradicular hypsodont teeth. Boar tusks maintain an open root apex and will continue to grow throughout the animal's lifetime. As the tooth ages and elongates, the dental progenitor cells and the apex of the tooth migrate caudal, with the apical region of the tooth being located ventral to the molar teeth on the mandible and dorsal to the premolar teeth on the maxilla. In adult male pigs, the tusk comprises a large portion of the mandibular horizontal ramus in a curved manner, with the rostral and caudal aspect of the reserve crown placed laterally and the midportion lingual. As a result, extraction of this tooth is challenging and risks the anatomic integrity of the mandible. The canine teeth of sows maintain an open root apex for approximately 2 years, at which point the apex closes and the tooth ceases to erupt.

The deciduous dental formula for domestic pigs is 2(Di 3/3, Dc 1/1, Dp 3/3), and the permanent dental formula is 2(I 3/3, C 1/1, P 4/4, M 3/3). Pigs are born with the deciduous third incisors and the deciduous canines erupted. These teeth are known as the needle teeth and have traditionally been clipped to reduce the potential for injuries to littermates or to the teats of the sow. However, clipping these teeth has the potential to cause pulpitis and apical infection of the deciduous third incisors and canines, potentially resulting in regional infections and abnormalities of adult teeth. The eruption dates of deciduous and permanent porcine dentition are given in Table 9-3.

The incisors of domestic pigs are rod-like and project rostrally for use in rooting behavior. The crowns of the cheek teeth increase in size from mesial to caudal (Figure 9-3). The second, third, and fourth premolar teeth have linear cusps that aid in tearing food material. The molars have four to six broad cusps that are used for crushing and grinding. The premolar teeth have two roots situated mesial and distal; molars one and two have four roots, located mesiobuccal, mesiolingual, distobuccal, and distolingual. Molar three has five to six roots (five in miniature pigs and up to six in domestic pigs) with reported locations mesiobuccal, mesiolingual, distobuccal, distolingual, and distal. The roots of the cheek teeth in pigs are long, slender, and often curved. A recent study utilizing micro-computed tomography and three-dimensional reconstruction nicely illustrates the crown and root structure in the miniature pig and clearly demonstrates the slow eruption and mesial migration of the third molar tooth.

Table • 9-3

Eruption Dates in Pigs

	DECIDUOUS	PERMANENT
Incisor 1	1-3 weeks	11-18 months
Incisor 2	8-12 weeks	14-18 months
Incisor 3	Before birth	8-12 months
Canine	Before birth	8-12 months
Premolar 1		4-8 months
Premolar 2	6-12 weeks	12-16 months
Premolar 3	1-3 weeks	12-16 months
Premolar 4	2-5 weeks	12-16 months
Molar 1		4-8 months
Molar 2		7-13 months
Molar 3		17-22 months

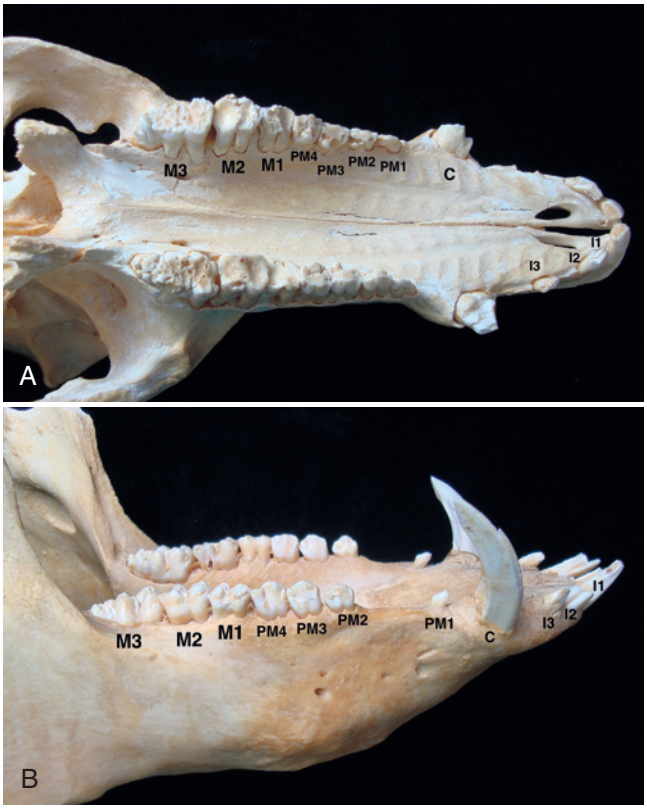


Figure 9-3 Skull depicting the dentition of a porcine maxilla (*A*) and mandible (*B*).

COMMON PATHOLOGY

Malocclusions

The rate of the eruption of ruminant cheek teeth roughly approximates attrition of these teeth due to physiologic

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wear. Any malocclusion of the jaw or of individual teeth may predispose the animal to uneven wear of the teeth. In maxillary brachygnathism (a class 3 malocclusion), the maxilla is relatively shorter than the mandible and in mandibular brachygnathism (a class 2 malocclusion), the mandible is relatively shorter than the maxilla. These conditions may be genetic or acquired as a result of injury or an illness occurring during maxillofacial growth. Animals with these malocclusions may exhibit uneven wear of teeth because of the discrepancy in length between the mandible and maxilla. Maxillary brachygnathism may predispose ruminants toward overgrowth of the mandibular second premolars and/or the maxillary third molars. Mandibular brachygnathism may predispose ruminants toward overgrowth of the maxillary second premolars and/or the mandibular third molars. Overlong second premolars usually do not cause a clinically significant problem in ruminants because of the relatively short reserve crown, but decreased attrition resulting in overlong maxillary or mandibular third molars can be clinically significant because this tooth's reserve crown is quite long and can create formidable hooks. Animals with more severe malocclusions tend to graze poorly on short pastures because of difficultly cutting grass with the incisors. Congenital brachygnathism is an inheritable condition; therefore, careful consideration should be given to breeding of these animals.

Cattle and small ruminants can also develop malocclusions as a result of pathology or loss of individual or groups of teeth. If a tooth is missing or damaged from fracture or decay or overworn from abrasive feeds or sandy soils, the opposing tooth will become overlong as a result of lack of contact and normal physiologic attrition (Figure 9-4). These dental overgrowths can result in marked waves and steps along the occlusal surface and have the potential to cause pain and impair normal mastication, particularly when soft tissue and bone become abraded and infected. Periodontal disease and increased mobility of overlong teeth is commonly seen especially in older patients with advanced waves and hooks. Consequently, extraction of these overlong, mobile teeth is typically straightforward.

Periodontal Disease

Periodontal disease refers to inflammation and infection of the structures that hold a tooth within the alveolar socket (the periodontal ligament, gingiva, alveolar bone, and cementum). Periodontal disease is initiated by an environmental change (e.g., malocclusion, fracture, asymmetric wear, etc.) in the region of a tooth, allowing for an overpopulation of detrimental oral microbes, particularly anaerobic bacteria. As these bacterial populations increase within and around the gingiva, resulting regional inflammatory responses along with bacterial byproducts and endotoxins start to break

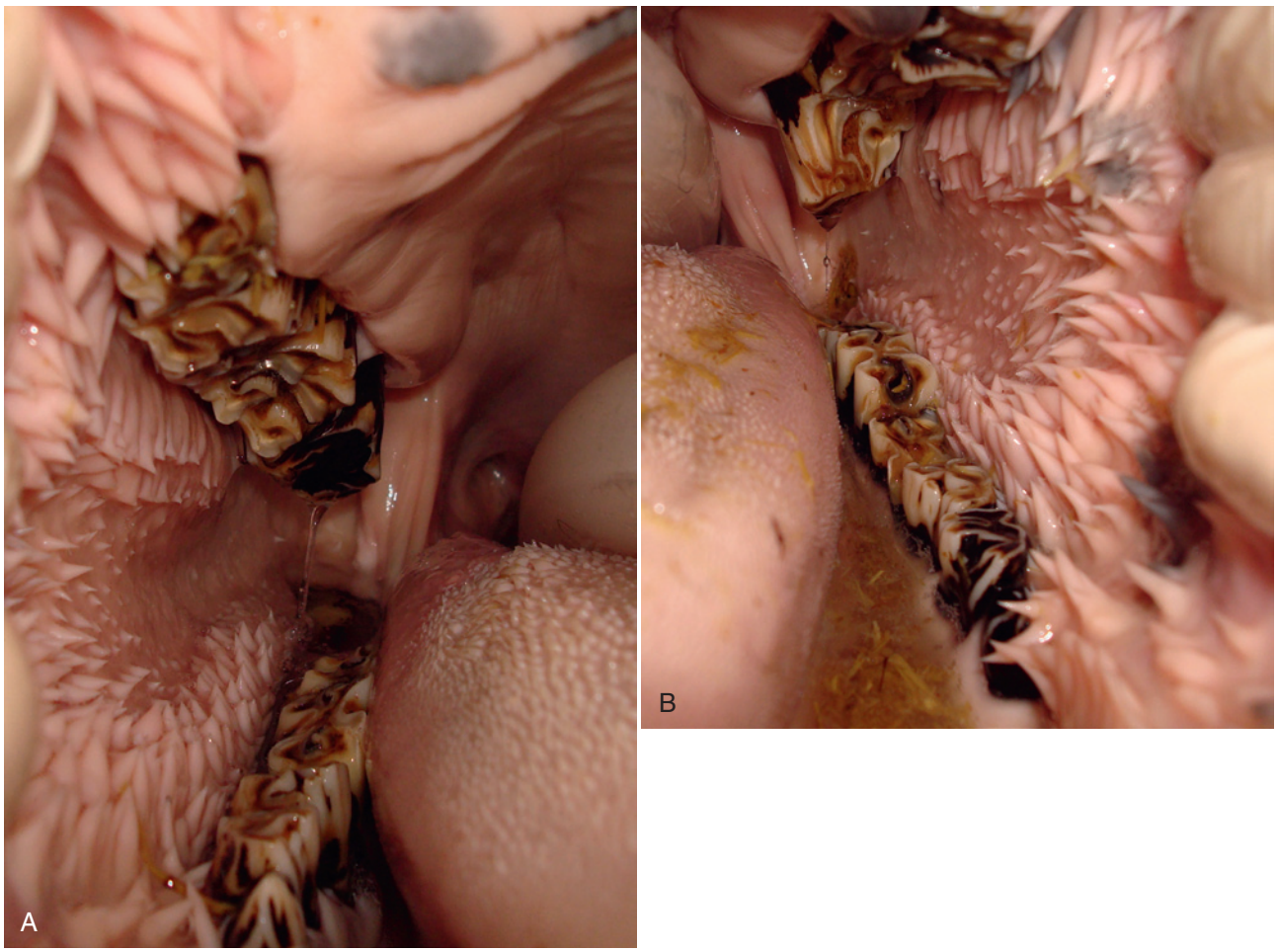


Figure 9-4 Dental malocclusion in an aged cow. Both right (*A*) and left (*B*) maxillary arcades have overlong molar teeth referred to as *step malocclusion*. The right maxillary last molar tooth is overlong due to loss of the third molar on the mandible. The left maxillary first molar tooth is overlong due to excessive attrition of the mandibular first molar tooth.

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down periodontal anatomy, resulting in loss of hard and soft tissue structures and the formation of periodontal pockets. Feed becomes entrapped within the periodontal defects, perpetuating and, in some cases, accelerating the progression of disease. The severity of periodontal disease is based on the loss of periodontal structure relative to the remaining dental structures within the alveolus. In general, 25% to 50% periodontal attachment loss leads to mild to moderate tooth mobility. Treatment or extraction decisions are based on oral examination and radiographs. Greater than 50% periodontal attachment loss usually results in significant tooth mobility, and extraction is recommended.

Cattle and Small Ruminants

Periodontal disease has the potential to cause pain, oral infection, dysmastication, and eventual tooth loss in ruminants. Formation of calculus on hypsodont teeth is uncommon. Periodontal disease of the cheek teeth of cattle and small ruminants most commonly begins with stasis of feed material either on the surface of the tooth secondary to fracture, decay, malocclusion, or malformation or in a gap in the interproximal space between teeth referred to as a *diastema* (*diastemata* for pleural). In the normal ruminant, the six cheek teeth in each arcade are tightly apposed and act as a single functional unit. When gapping occurs in the interproximal space, food becomes entrapped and initiates periodontitis resulting in periodontal pocketing and increased feed entrapment (Figure 9-5). Interproximal gapping or diastema formation may be congenital due to dental malformation/maleruption or developmental due to senile changes or abnormal forces from overlong, maloccluded teeth. Sharp enamel points can also initiate food stasis and abnormal orthodontic forces predisposing cattle and small ruminants to periodontitis. As periodontitis of premolars and molars progress, it can be associated with alveolar bone lysis, apical infection, and fistula formation. Secondary sinus disease, although possible, is less common due to the ruminants' shorter reserve crowns, particularly when compared with those of horses (Figure 9-6).

The majority of ruminants have some degree of chronic gingivitis in the region of their incisors. In some animals, this gingivitis progresses to periodontitis (Figure 9-7). The loose attachment of ruminant incisors as well as the shallow depth of the incisor alveoli predisposes these species to the development of deep periodontal pockets. Feed material becomes packed into the periodontal pockets and results in gingival attachment loss, alveolar bone resorption, and eventual incisor exfoliation.

Pigs

Periodontal disease is extremely prevalent in domestic pig species. Gingivitis is generally present at less than a year of age and it is very common to find severe periodontal disease in animals older than 16 months. The disease seen in pigs closely resembles that seen in humans, and as a result, they are a good model for human periodontal research. Porcine teeth readily accumulate plaque that can mineralize to form dental calculus. Irritation from plaque and calculus and the impact of feed material around the teeth lead to gingival inflammation and periodontitis (Figure 9-8). As the condition progresses, alveolar bone is lost, resulting in the formation of deep periodontal pockets (Figures 9-9 through 9-11). Tooth abscessation and loss are common sequelae. Although

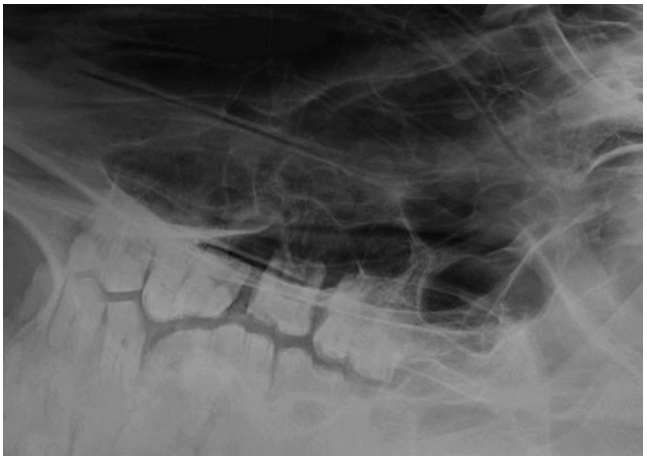


Figure 9-6 A left-dorsal/right-ventral oblique radiograph of a 16-year-old steer with severe periodontal disease of maxillary molars 1 and 2. Note the severe loss of interproximal bone between the teeth. Maxillary molar 1 is also overlong, resulting in a step malocclusion.

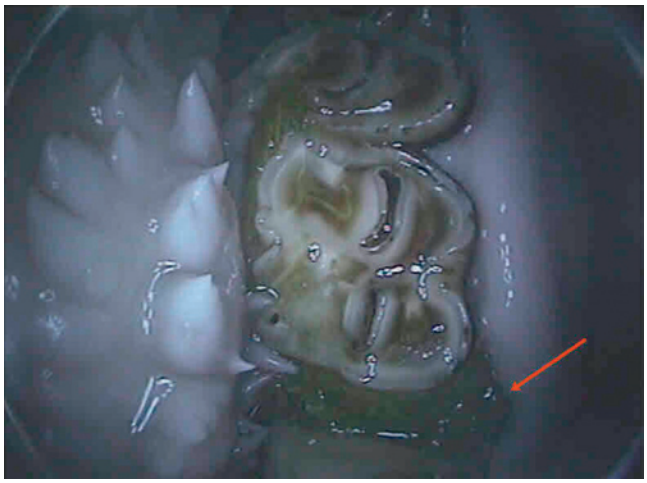


Figure 9-5 Periodontal disease in a 16-year-old steer. The *red arrow* denotes a widening of the interproximal space leading to feed entrapment and diastema formation. (Image courtesy of Edward T. Earley, DVM, Dipl. AVDC-Eq.)



Figure 9-7 Moderate gingival recession of aged bovine incisors. Gingival recession can become severe (*black arrow*), causing marked mobility and necessitating extraction.

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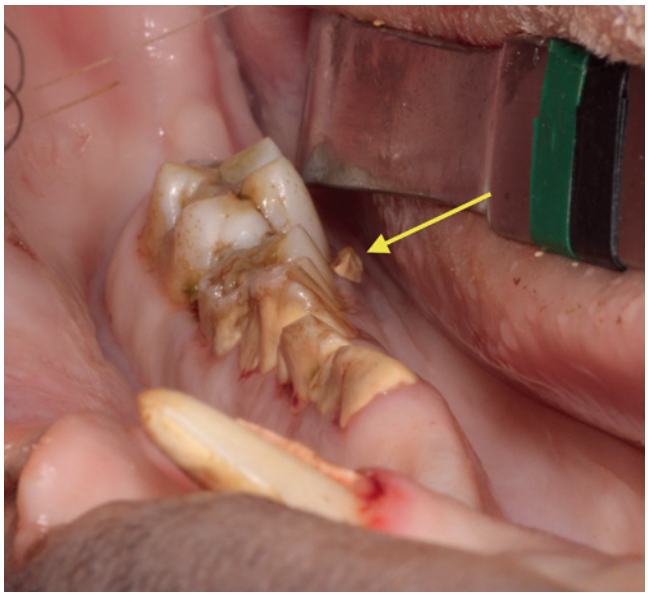


Figure 9-8 A porcine periodontal foreign body is indicated by the *yellow arrow.* The foreign body was a stick and had been in place so long that calculus had formed on the portion protruding into the mouth.



Figure 9-9 Feed impaction in a periodontal pocket of a pig. Note the formidable size of the last molar tooth.

this disease process may affect commercial pigs very little due to the age of slaughter, it can cause significant disease and clinical signs in pet pigs and older pig populations. Therefore a complete oral examination and dental radiographs are recommended for pigs displaying reluctance to

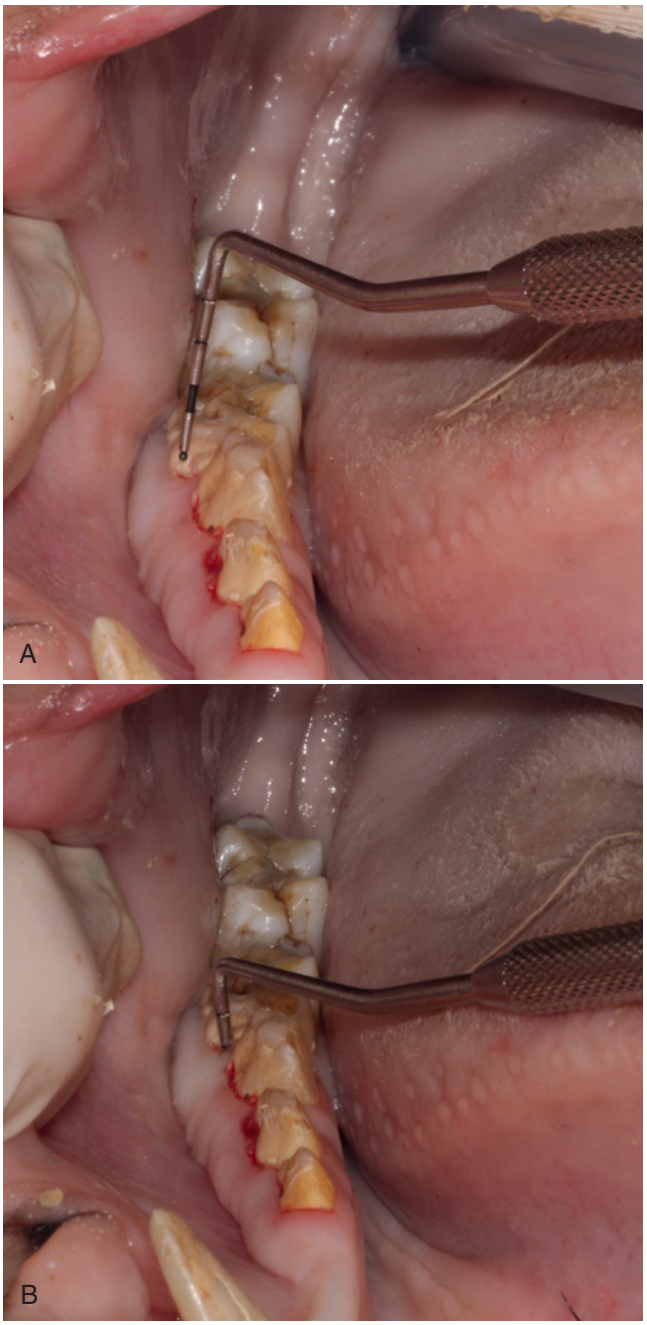


Figure 9-10 Periodontal pocketing associated with a pig first molar tooth. *A*, Before placement of a periodontal probe. *B*, The depth of the pocket, roughly 1 cm.

eat, pain on mastication, and abnormal chewing behaviors. Dental radiographs should be considered for pet pigs undergoing sedation or anesthesia for annual examinations, hoof trimming, and/or dental cleaning because diagnosis and treatment of periodontal disease in earlier stages reduce the need for extractions in the future.

Endodontic Disease

The pulp cavity of both brachydont and hypsodont teeth contains connective tissue, vasculature, lymphatics, and nerves that maintain the vitality of the tooth. Endodontic disease refers to inflammation and infection of these internal dental structures. Penetration of the protective layer of hard dental

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Figure 9-11 Severe gingival recession of the incisors of an aged pig.

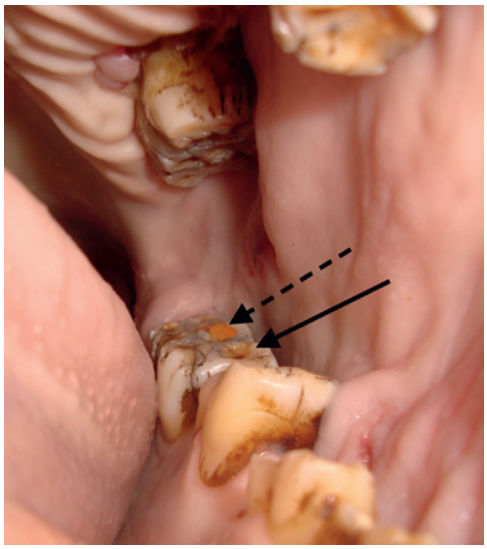


Figure 9-12 **Dental caries in a pig.** Dental caries usually have some degree of feed packing on initial examination, as has this pig with carrot entrapped in the defect (*dashed black arrow*). Once cleaned, the depth and entirety of the dental cavity becomes apparent (*solid black arrow*).

tissue surrounding the pulp may occur due to trauma, dental fracture, excessive wear, caries, severe periodontal disease, or iatrogenic damage. Pigs are particularly prone to carious decay resulting in pulp exposure because some pet pig diets are high in sugar content (Figure 9-12). Exposure of the pulp to the oral environment results in pulpitis due to pH changes, irritation, and bacterial infection. Hypsodont teeth may better withstand an insult to the pulp due to their delayed apical closure, good blood supply, and ability to lay down reparative dentin to close communications between the pulp and the oral cavity. However, both types of teeth may experience pulpar ischemia and/or necrosis as a result of the swelling of the pulp tissues within the enclosed pulp pathways of the tooth. As a result, exposure of the pulp to the oral environment can ultimately lead to tooth death and apical infection or abscess.



Figure 9-13 Transverse computed tomography images demonstrating severe bilateral osteomyelitis associated with bilateral mandibular tusk endodontic disease.

Pigs can have severe regional infection related to endodontic disease of the tusk (Figure 9-13). Tusks are at risk for naturally occurring dental fracture and iatrogenic trauma secondary to tusk trimming. Although pulp exposure is relatively uncommon during a reduction of a tusk to roughly 1 cm above the gingiva, the technique chosen to perform the reduction can affect the potential for endodontic insult. It has long been recognized, in multiple species requiring periodic dental reduction, that dental cutters or nippers can cause both macroscopic and microscopic longitudinal fractures or fissures throughout dental hard tissue. These fractures can lead to pulpitis and endodontic infection; therefore, tusk reduction with cutters is discouraged. Tusks can be safety reduced with Gigli wire, motor-driven cutting discs, and dental drills. Consideration of water cooling to prevent pulpar thermal injury is recommended and will depend on the tool used.

Pharyngeal Trauma

Animals with pharyngeal trauma are sometimes presented to veterinarians for suspicion of a dental malady. Ruminants

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may develop pharyngeal trauma after having medication administered via a balling gun or drenching syringe. Forceful use of one of these tools can result in severe trauma to the pharynx or esophagus, especially when the animal is not properly restrained. The damage to the pharyngeal or esophageal soft tissues may not be apparent until the site of trauma abscesses or begins to pack feed material. Affected animals generally present with anorexia and swelling around the pharynx. The animal may also have dysphagia, hypersalivation, and/or malodorous breath. The infection can migrate to the cervical spinal cord, causing neurologic signs. Pharyngeal swelling may compress the larynx, resulting in increased respiratory noise or distress. Large tears in the pharyngeal wall may cause emphysema of the pharyngeal and laryngeal soft tissues. The emphysema may dissect into the fascial planes of the neck and can even reach the mediastinum, resulting in mediastinitis. The dysphagia experienced by animals with pharyngeal and esophageal swelling may predispose them to the development of secondary aspiration pneumonia.

Treatment of pharyngeal and esophageal tears in ruminant species is difficult and often unsuccessful. The tear formed by the trauma generally becomes impacted with feed material. In addition, the medication in the original bolus can act as a foreign body and continuous source of inflammation. Attempts may be made to remove the bolus and clean out the pocket of entrapped feed material either orally or via an external surgical incision. However, unless closed, these tears generally become rapidly reimpacted with feed. Attempts have been made to suture the mucosa and close the tear from the oral side, but the site generally dehisces due to infection and continuous bacterial contamination. Successful treatment and return to full function and production are rare, especially in chronic cases, and may not be economically feasible. It is preferable to prevent these injuries with diligent instruction on balling gun and drenching syringe technique and with careful restraint of the animal being medicated.

Lumpy Jaw

Actinomyces infection of ruminants can result in a chronic granulomatous abscess of the mandible, maxilla, or other bones of the skull. This disease process is colloquially known as "lumpy jaw" and generally originates from an opportunistic infection of intraoral wounds or dental pathology. The most common etiologic agent in domestic ruminant species is *Actinomyces bovis*, a gram-positive, anaerobic, rod-shaped bacteria with a filamentous or branching appearance. The chronic osteomyelitis caused by actinomyces infection results in extensive periosteal reaction and proliferation of fibrous tissue. Affected animals develop dramatic distortion of the bones of the skull. Depending on their locations, the lesions may be associated with loose teeth or dyspnea. The granulomatous mass may develop external or intraoral ulcerations or fistulous tracts draining purulent material.

Actinomyces infection can be diagnosed by anaerobic culture, but there may be false-negative results depending on the area sampled and sample handling. It can also be diagnosed via histopathology. Radiology of the affected area reveals radiolucent areas of osteomyelitis surrounded by periosteal reaction and fibrous tissue. Treatment involves a combination of intravenous sodium iodide along with administration of an antibiotic such as penicillin, florfenicol, or oxytetracycline. Surgical debridement of the lesion has been used to treat the condition. If diseased teeth are associated with the lesion, they are extracted and the extraction sites are debrided. Care should be taken when extracting teeth because osteomyelitis of the mandible or maxilla can weaken the bones, making them more prone to fracture. Treatment has the potential to stop the proliferation of the lesion, but the proliferative changes to the bones of the skull may not completely regress. Course roughage and feeds containing plant awns are generally avoided because of suspected association with this disease process.

Oral Masses

Cattle and Small Ruminants

Numerous oral tumors can occur in farm animal species, but information is limited regarding the incidence, metastatic potential, and long-term prognosis of many types of these neoplasms. In geriatric ruminants, oral sarcomas, adenosarcomas, osteomas, fibrosarcomas, and fibromas have been reported. Depending on their locations, these tumors may be associated with pain, tooth loss, and pathologic fractures of the mandible or maxilla. Prognosis for oral tumors in ruminant species depends on the location, size, and invasiveness of the tumor. If locally aggressive and metastatic tumors are not radically resected early, prognosis is poor.

Dentigerous cysts have also been reported in cattle and small ruminants. These masses are generally identified in younger animals and are associated with malformed or unerupted teeth. Complete debridement of the cyst with removal of all dental material and the epithelial lining is considered curative. Another congenital abnormality that may be associated with orofacial masses in ruminants is the hamartoma. These masses consist of an overgrowth of mature cells normally found in an organ located elsewhere in the body. Most oral hamartomas of ruminants are made up of a mass of disorganized capillaries. Complete resection of these tumors is considered to be curative, but regrowth can occur if the tumor is not completely removed.

Pigs

Oral and maxillofacial neoplasms in domestic pigs are not well reported. The lack of information about porcine neoplasms is most likely due to the short life span of domestic pigs in production operations. As the number of pigs kept as pets and in zoo collections increases, the resulting increase in aged and geriatric populations of pigs will likely contribute significantly to the literature available on porcine oral neoplasms. A case report was published in 2009 describing mandibular squamous cell carcinoma in a potbelly pig. Initially the neoplasm was mistaken for severe periodontal disease due to its ulcerative nature and bone destruction surrounding the roots of the teeth. When examining a pig with chronic severe periodontal disease, care should be taken to include squamous cell carcinoma as a differential diagnosis because these tumors are extremely aggressive and prognosis is poor without early diagnosis and radical resection.

MANDIBULAR AND MAXILLARY FRACTURES

Mandibular and maxillary fractures of farm animal species may occur due to trauma or a primary infection or neoplasia. Fractures due to trauma generally have a better prognosis for healing than pathologic fractures. The most common site for mandibular and maxillary fractures in cattle is rostral to the cheek teeth, with mandibular fractures being more common. Rostral mandibular and maxillary fractures in the neonatal ruminant are often associated with trauma sustained during dystocia manipulation. Fracture of the more caudal portion of the mandible and maxilla is more rarely encountered due to the large forces required to produce such a fracture.

Fractures that are minimally displaced and stable may be treated conservatively with wound debridement and/or

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suturing, antiinflammatory medications, and a soft diet. An unstable mandibular or maxillary fracture can cause difficulty in prehension and mastication and the animal may present with dripping of saliva, local swelling, and/or tongue protrusion. The ultimate goal of splinting or surgical stabilization is to provide adequate support to enable comfortable prehension and mastication during callus formation. The fracture site should be reduced and stabilized quickly because delay in treatment can lead to malocclusion, tooth loss, osteomyelitis, and loss of function. Before splinting or surgical repair, all oral wounds should be cleaned, debrided, and sutured if necessary.

The proximity or inclusion of teeth within a fracture should be evaluated closely due to implications for bone healing and treatment options. In general, teeth should be preserved at the fracture site to aid in stabilization, although this may not always be possible or practical. Teeth involved with fractures of only the dental alveolus (leaving the tooth and root apex intact) can be salvaged if stabilized, as the periodontium will reattach with healing of the fracture. Even teeth with minor disruptions at the root apex should be preserved, as healing and continued longevity of the tooth are possible. Extraction of involved teeth is warranted if there is visible complete disruption of apical blood supply and complicated crown and/or root fracture. In some instances, tooth removal at the time of fracture repair can severely complicate fracture stabilization. In these cases, teeth can be left in place to provide stabilization but extracted once the fracture has healed. Severely infected or fractured teeth should be removed at the time of initial repair to prevent delays in healing at the fracture site. Endodontic therapy can be considered when necessary and appropriate for some fracture-involved teeth, but this is experimental and uncommon in livestock. All teeth located in the region of a fracture should be radiographically monitored for up to a year to ensure continued viability, as most secondary dental pathology is slow to develop and will not be clinically apparent at the 6- to 8-week recheck for fracture healing.

Options for stabilization of oral fractures include external splints, intraoral acrylic splints, cerclage wires, interdental wires, tension band wires, intramedullary pins, lag screws, metal U bars, compression plates, and external fixators. A treatment plan should be developed based on the appearance of the fracture on radiographs. The techniques listed here can be used either separately or in combination to achieve good stability of the fracture. The tension side of maxillary and mandibular fractures is located within the oral cavity aligned with the crowns of the teeth. Intraoral wiring and composite splinting stabilize fractures on the tension side although anatomy, home environment, and fracture characteristics may not allow for this type of repair. No matter the stabilization method chosen, healthy teeth should remain undamaged during the repair. Intraoral wiring and composite splinting are discussed in the treatment section. See Chapter 14 for a complete accounting of all possible stabilization techniques.

DIAGNOSIS

A complete history and physical examination are recommended for any animal presenting with dental or oral clinical signs. Acquiring a vaccination history including date of last rabies vaccine is highly suggested. Signs of dental pathology can include ptyalism, halitosis, abnormal mastication, pain during mastication, dropping of feed, decreased appetite, and inappetence. In addition, pet pig owners commonly report a more ornery disposition and excessive lip smacking. If animals are anorexic or losing weight quickly, systemic health should be considered before dental pathology unless an obvious major oral malady is readily evident.

ORAL EXAMINATION

A complete dental examination should begin with an extraoral maxillofacial examination. The bones of the skull are palpated to check for any bony swellings or malformations. The facial and masticatory muscles, salivary structures, and lymph nodes are also palpated to check for any soft tissue swelling, muscle atrophy, or lymph node enlargement. The intraoral examination includes a thorough examination of all surfaces of the teeth as well as the lips, mucosa, tongue, gingiva, and hard and soft palate. The patient must be well sedated or anesthetized to perform a thorough dental examination. A full-mouth speculum in ruminants and a bright light source are essential to properly visualize the structures of the oral cavity (Figure 9-14). Static mouth props can be



Figure 9-14 A goat (*A*) and cow (*B*) ready for oral examination. A padded stool will be used for a head rest for the goat. The gray AlumiSpec (available through Equine Dental Instruments) is a perfect speculum for most farm animal species because it has smooth, broad dental plates to rest the maxilla and mandible and infinite adjustment possibilities. It can be used in animals ranging in size from a pygmy goat to a steer to a Belgian horse.

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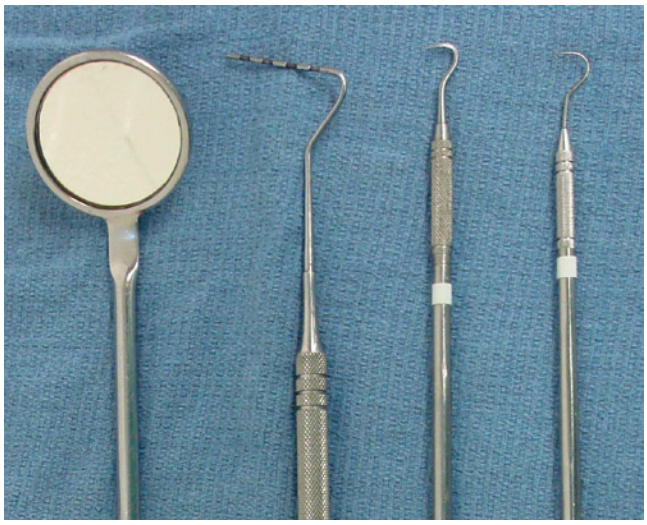


Figure 9-15 Dental examination equipment for large animals. From left to right: dental mirror, periodontal probe, scaler, and dental explorer. The scaler can be used to remove debris for supragingival coronal defects before inspection with the explorer.

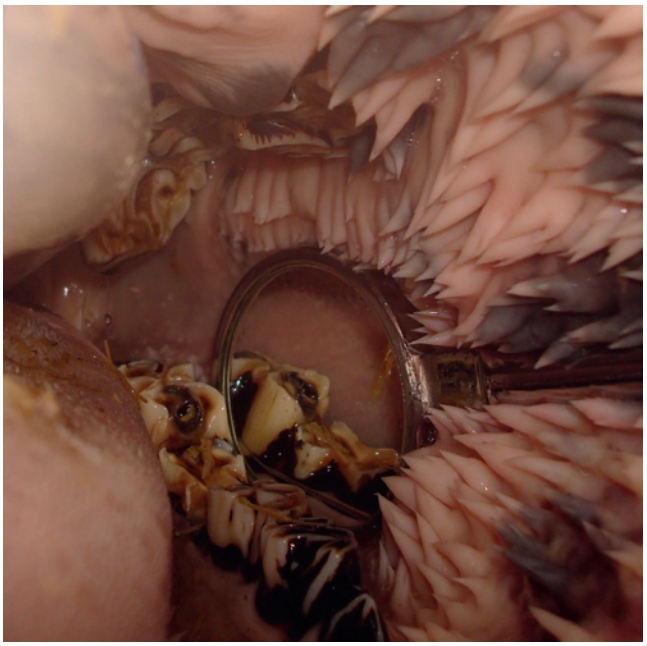


Figure 9-16 Use of a dental mirror to visualize the teeth of a cow.

used in pigs. Before examination, feed material must be rinsed from the mouth using an oral dosing syringe or a hose adapted with a large animal water pick. Extra towels, gauze, or suction will be necessary in ruminants to remove copious amounts of saliva that can obscure visualization of the oral cavity.

Cattle, small ruminants, and pigs have long oral cavities. This makes examination of caudal teeth and soft tissue structures challenging. Basic examination equipment should include a fine-tipped dental explorer, a fine-tipped periodontal probe, and a dental mirror (Figure 9-15). The dental explorer is used to check the occlusal surface of the tooth for hard tissue defects such as small fractures and pulp exposure. The periodontal probe is used to evaluate gingival and periodontal health by measuring the depth of gingival sulci and periodontal pockets. The mirror aids in visualization of the buccal, lingual, and occlusal surfaces of the teeth (Figure 9-16). Common oral examination findings for diseased teeth include discoloration, coronal defects, dental malpositioning, excessive wear, gingival recession and inflammation, periodontal feed impaction, tooth mobility, periodontal pocketing, gingival or mucosal fistulation, and purulent drainage adjacent to a tooth. It is critical that regions of crown irregularities, gingival defects, and feed packing be evaluated closely with the equipment listed here. Severe periodontal and endodontic pathology may produce only subtle changes intraorally, and fine-tipped explorers and probes are necessary to detect disease. Another tool that is very valuable for oral examination is an oral endoscope (Figure 9-17). Use of such a system is the most effective way to visualize subtle oral pathology. In addition, client communication and dental record keeping can be enhanced with the images produced by the endoscope.

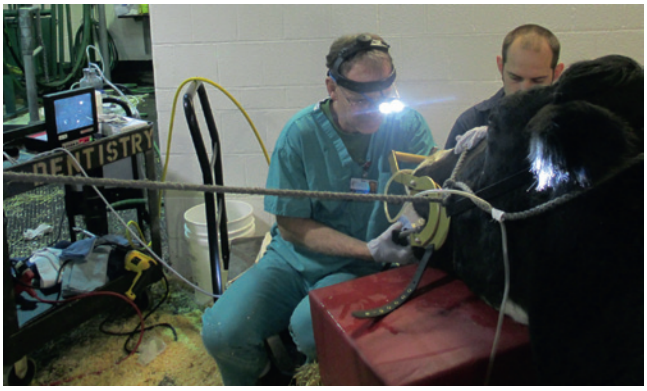


Figure 9-17 Oral examination of a cow utilizing an oral endoscope. (Image courtesy of Edward T. Earley, DVM, Dipl. AVDC-Eq.)

RADIOGRAPHY

Radiographs can be used to assess the crown, reserve crown, and roots of the teeth as well as adjacent anatomy and pathology. Radiographic imaging of the skull can be accomplished via a combination of extraoral and intraoral views. It is imperative to image both the right and left side of the head to allow for accurate radiographic interpretation and pathology recognition. Common extraoral views include lateral, dorsal oblique, ventral oblique, dorsoventral, and off-set mandible dorsoventral views. To minimize radiation exposure to staff, radiographic cassettes can be secured to the patient's face using bungee cords or the strap of a full mouth speculum that has minimal metal in the area of the cheek teeth. An open-mouth technique is recommended for lateral, dorsal oblique, and ventral oblique views. A block of wood, roll of white tape, or Kong toy can be placed in the rostral oral cavity to hold the mouth in an open position. The off-set mandible dorsoventral view helps reduce the superimposition of cheek teeth encountered in the straight dorsoventral view. For this view, cotton ropes or brown gauze are inserted or tied caudal to the incisors on both the maxilla and mandible. The mandible and maxilla are gently pulled in opposite directions, shifting the position of the cheek teeth.

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Intraoral views are particularly helpful for evaluation of dental pathology due to decreased superimposition. Intraoral radiography using size 4 dental film and a dental x-ray generator is the best way to image small ruminant and porcine teeth if the modality is available. Even large domestic pig teeth can be captured on size 4 dental film with the exception of the tusk. If no dental film or dental x-ray generator is available, both rigid and flexible cassettes can be used for intraoral incisor and canine views. However, if rigid cassettes are used, they should be rotated 45° so that the corner is pointed caudally into the oral cavity in order to maximize the amount of the rostral mandible or maxilla that can be imaged. Common intraoral images include the bisecting angle technique for maxillary and rostral mandibular teeth and parallel technique for mandibular premolars and molars caudal to the symphysis (Figure 9-18).

TREATMENT

Routine Care and Odontoplasty

Depending on the type of dental pathology present, producers may elect to cull the affected animal from the herd if the animal is experiencing a loss of production and/or treatment is cost prohibitive. Sharp enamel points and overlong teeth can be treated via odontoplasty. Odontoplasty refers to the removal of enamel and dental hard tissues to reshape a tooth. If only excessively sharp enamel points are present, only the enamel should be reduced and the cementum and dentin should remain untouched. If an overlong tooth needs reduction, cementum, dentin, and enamel will need to be removed, and consideration to the placement and depth of pulp horns is critical. Care needs to be taken when performing crown reduction because overaggressive odontoplasty can result in pulp exposure, pulpitis, and possible subsequent apical infection. The crown of severely overlong hypsodont teeth should be reduced slowly over a series of visits to allow the tooth to lay down secondary dentin at the coronal aspect of the pulp horns. The general rule in equids is 3- to 4-mm reduction of whole tooth structure (not just enamel) every 3 months; there is no such established reduction guideline for ruminants. Because reserve crowns are smaller in ruminants than in equids, reductions should occur less frequently and only when a detrimental condition is diagnosed. Reductions should be localized and performed with equipment, either hand or motor powered, that allows accurate placement on the desired location of a tooth. Teeth without pathology should be left untouched. Normal occlusal ridging and conformation should be preserved; therefore, most reductions are minor.

The only porcine tooth requiring routine odontoplasty or reduction is the tusk. Animals should be sedated for the procedure. Tusks are generally trimmed at regular intervals to address safety concerns for handlers and other animals and to prevent soft tissue trauma from overlong tusks, particularly if they are malpositioned. Tusks can be trimmed with Gigli wire, motorized cutting wheels, and dental drills (Figure 9-19). The use of cutters and nippers should be avoided because longitudinal fractures of the tusk may occur. Although uncommon, care should be taken when performing this procedure because the pulp cavity of the tusk may extend to or above the level of the gingival margin. Tusks should be trimmed or crown amputated to roughly 1 cm above the gingiva and contoured to a smooth finish (Figure 9-20). When the tusk is cut too short, the pulp can be exposed, leading to painful pulpitis and potential apical infection. If the pulp is exposed when the tusks are trimmed, a vital pulpotomy procedure can be performed to prevent endodontic disease.

It is suggested that pet pigs have scheduled routine sedated oral examinations and intraoral radiographs due to their propensity for developing periodontal disease and caries as they age. Periodic dental cleaning under general anesthesia may

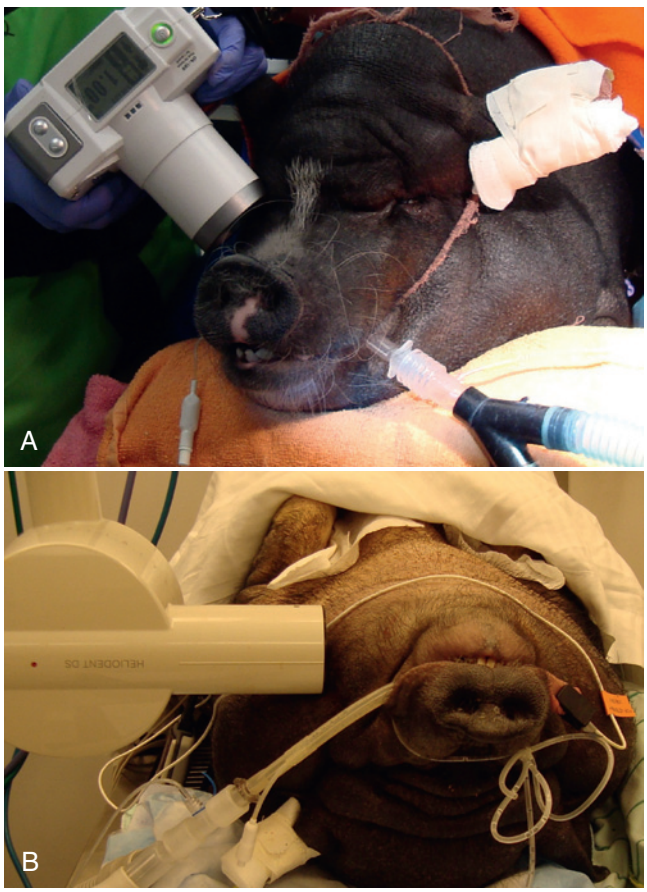


Figure 9-18 The acquisition of porcine intraoral radiographs utilizing two different types of x-ray generators. Size 4 dental film is placed within the oral cavity. *A*, bisecting angle technique; *B*, parallel technique.



Figure 9-19 Trimming of a boar tusk using a high-speed dental drill with water cooling.

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Figure 9-20 Smoothing after crown amputation of a tusk is important to prevent regional soft tissue trauma and ulceration. *A*, an improperly trimmed tusk that caused extensive regional soft tissue ulceration. *B*, A properly smoothed tusk.



Figure 9-21 Dental cleaning in a pig utilizing an ultrasonic scaler.

also prove beneficial, particularly if an individual pig is prone to plaque and calculus accumulation (Figure 9-21). The timing of these treatments should be based on oral examination findings. A discussion with owners regarding the cariogenic nature of high-sugar diets and treats is also important to help prevent the development of tooth decay.

Extractions

Cattle and Small Ruminants

Extraction of incisor and canine teeth in cattle and small ruminants requires only simple elevation of the gingiva and periodontal ligament and avulsion of the tooth. Due to the conical nature of the tooth and preexisting mobility, extraction is typically uncomplicated. Extraction sites can be left either open or closed, depending on the nature of the pathology. Cheek teeth in cattle and small ruminants can be extracted intraorally or via an external surgical approach. Intraoral extraction is generally performed in the sedated patient with the use of appropriate regional nerve blocks. Equine extraction equipment can be used to intraorally extract ruminant teeth. Typically, miniature horse instruments fit best in the mouths of small ruminants. To intraorally extract a tooth, the buccal and lingual/palatal gingiva is elevated using long-handled gingival elevators. If the tooth is not already mobile, molar spreaders can be used in the mesial and distal interproximal spaces of molar teeth to begin straining periodontal attachments. Spreaders are typically not useful for the smaller premolar teeth in ruminants. Care should be taken when using spreaders around the premolars and between the second and third molars as detrimental luxation of healthy adjacent teeth may occur. Molar spreaders also have the potential to damage the crowns of the adjacent teeth if applied carelessly. After spreading or if the tooth is already mobile, extraction forceps that best match the size and shape of the diseased tooth are used to grip the tooth (Figure 9-22). The tooth is carefully rotated from side to side in the alveolus to break down the periodontal ligament. Great care must be taken to avoid using excessive force that might risk fracturing the crown or root tips. The extraction forceps should be seated tightly on the crown of the tooth to avoid grinding away of dental structure during rotation of the forceps. When the tooth becomes loose enough to permit extraction, a dental fulcrum can be placed between the occlusal surface of the arcade and the hinge of the extraction forceps. Steady avulsion force is exerted on the tooth in the direction of eruption to complete the extraction. In many cases, the use of a fulcrum is unnecessary because ruminant teeth loosen more quickly than equid teeth due to a much shallower alveolar socket and shorter reserve crown. The alveolus is curetted clean and flushed copiously. Typically alveolar sockets are too shallow to retain a packing material, but if the sockets are sufficiently deep they can be packed to prevent food from collecting at the extraction site. Vinyl polysiloxane putty is an effective and convenient alveolar packing material. The dental plug should be removed and the extraction site rechecked 3 to 4 weeks

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Figure 9-22 Oral extraction of a maxillary cheek tooth in a 16-year-old steer using equine extraction forceps. (Image courtesy of Edward T. Earley, DVM, Dipl. AVDC-Eq.)

postextraction. If no packing material is placed, oral lavage is recommended daily to remove feed from the extraction site until it is fully healed. The use of a systemic antibiotic, pain medication, and softened feed depends solely on the nature of the extraction and the pathology addressed. Pre- and postoperative radiographs are highly suggested to ensure a successful and complete extraction.

Indications for surgical extraction of cattle and small ruminant teeth include severe damage to or missing clinical crown, failure of oral extraction, ankylosis of the reserve crown or roots, abnormal root architecture, and maleruption or dental impaction. Reports of surgical extraction techniques in cattle and small ruminants are scarce, most likely because of the high success rate of intraoral extraction. Buccotomy techniques similar to those described in the equid can be applied if necessary but are rarely employed.

Pigs

Porcine incisors, female canines, premolars, and molars are extracted in a very similar fashion to human and small animal teeth. The construct of the tooth and the increased oral aperture allows for adequate intraoral access to regional dental anatomy with small animal extraction instrumentation. A combination of intraoral simple and surgical extraction techniques are employed depending on the tooth and dental pathology. Tusk extractions are complex and risk compromising the structural integrity of the mandible and maxilla. Tusk extraction typically requires an extraoral surgical approach, but treatment planning is required to determine the best course of action for the tooth and the pig (Figure 9-23).

Intraoral extraction is performed under general anesthesia with regional nerve blocks (Figure 9-24). A thorough dental examination and a set of full-mouth intraoral radiographs are recommended to fully assess the pig's oral health and develop a treatment plan. Treatment plans typically contain a dental cleaning, basic periodontal therapies, and tusk trimming and shaping in addition to work needed to address primary pathology. Intraoral surgical extractions necessitate the creation of a mucoperiosteal flap elevated over the buccal aspect of the tooth using a scalpel and periosteal elevator. The alveolar buccal bone overlying the roots is removed with a high-speed dental drill, exposing roughly 60% of the buccal root surface. Multirooted teeth are sectioned at the level of the furcation into individual root

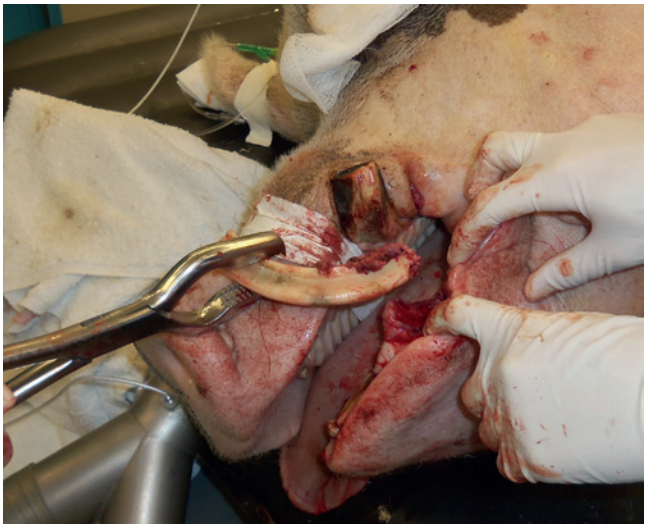


Figure 9-23 Intraoral extraction of a boar tusk. The periodontal and endodontic disease associated with this tusk was so severe that the tooth could be extracted with simple periodontal elevation and avulsion force. No surgical approach was required. (Image courtesy of Richard Hackett, DVM, MS, Dipl, ACVS.)



Figure 9-24 Infraorbital nerve block performed with a Tuohy needle in a pig needing maxillary extractions for periodontal disease.

segments to allow for direct root elevation (Figure 9-25). Dental elevators or luxators are used to carefully break down the periodontal ligament attachments surrounding each of the tooth roots. When each root becomes sufficiently mobile, extraction forceps are used to remove the root. After all dental material has been removed and postoperative radiographs taken to rule out retained root tips, the extraction site is debrided and flushed, and bone margins are smoothed. The periosteum is transected on the deep portion of the flap to allow for greater flap mobility and tension-free closure. Finally, the site is closed with absorbable monofilament suture material in a simple interrupted pattern.

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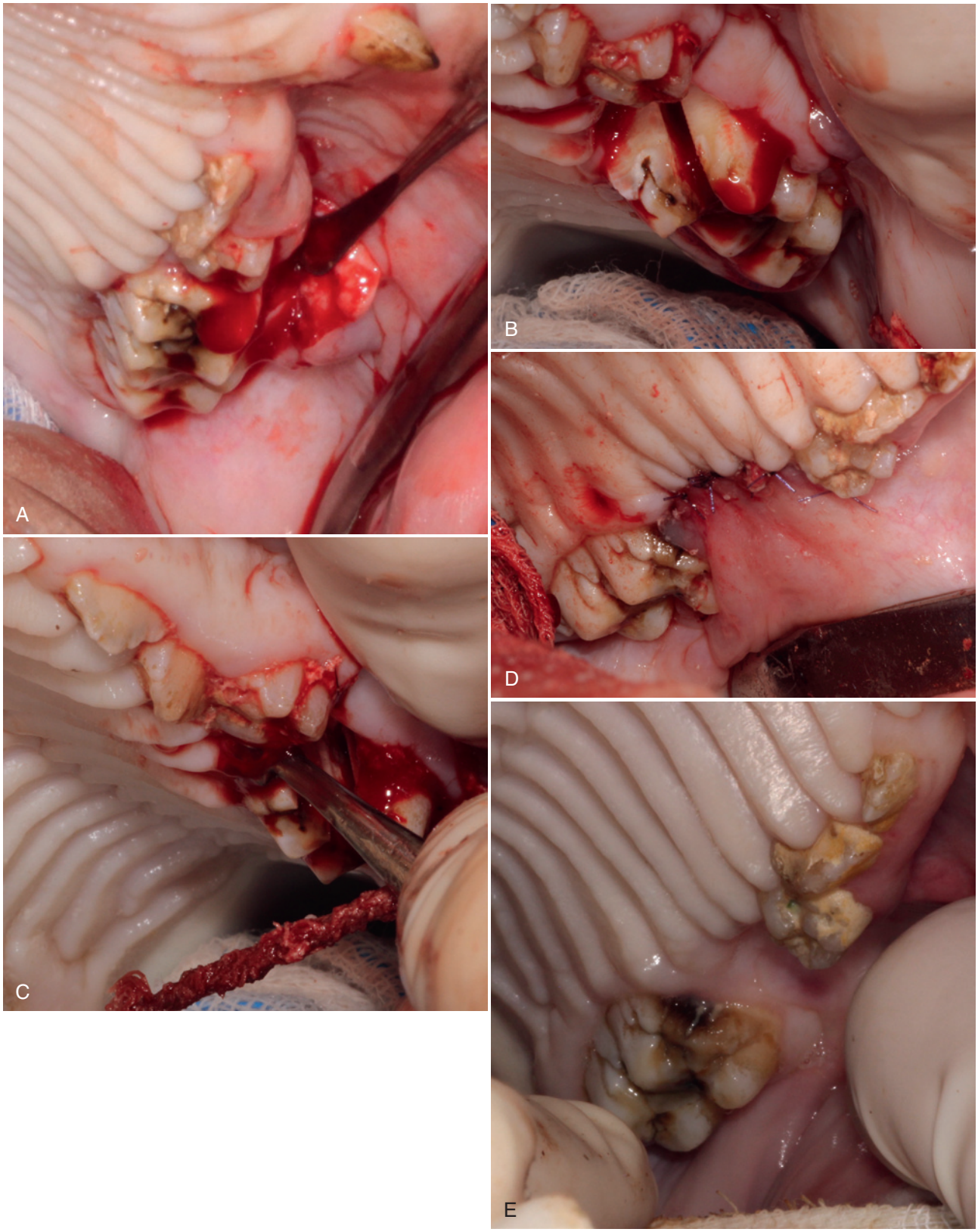


Figure 9-25 Steps to intraoral surgical extraction of the first molar tooth in a pig. Creation of a mucoperiosteal flap (*A*), tooth sectioning (*B*), dental elevation (C), and flap closure (*D*). Buccal alveolar bone removal and regional debridement postextraction are not imaged. The site healed well (*E*).

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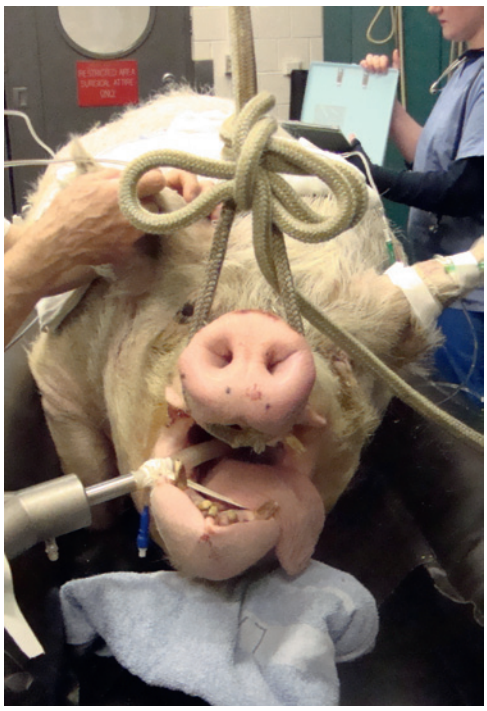


Figure 9-26 Anesthetized domestic pig ready for oral examination. A rope supported by an overhead beam was used to hold the mouth open as mouth gags and props kept slipping. It became quickly apparent that the rope needed padding to prevent damage to the oral mucosa.

Depending on the extent of extraction and regional pathology, postoperative antibiotics and nonsteroidal antiinflammatories may be recommended in addition to a soft food diet for 2 weeks.

Although extractions progress in pigs similar to that of small animals, there are a few caveats that make pig dental extractions some of the hardest of any domestic species. Despite the increase in oral aperture compared with ruminants, access is still quite restricted, particularly in the caudal aspect of the mouth. Tissue retraction can be challenging due to the large stature of some pot-bellied and domestic pigs and the thick nature of porcine tissue (Figure 9-26). Despite the thickness of tissue in general, porcine oral mucosa is relatively delicate and bruises easily. This complicates tissue retraction further. In addition, it is not uncommon to discover on examination that one or more of the premolars and/or molars is partially erupted or impacted, particularly in miniature and pot-bellied pigs. This can complicate regional treatments and extraction techniques. Pig premolar and molar roots are small and delicate; therefore, root fracture is common. Due to restricted access and limited extraction equipment for pigs, sometimes these roots need to be atomized rather than extracted as one piece. Small animal dental instruments work well for miniature and small pot-bellied pigs but are sometimes inadequate for larger domestic pigs. Therefore instrumentation may be comprised of both large and small animal surgical and dental tools. Unfortunately, sometimes the right size and angle of instrumentation are wanting, and creativity with tools at hand is necessary. Finally, the size of the third molar tooth combined with the limited access in the caudal aspect of the mouth makes extraction of this tooth a serious challenge. It is recommended that this tooth be extracted only when other therapeutic options are inadequate or the oral pathology associated with the tooth is severe. As a result, comprehensive pig dentistry requires a good deal of knowledge, equipment, patience, time, and assistance.

Endodontics and Vital Pulp Therapy

Endodontic therapies for farm animal species have been minimally explored and the long-term outcomes for these procedures is unknown. However, there is a potential use for endodontic therapeutics in farm animals, particularly in the treatment of dental fractures and iatrogenic pulp exposures in boar tusks. Due to the size of the boar tusk and its important role in the structural integrity of the mandible, extraction is difficult and carries great risk. When dealing with fresh fractures and pulp exposures of the tusk, the best option is vital pulp therapy. This involves sterile, surgical removal of the inflamed coronal portion of the exposed pulp horn. Once the inflamed pulp material is removed, a pulp medicant like calcium hydroxide or mineral trioxide aggregate is placed gently on the pulp to encourage regional disinfection and healing. A layer of glass ionomer is placed over the pulp medicant to form a bacteria-tight seal over the pulp horn. The crown of the tooth is restored with a dental composite material. If the fracture or pulp exposure has been present for a prolonged period of time, other endodontic procedures such as a complete pulpectomy (root canal), modified apexification, or surgical partial pulpectomy may be required to treat the tooth. These treatments would be considered experimental in farm animals. To maximize the success of the procedure, involvement of a certified veterinary dentist is recommended.

Intraoral Wiring and Composite Splinting

Intraoral wiring and composite splinting can be used to stabilize fractures rostral to the premolars and molars in ruminants and theoretically all porcine fractures along the dental arcade. The composite recommended is a nonexothermic self-cured bis-acryl composite typically used for temporary crowns and bridges (Protemp Garant).[1] The wear-resistant material, available in automix cartridges, is easy to work with and bonds directly to dental structures. If a temporary composite material is unavailable, cold-cure polymethyl methacrylate can be used as described in the literature. Application of composite is nearly impossible on premolars and molars in ruminants due to limited access and copious salivation. Intraoral wiring alone or in conjunction with another fixation modality can be used to help stabilize some minor, caudal dental arcade fractures in ruminants. Before placing the wires and composite, the fracture must be reduced, and any oral lacerations must be cleaned, debrided, and sutured.

Interdental wiring techniques will depend on the fracture type and the species involved. Interdental wire placement for pigs can utilize either a modified Stout loop or Risdon technique similar to that in dogs. Unfortunately, the tight contact and coronal structure of ruminant cheek teeth prevent the use of the Stout loop technique. Instead, wires are passed through interproximal spaces at the level of the gingiva and either looped around teeth on the opposing side of the fracture or anchored within the regional bone. Ruminant premolars provide inadequate anchorage for rostral fractures; therefore attempts should be made to include at least the first molar in the caudal aspect of the wire loop. If the wire spans the canine-premolar diastema, it should be twisted to decrease the possibility of lingual trauma and breakage. Once the wires are set, the composite splint can be placed. Dental structures to be included in the splint are cleaned

[1]Protemp Garant, 3M ESPE, Seefeld, Germany.

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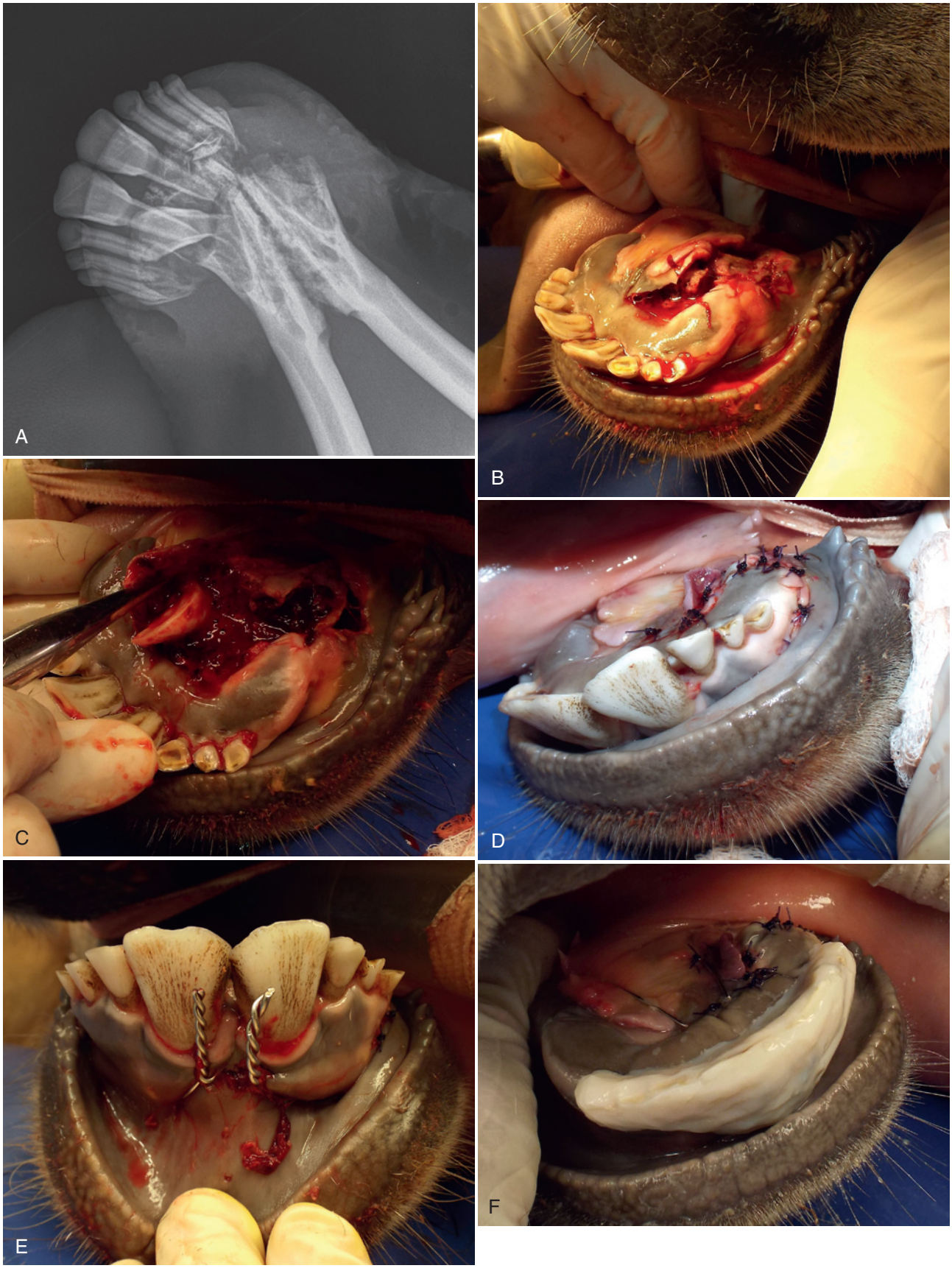


Figure 9-27 Rostral mandibular fracture repair in a 2-year-old cow (*A* and *B*). The fracture was debrided carefully to preserve blood supply and remove bone shards and avulsed teeth (C) and sutured closed (*D*). Interdental wiring was anchored distal to the first molar and passed through the rostral mandibular bone (*E*). A composite splint was placed to hold wires and teeth in place (*F*).

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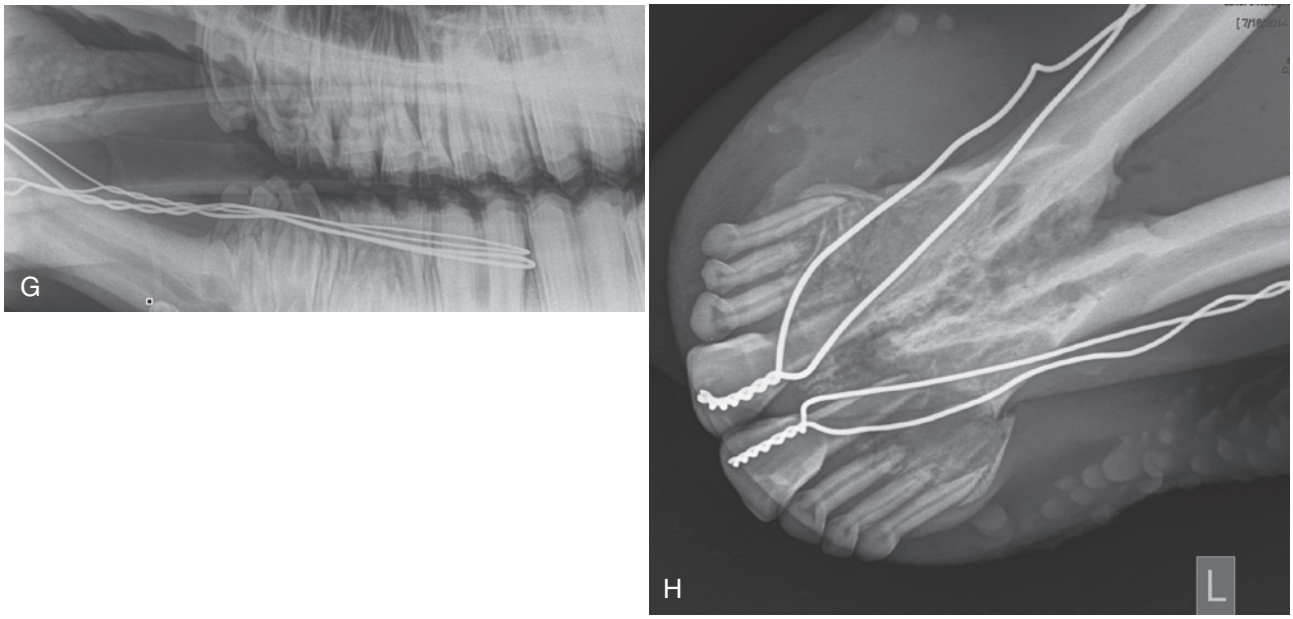


Figure 9-27, cont'd Postoperative radiographs showed good alignment and placement of wires (*G* and *H*).

free of debris, etched, rinsed, and dried. The composite material is applied directly to the dental structures and twisted ends of wire in the region of the splint. Once the composite has hardened, it is smoothed and shaped with an acrylic working laboratory bur, ensuring that no sharp edges or protrusions are left behind (Figure 9-27). It is critical to ensure that the splint does not interfere with normal occlusion, prehension, and mastication or damage regional soft tissue structures like the tongue or salivary caruncles. The wires and splint should be left in place until the fracture lines are no longer visible on radiographs, typically 6 to 8 weeks in adult animals and 3 to 5 weeks in juveniles. Wires and splints require daily oral rinsing and inspection to ensure they remain intact and debris free.

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CHAPTER 10

Surgery of the Eyes

Nita L. Irby

Healthy eyes are important to any animal, for quality of life, to safely exist in their environments, and to successfully compete for food and thrive. Many common ocular diseases cause marked discomfort, with potential poor weight gain, decreased milk production, behavioral problems, poor performance, and so on, affecting the animal and the producer.

HISTORY, EXAMINATION, OCULAR ANALGESIA, AND EYELID AKINESIA

A complete history and physical examination should be performed on all patients, even if the complaint concerns "just" the eye. Many ocular problems in farm animal species are manifestations of systemic diseases, and systemic disorders should be ruled out before the ocular examination commences because dehydration, anemia, icterus, sepsis, and other such systemic problems may affect the ocular findings. Historical information should include the owner or herdsman's assessment of the patient's visual status. Careful observation of the patient may be necessary if normal vision is in question; this can be difficult to assess in animals in a herd. Head carriage and movement should be noted (visually deficient animals often carry their heads extended or close to the ground and searching-type head movements may be seen). Previous ocular diseases should be queried. Current and previous ocular and systemic medications—including conventional and alternative therapeutic modalities—should be noted.

Treatment of any eye problem begins with a proper diagnosis made during a careful, complete eye examination, which every veterinary student learns and available reference textbooks illustrate. However, the difficulties encountered during examination of the eyes of a ruminant patient in a stanchion, chute, barn, or field can make an ocular examination a challenge, even for experienced veterinary ophthalmologists. Whenever possible, examination of the eyes should be performed in a quiet, darkened room because intraocular structures cannot be adequately assessed in brightly lit conditions. Adequate restraint of the head is essential, and most procedures in dairy cattle can be performed with good head restraint and locoregional anesthesia; sedation of some bovine patients with xylazine (0.015 to 0.025 mg/kg intravenously [IV or 0.05 mg/kg intramuscularly [IM]) may be necessary. Xylazine may cause uterine contractions and should be used with caution in pregnant patients. The effects of xylazine may be reversed, if needed, with yohimbine (0.12 mg/kg IV) or tolazaline (0.5 to 1.0 mg/kg IV or IM). For surgical procedures, double haltering and cross tying in opposing directions is recommended; if they are available, tilt tables are very useful.

Minimal specialized equipment is necessary for a complete ophthalmic examination. In addition to an ophthalmoscope with a very bright light, Box 10-1 lists diagnostic and therapeutic equipment that fits easily inside a small, three-tiered fishing tackle box to make a compact and readily portable case for field eye examinations and simple procedures. Lint-free cellulose sponges[1] are a helpful addition for fluid absorption from the cornea, but these are expensive and are only mandated when manipulating corneal or iris tissues in a ruptured eye that is to be salvaged. A black cloth or cape for shrouding the head of the patient and examiner may be helpful if a darkened area for examination is not available but should be used with care to avoid startling patients.

A basic ophthalmic examination in any species should follow the same sequence every time. First, perform a general inspection of the eyes using a bright light to ensure further testing and manipulations can be performed without causing further damage to the eye. This is especially critical if the eye(s) to be examined are squinted shut, as discussed later in this chapter. Initial examination is followed by a visual assessment of tear volume; a Schirmer tear test[2] should be performed if there is any suggestion that the eye lacks its normal luster and always if a tear meniscus is not present. Tear production must be assessed before any other procedures are performed because ocular manipulation will stimulate tearing and further diagnostic testing, such as fluorescein staining, requires that moisture be applied to the eye. Although dry eye is extremely rare in food animals, it should be considered in all cases of chronic, recurring corneal disease and should be quantitatively assessed via Schirmer tear testing (normal values in farm animal species are greater than 15 mm wetting per minute). Fluorescein staining should be performed next and is a crucial procedure to perform in any painful eye. Excess stain should be rinsed from the eye, and the corneal and conjunctival surfaces should be assessed using white and cobalt blue light for any dye retention on the ocular surface such as would occur with an abrasion, erosion, ulceration, laceration, etc. Last, intraocular pressure measurements should be performed routinely, even though glaucoma is rarely reported in food animal species. For intraocular pressure measurements, a Tono-Pen[3] or similar device should be applied to the eye following application of topical anesthetic drops. If intraocular pressures are normal, 1% tropicamide is then applied to effect mydriasis within 15 to 20 minutes in a normal eye. Following full mydriasis, assessing the entire lens and fundus completes the remainder of the eye examination. While the pupil is dilating, the anterior portions of the eye can be examined in detail using a direct ophthalmoscope, the magnification provided by an otoscope head magnifying lens, or ideally, a slit lamp biomicroscope.

The standard, complete eye examination is unfortunately quite often an abbreviated one in many food animals because

[1]Weck-Cel, Beaver-Visitec International, Inc. 411 Waverley Oaks Road, Waltham, MA 02452, USA. http://www.beaver-visitec.com/brands/merocel-keracel-weck-cel.cfm.
[2]Schirmer Tear Test Strips, Sigma Pharmaceuticals, LLC, 106 West First St., PO Box 228, Monticello, IA 52310, USA.
[3]Reichert, Inc., 3362 Walden Avenue, Depew, NY 14043, USA. http://www.reichert.com/eye_care.cfm.

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Box • 10-1

Suggested Diagnostic and Therapeutic Ophthalmic Equipment and Supplies

Welch Allyn pneumatic otoscope head (No. 20200)[1]
Welch Allyn 3.5 V coaxial halogen direct ophthalmoscope head (No. 11720)[2]
Welch Allyn 3.5 V rechargeable battery handle (No. 71000-A)
Welch Allyn 3.5 V fiberoptic Finhoff transilluminator (No. 41100)
Cobalt blue filter for transilluminator above (Welch Allyn no. 41102) to enhance fluorescein stain fluorescence
4× magnifying loupe (e.g., Optivisor loupe)
20D magnifying lens
Sterile cotton-tipped applicators
Sterile gauze pads
Fluorescein sodium impregnated strips for ophthalmic use—sterile, single use
Mosquito hemostats, 2
Allis, Bishop-Harmon, and Colibri tissue forceps, 1 each
Stevens tenotomy scissors
Small needle driver (Derf)
Castroviejo needle holder, 5.5-inch, 1.5- to 2-mm tip width, locking type recommended for field use
2-0 nylon on a straight needle
4-0 silk suture on cutting needle
5-0 polyglactin 910 (Vicryl) suture with P-2 needle (Ethicon No. J503G)
6-0 polyglactin 910 (Vicryl) suture with PS-6 needle (Ethicon No. J510G) and G-6 needle (Ethicon No. J551G)
Schirmer tear test strips (Schering-Plough/Merck Animal Health)
Xylazine, 1 vial each of 20 mg/mL and 100 mg/mL concentrations
Detomidine 10 mg/mL (for horses only)
2% mepivacaine or lidocaine injectable
2% lidocaine gel
Tropicamide 1%—short-acting mydriatic to dilate pupils
Proparacaine 0.5%—topical anesthetic
10% phenylephrine
Sterile eye collyrium/eye irrigating solution in a spray bottle
Sterile saline, 50 mL
5% povidone-iodine solution
Alcohol swabs
Cyanoacrylate tissue adhesive
#11, 12, and 15 Bard Parker scalpel blades (#12 is great for suture removal)
#64 Beaver blades
Glass slides (cleaned and in carriers)
Matches or lighter
20-gauge intravenous catheters for normograde nasolacrimal cannulation and for lavage of the palpebral fissure
3.5 and 5.0 French red rubber feeding tubes and polypropylene canine urinary catheters for nasolacrimal lavage
Equine nasolacrimal lavage catheter (Surgivet No. ENLC603540 or MILA International No. NL525)
Teat cannulae and tomcat catheters for retrograde nasolacrimal duct cannulation
30-, 25-, 20-, 19-, and 18-gauge disposable needles
1-cm^3, 3-cm^3, 5-cm^3, and two each of 12-cm^3 and 20-cm^3 syringes
Blood tubes—particularly red top (include 1 or 2 filled with formalin)
Culturettes—preferably minitip
Polyester swabs for cultures (cotton is bacteriostatic)
Broth for bacterial culture
Anaerobic bacterial transport media
Subpalpebral eye lavage kits (Mila International No. 6612L)

[1]This is the most useful instrument in large-animal veterinary ophthalmology. It can be used as a penlight and, with its rotating lens in place, is an excellent tool for close-up inspection of the external eye, cornea, anterior chamber, iris, and lens. With the magnifying lens rotated out of the examiner's line of sight and the instrument held against the examiner's brow, the device is excellent for direct examination of the ocular fundus of the large-animal eye (the optic nerve and fundus of horses, cows, etc. can be readily examined using just a focal bright light such as this or a transilluminator; an ophthalmoscope head is not required for routine fundus exam in these species).
[2]When performing an examination of the tapetal portion of any fundus the examiner must ensure that the cross-linear polarizing filter on this device is not being used (the filter indicated by an X) because this filter causes severe chromic aberration of light reflected from the tapetum.

of their resistance to complete examination, because of poor lighting conditions in which to conduct the examination, or because of time and expense considerations.

In some farm animals, the eyes cannot be examined until the upper eyelids are paralyzed. In contrast to the powerful orbicularis oculi muscle of the equine, the eyelids of most other farm animal species are much easier to open. Even so, any eyelid that is being held firmly shut by the patient should not be forced open for examination purposes unless the underlying disease process is known because forceful attempts to open eyelids over a full-thickness corneal laceration may result in all the ocular contents being expelled into the examiner's hand. In every instance, eyelids are most safely opened with the examiner's hand(s) resting securely on the underlying orbit bones while the examiner's fingers "walk" the lids open. Lids should never be forced open by direct application of pressure to the lid margins and thus to the underlying eyeball.

Eyelid akinesia is recommended as the safest way to open eyelids and is essential for standing ocular procedures such as normograde nasolacrimal duct lavage (Figure 10-1*A* and *B*) or standing surgical procedures (eyelid mass removal or laceration repair, nictitans, conjunctival or corneal surgery, etc.). Several nerve blocks are available to paralyze the upper eyelids, and akinesia should result within 5 minutes. In thinner-skinned animals (calves, sheep, and goats), the palpebral branches of the auriculopalpebral nerve may be blocked at any number of sites as branches cross the bony orbit rim dorsocaudal or dorsolateral to the eye or midway along the zygomatic arch. Subcutaneous injection of local anesthetic 2 to 3 cm rostral to the base of the ear generally results in a more complete motor blockade, however. One or more sites are cleansed, and a local anesthetic such as 2% (1% in small ruminants) lidocaine is injected subcutaneously (1 to 5 mL/site) via a 22- or 25-gauge needle; the needle size and amount injected depend on the patient's size and skin

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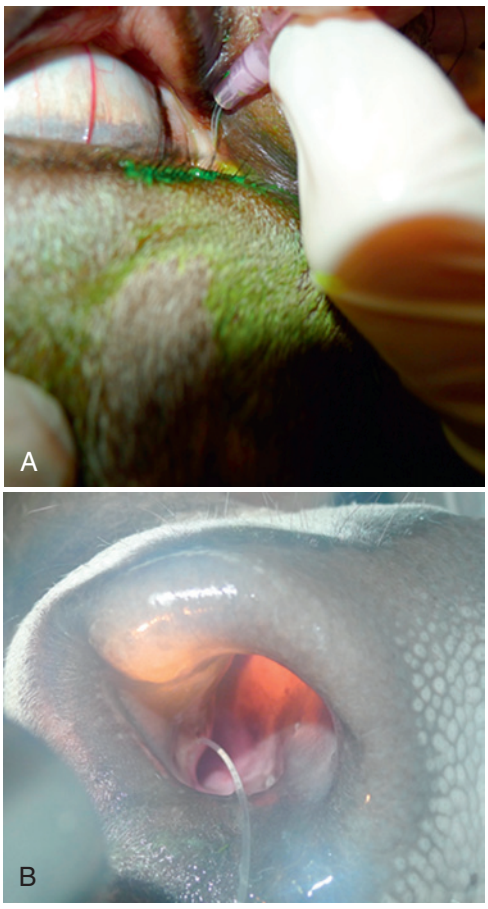


Figure 10-1 *A*, 20-gauge intravenous catheter in the superior lid nasolacrimal puncta before normograde nasolacrimal lavage. Fluorescein dye is present overflowing onto the face. *B*, 3.5 French polypropylene canine urinary catheter in the nasal orifice of the nasolacrimal duct, located on the rostroventral aspect of the alar fold in the right nostril of this adult Brown Swiss cow.

thickness. Nerve branches may be difficult to palpate in adult cattle so knowledge of regional anatomy is important. For most adult cattle, local anesthetic injected along the zygomatic arch caudolateral to the lateral eyelid commissure will result in excellent upper eyelid akinesia within 5 minutes. A 12-cm needle is inserted subcutaneously caudolateral to the lateral commissure of the eyelids, near the angle between the frontal and temporal processes of the zygomatic bone. The needle is directed caudally along the zygomatic arch, and 5 to 10 mL of local anesthetic is infiltrated as the needle is advanced. Alternately, 3 to 5 mL of local anesthetic can be injected subcutaneously rostral to the base of the ear, immediately caudal to the high point of the zygomatic arch (Figure 10-2).

Complete lower lid akinesia is impossible to achieve with a single nerve block in any species, and although specific nerve blocks have been described the author prefers to perform a line block using a 20- to 22-gauge spinal needle (7-12 cm) inserted 1 cm ventral to the lateral canthus and directed medially through the lower eyelid to diffusely infiltrate local anesthetic throughout the lower eyelid. Before needle placement, topical anesthesia is applied to the ocular surface, and the lower eyelid is supported with finger pressure applied from inside the eyelid as the needle is advanced, thus protecting the globe.

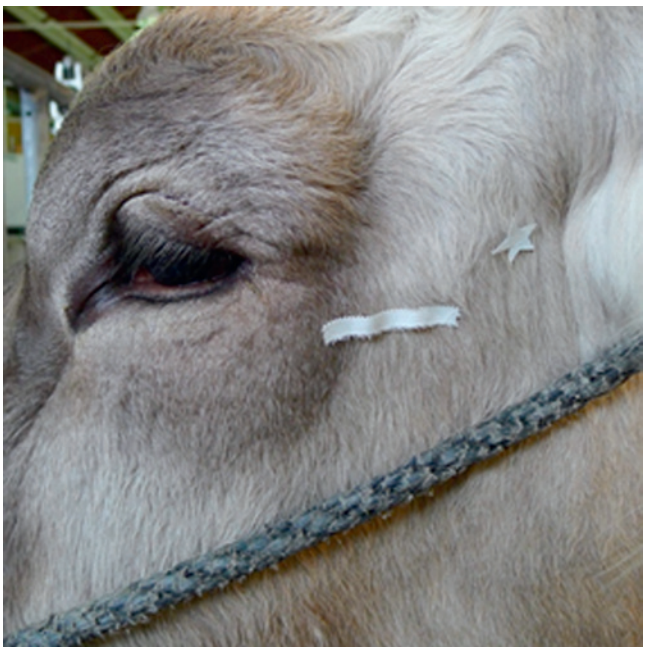


Figure 10-2 Line of anesthetic administration along the zygomatic arch for eyelid akinesia (1 cm dorsal to line of tape in this picture). Alternately, 3 to 5 mL of local anesthetic can be injected subcutaneously rostral to the base of the ear, caudal to the highest point of the zygomatic arch (*star*).

Complete akinesia and analgesia of not only the eyelids but the orbit and globe as well may be necessary in some cases, such as with enucleation. In these cases, the classic nerve block described by Peterson can be used or a retrobulbar block or 4-point block can be performed. Pearce et al. showed greater distribution of anesthetic around target nerves and muscles with the retrobulbar block compared with Peterson's block. If performing either a retrobulbar or Peterson block, the owner should be advised in advance that death has resulted in rare cases, presumably because anesthetic has been injected subdurally in the optic nerve. When properly performed, each of these blocks desensitizes cranial nerves II, III, IV, and VI and the ophthalmic branch of V. Possible complications include orbital hematoma, globe penetration, and, as noted, seizures or death.

For Peterson's block, a 12-cm curved needle is inserted in the angle between the frontal and temporal processes of the zygomatic bone, advanced and "walked off" of the cranial aspect of the coronoid process of the mandible, and then directed an additional 1 cm caudoventrally toward the foramen orbitorotundum (Figure 10-3). In adult cattle, 15 mL of local anesthetic can be deposited at this location. Mild proptosis should be present when the block is completed; complete anesthesia of the contents of the periorbital connective tissue should be achieved in 15 to 20 minutes (recognized by lack of eye movements when the head is turned, ipsilateral pupil dilation, and lack of corneal sensation). Retrobulbar and 4-point blocks are discussed later.

Administering Medication to Eyes

Although some ruminants are surprisingly tolerant of eye manipulations, the use of commercially available topical anesthetics such as 0.5% proparacaine or tetracaine solution is essential for certain ophthalmic procedures that require extensive touching or manipulation of the globe, nictitans, or conjunctiva. Topical anesthetic agents cause mild stinging

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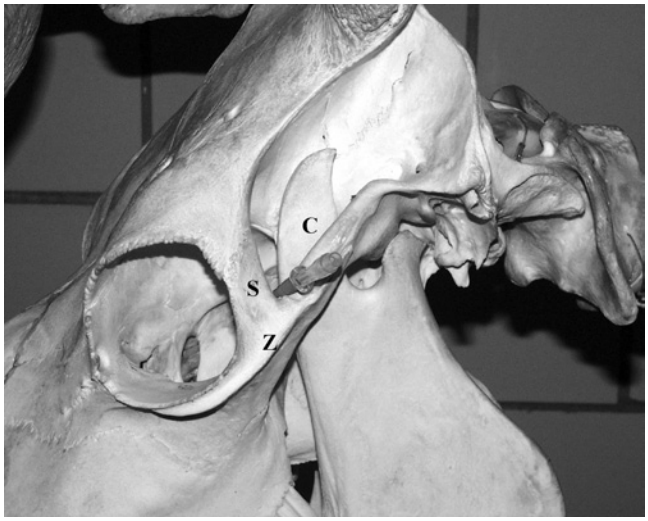


Figure 10-3 Peterson nerve block: a 12-cm needle is inserted subcutaneously at the angle between the frontal and temporal processes of the zygomatic bone. This site is bounded by the zygomatic arch (*Z*) ventrally, the supraorbital process (*S*) rostrally, and the coronoid process (C) of the mandible caudally.



Figure 10-4 Commercially available transpalpebral lavage catheter insertion needle and silicone tubing with footplate.

upon installation, cause hyperemia of the conjunctiva, and are mildly toxic to the corneal epithelium, thus resulting in a mild, diffuse corneal epithelial thickening. Faint, diffuse fluorescein uptake will be present after topical anesthetic administration. Complete external examination of the eye, including fluorescein staining, should always be performed before anesthetic installation. For procedures such as foreign body removal, conjunctival biopsy, and so on, the depth of anesthesia achieved by using topical drops will be increased if anesthetic drop administration is repeated by applying 1 to 2 drops to the eye every 20 to 30 seconds for 3 to 5 minutes. The depth of topical anesthesia and the patient's tolerance for ocular manipulations can be further enhanced if anesthetic-soaked cotton-tipped swabs are pressed on or adjacent to the area of concern (such as over a lesion to be biopsied) for 30 to 60 seconds, gradually increasing the gentle pressure with time. If these procedures result in inadequate depth of anesthesia, 1 mL of a local anesthetic can be administered subconjunctivally adjacent to the planned surgical site.

Alternatively, the application of topical anesthetics or any other ocular solution is most easily and aseptically performed by *gently* spraying the medication or solution onto the surface of the eye rather than trying to apply drops directly from a bottle. This technique conserves costly ophthalmic medications, can be performed without touching the patient's eyelids, and is very hygienic. If the spray device is kept clean, it can be used repeatedly over many days, thus maintaining sterility of the stock medication bottle. A very effective spray device is made by aspirating 1 to 3 mL of the ophthalmic stock solution into a tuberculin or 3-cm^3 syringe with a 25-gauge needle attached. The needle is immediately broken from the needle hub by grasping it between clean fingers and bending the needle at the hub until the needle breaks from the hub. Note that the end of the hub is still sharp; thus the spray device should not be held too closely to the patient's eye. During spray administration, the administrator's hand should rest somewhere on the patient's head so that the hand will move away simultaneously if inadvertent movements of the patient's head occur during spray administration. Thus the patient's eye will not inadvertently touch the abrasive hub. A test spray before administration will ensure that the medication is coming straight out of the syringe and is not being diverted to the side as a consequence of bending during needle removal.

Transpalpebral Ocular Lavage Apparatus

The transpalpebral catheter can be an extremely valuable adjunct to topical ocular therapy in ruminants, notably bulls that are otherwise unsafe to treat. A commercially available silicone elastic tubing device[4] (Figure 10-4) is readily available and is highly recommended. Similar devices can be easily fabricated, and very inexpensively so, by using polyethylene tubing (Figure 10-5), but polyethylene is much more reactive in tissue and more susceptible to breakage. Medication infusion pumps or IV drip sets can be attached to either catheter setup to help alleviate some handling of intractable patients, especially those with severe ocular disease that might need medication as often as every hour.

The patient is sedated, and the skin overlying the planned catheter exit point (usually at the dorsolateral orbit rim) is cleansed using povidone-iodine solution (note: soap solutions, especially those containing chlorhexidine, are very toxic to the eye and should not be used near the eye). The upper eyelid is paralyzed as described previously, and 3 to 5 mL of local anesthetic is infiltrated subcutaneously at the planned exit site. If using the commercial kits, ensure that the tubing is secured onto the insertion needle. The point of the insertion needle is securely cushioned in the tip of the surgeon's index finger with the blunt end held against the surgeon's palm. The surgeon's hand is turned so the index fingernail is toward the cornea and the index finger is inserted in the palpebral fissure, deep into the conjunctival fornix between the globe and the upper lid, and directed dorsally until the needle tip is touching the conjunctiva lining the inside of the orbit rim. Meanwhile, the opposite hand should simultaneously pull the upper lid out from the globe and down over the inserting finger. This maneuver ensures that the needle tip does not snag a conjunctival fold close to the

[4]Eye Lavage Kit—Part #6612 or 6612L, MILA International, Inc., 7604 Dixie Hwy, Florence, KY, US. milaint@att.net.

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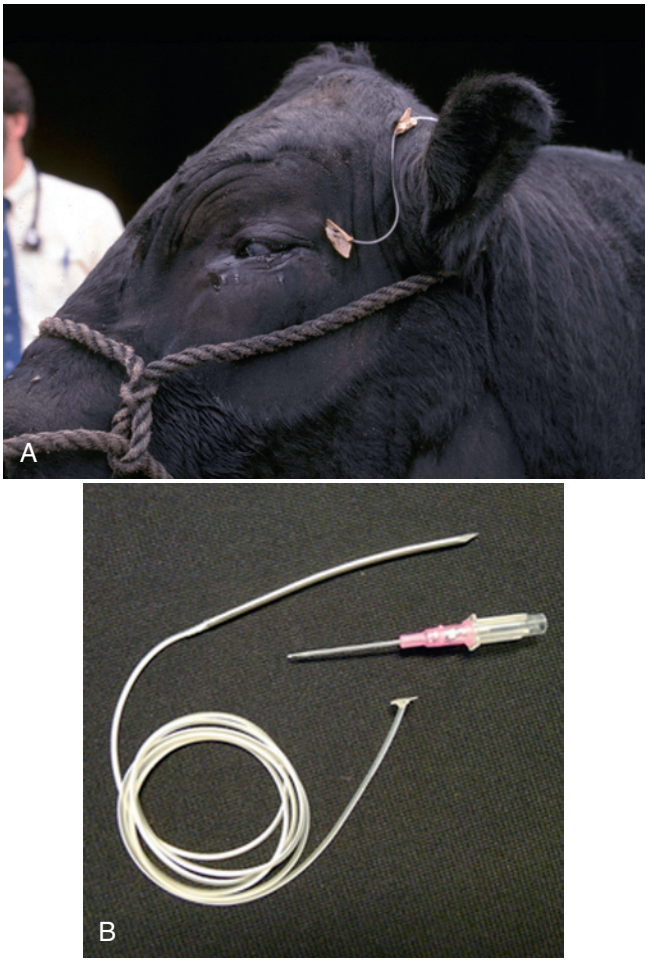


Figure 10-5 *A*, Four-year-old Angus bull with *B*, homemade transpalpebral ocular lavage apparatus consisting of size #190 polyethylene tubing with footplate flange. This was made by warming tubing over a match flame until it softened; then the tubing was pressed gently against a metal surface to create a footplate (footplate size and angulation of the tubing are easily customized).

lid margin, which could prevent proper blinking or a corneal ulcer after the tube is secured. The needle-tubing unit is pushed through the upper lid, just rostral to the bony orbit rim. The needle is carefully pulled through the upper lid, carrying the tubing with it until the footplate on the tubing is seated into the dorsal conjunctival fornix, taking care that the footplate remains inside the dorsal fornix of the conjunctival sac and is not pulled into the subcutaneous tissues of the dorsal eyelid. At this point, the eyelid should be manipulated to ensure that it moves freely and has not been snagged by the needle (when the lid is manually closed, the tubing should move very little or not at all). Alternately, the commercial kits contain a 3-inch plastic hollow tube or "introducer," which can be put over the needle before the needle is placed inside the palpebral fissure. The author finds placement more precise and simpler without using the introducer. Once the tubing is in place, it should be wiped clean of blood and thoroughly dried. Next, small pieces of waterproof adhesive tape ("butterflies") are placed around the tube 1 inch from the exit wound in the lid, with a second butterfly 2 inches away from the first. Ensuring that the footplate is properly positioned, the tubing is held taut and the



Figure 10-6 A 3-day-old Hereford calf with hydrocephalus, variable strabismus and nystagmus, and cardiac and vertebral defects.

butterflies are sutured to the skin to prevent retrograde movement of the tubing and footplate into the conjunctival sac. The tubing should be taut between each butterfly. Cyanoacrylate glue is applied over the tape and tube, further securing the tube to the tape and the tape to the skin. The tubing is directed under the halter, over the poll and along the neck, or elsewhere as convenient. The needle is removed and a catheter and injection cap installed in place of the needle. Additional adhesive-tape butterflies may be placed along the length of the tubing and secured as needed. If a homemade polyethylene tubing device has been created, be aware as the tubing is secured that polyethylene is not as elastic as silicone tubing and be sure to plan placement to allow for head flexion.

DIAGNOSIS OF GLOBE AND ORBIT DISEASES

Congenital

Common congenital abnormalities of the orbit and globe in ruminants include microphthalmos (a smaller-than-normal eye usually with multiple associated ocular defects) and strabismus (Figure 10-6). Patients with microphthalmos (Figure 10-7*A* and *B*) have correspondingly small orbit bones that will not develop normally. Patients with microphthalmos may have associated cardiac, abdominal wall, or caudal spinal closure defects, and a careful physical examination is warranted. Culling may be indicated; a heritable component has been reported in some dairy breeds. Microphthalmos and a wide spectrum of blinding and nonblinding ocular anomalies such as cataracts (Figure 10-8) can occur with chronic vitamin A deficiency in pigs.

Unilateral or bilateral congenital strabismus of variable degree and direction may be seen in any species and may be seen associated with other physical and neurologic defects. Bilateral convergent strabismus (esotropia, Figure 10-9*A* and

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Figure 10-7 *A*, Two-week crossbred piglet with bilateral microphthalmos. Piglet was born to a sow that was fed doughnuts and was severely vitamin A-deficient. *B*, Calf with microphthalmos. Other congenital abnormalities were found in this Jersey calf: wry tail and ventricular septal defect.

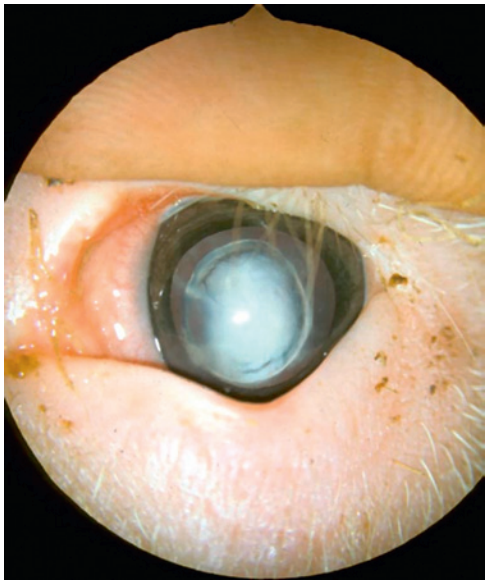


Figure 10-8 Three-week-old crossbred piglet with microphakia, cataract, and other congenital ocular anomalies. Piglet was born to a sow that was fed doughnuts and was severely vitamin A–deficient.



Figure 10-9 *A*, A 4-week-old female Holstein calf with severe esotropia and a constant "star-gazing" head carriage was unable to walk without stumbling and could not eat from the ground. *B*, Dorsal oblique and lateral rectus muscle shortening procedures were performed with resultant marked improvement in the head position, vision, and behavior. The calf was maintained as a pet and was not bred. Such procedures are best referred to specialists.

B) with or without exophthalmos and nystagmus occurs in dairy cattle and may progress with age. Visual acuity is variable; the condition has been proven to be inherited in some dairy breeds, and culling of affected animals may be indicated. If vision is impaired, affected animals may fail to thrive and have difficulty negotiating their environments. Surgical transposition of the extraocular muscles may effect improvement in vision in some pet animals; this should be performed by a board-certified veterinary ophthalmologist.

Exophthalmos

Marked exophthalmos can be "normal" in some dairy cattle breeds. Several cases of acquired exophthalmos have been seen in young cattle associated with cavernous sinus syndrome or vascular malformations and this area should be assessed in all cases of exophthalmos and a complete cranial nerve exam performed, but for the most part, acquired exophthalmos in adult cattle is usually attributable to either

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Figure 10-10 Left unilateral exophthalmos in a cow.



Figure 10-11 Orbit cellulitis with severe secondary exposure keratitis caused by a wooden foreign body found in the retrobulbar tissues in a cow.

orbital inflammatory disease or to orbit neoplasia. A simple history and clinical presentation can often differentiate between these two broad categories. Inflammatory causes of exophthalmos (foreign body, cellulitis, sinusitis, infected tooth, myositis, etc.) are usually peracute to acute in onset, with the patient exhibiting marked pain when the affected eye is retropulsed into the orbit and when the jaw is opened (Figure 10-10). Affected animals are often febrile, are depressed, and are usually very reluctant to move their jaw to eat or chew cud. Abnormal ipsilateral nasal odor and discharge may be present with concurrent sinus involvement. In contrast, exophthalmos due to orbital neoplastic diseases is of slower onset, and the patient is rarely in discomfort except in cases of exposure damage to the cornea and ulceration. Exophthalmos should be distinguished from glaucoma (rare in ruminants, diagnosed by assessing intraocular pressures) and proptosis (protrusion of the eye from the orbit, usually due to trauma). In a ruminant, an eye protruding from its orbit because of trauma has a grave prognosis and is usually associated with other serious craniofacial injuries and possibly neurologic signs. A proptosed eye may require enucleation if it is ruptured or if extensive extraocular muscle avulsion exists. Regardless of cause, any exposed eye requires immediate and frequent cleansing and moistening. The eye and periocular tissues can be moistened in an emergency with sterile saline, sterile eye wash, or any number of non-peroxide contact lens solutions until medical attention is available.

Orbital Inflammation and Cellulitis

As stated previously, orbit inflammatory disease in cattle is usually of peracute to acute onset and may be caused by foreign-body penetration, puncture wounds, sinusitis, or extension of a severe infection in the eye (panophthalmitis). Puncture wounds and foreign bodies can enter the orbital space through the facial skin, eyelids, conjunctiva, or mouth; all of these areas should be examined carefully during the physical examination. Manual examination of the oral cavity may be difficult or impossible because of the pain caused by opening the mouth. Pain with jaw movement may be extremely severe and result in complete anorexia in some patients. The pain is usually a result of movement of the coronoid process of the mandible compressing the inflamed retrobulbar tissues. Adjacent muscles of mastication may also be inflamed. Additional physical examination findings include fever, anorexia, depression, mild to severe exophthalmos with possible exposure keratitis, periorbital swelling, and pain (Figure 10-11). Inspection and manipulation of wounds or draining tracts may reveal the presence of a foreign body. Abnormal ipsilateral nasal odor and discharge may be present with concurrent sinus involvement; sinus swelling may be evident and sinus resonance after percussion may be reduced or absent. Ultrasound and radiographic examinations may be helpful in locating foreign objects and ruling out fractures, sinusitis, lumpy jaw, or a large mass such as a tumor. Magnetic resonance imaging or computed tomography with and without contrast may be ideal in many cases where initial workup fails to disclose an etiology. Fistulograms can be performed if draining tracts are present. A tissue aspirate for culture and cytology can be useful to confirm the presence of bacteria. Additional information regarding diagnosis and treatment of sinus disorders can be found in Chapter 13.

Treatment is directed first at protecting the cornea and also treating inflammation and relieving any known causes of the cellulitis. The cornea is treated with sterile artificial tear ointments six to eight times a day to maintain corneal lubrication; if corneal ulcers are present, standard medical or surgical ulcer treatment is indicated according to the severity of the ulcer. Temporary tarsorrhaphy using split-thickness horizontal mattress sutures of 4-0 silk (ideally) or 5-0 Vicryl is highly recommended if the exophthalmos is not improved within 24 hours. If exposure keratitis results in corneal ulceration and rupture, enucleation may be required.

Orbit inflammation can be managed with hot packs four to six times a day, broad-spectrum antibiotics (based on bacterial sensitivity results), and antiinflammatory drugs. If the inflammation persists, surgical drainage may be necessary. Usually, over time, the swelling will localize and ventral drainage can be established. It may be possible to localize a fluid pocket by palpation or with ultrasound. An adjacent skin site should be prepped and aspirated using aseptic technique. Ventral drainage is established and vital structures are avoided. Parenteral penicillin therapy is appropriate initial therapy while awaiting culture results. If the orbit disease is secondary to sinus infection, sinus trephination, lavage, and drainage are indicated.

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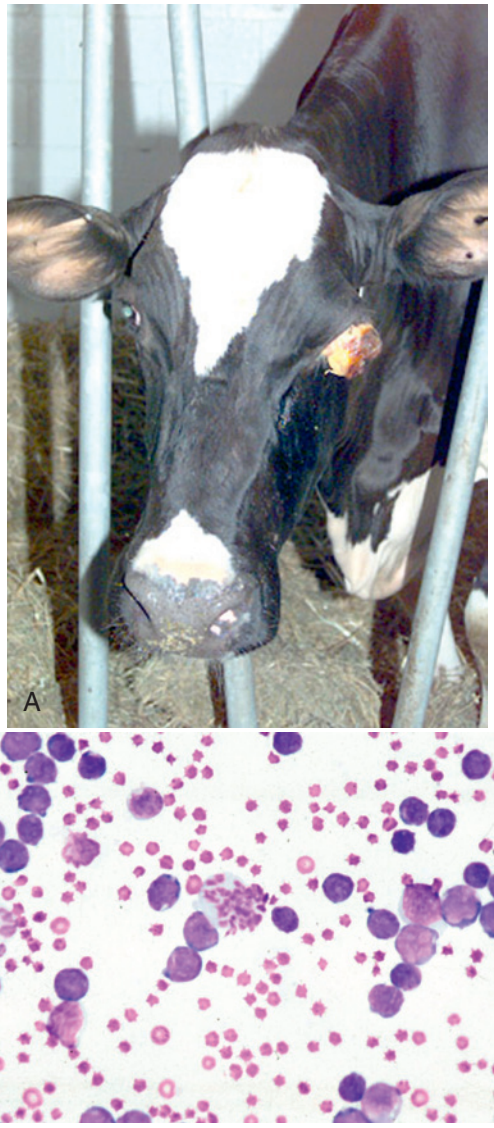


Figure 10-12 *A*, A 7-year-old Holstein with subacute, unilateral exophthalmos. *B*, Orbit aspirate of lesion showing typical appearance of lymphosarcoma. Neoplastic cells are predominantly large with a high nuclear to cytoplasmic ratio and a moderate variability to nuclear and cytoplasmic size. Several nuclei contain very prominent nucleoli. Centrally, a neoplastic cell is undergoing mitosis.

Orbital Neoplasia

An adult dairy cow with nonpainful unilateral or bilateral exophthalmos of subacute to chronic onset most likely has lymphosarcoma (Figure 10-12*A* and *B*). Other orbital neoplasias occur rarely, primarily to the orbit or as extensions from adjacent tissues. Excessive orbital fat or orbital fat prolapse (Figure 10-13*A* and *B*) may present similar to orbit neoplasias but can often be ruled out by palpation, ultrasound, cytologic sampling, or biopsy. If a biopsy is performed, the conjunctiva must be carefully sutured closed or orbit fat prolapse may occur. Digital palpation of the retrobulbar area through the palpebral fissure after application of topical anesthesia is a useful adjunct examination technique (Figure 10-14). Orbital fat is soft, fluctuant, and nonpainful to palpation; inflammatory lesions usually are painful and firm whereas lymphosarcoma or other neoplasias are nonpainful and firm.

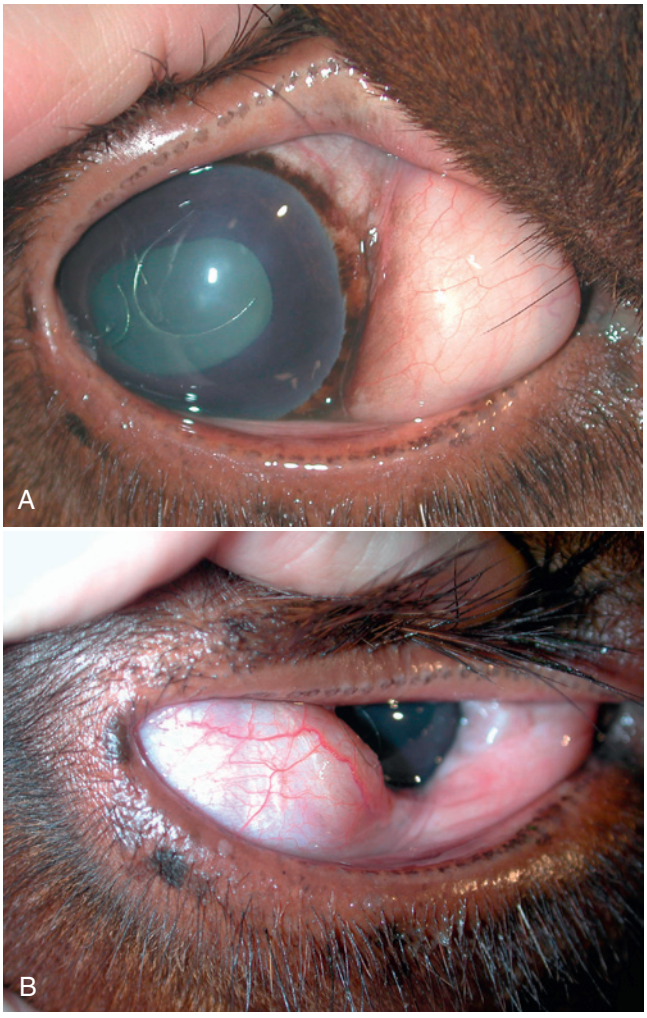


Figure 10-13 *A*, Orbital fat prolapse in an adult Shorthorn cross. *B*, Close-up view.



Figure 10-14 Digital palpation of palpebral fissure.

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A complete physical examination should be performed, including careful cardiac auscultation and palpation of peripheral lymph nodes. Rectal examination should be performed, paying particular attention to uterine palpation and evaluation of regional lymph nodes. In some cases, the orbital mass may be directly palpated through the conjunctival fornix if, following the application of topical anesthetic, a finger is placed within the palpebral fissure and directed beyond the equator of the globe. Fine-needle aspiration of orbital tissues using a 20- to 22-gauge 7- to 12-cm needle with or without ultrasound guidance may be diagnostic (see Figures 10-12*B*). Serologic testing and polymerase chain reaction may be performed to assist in diagnosing lymphosarcoma.

Cows affected with orbital lymphosarcoma usually die within 3 to 6 months, but a cow in late gestation may survive sufficiently long to deliver a healthy calf. In such cases palliative treatment to protect the eye and reduce ocular pain from exposure may be indicated. If the cornea is healthy, the exophthalmos is mild and only slowly progressive, and if parturition is imminent, topical artificial tear ointments applied six to eight times a day may suffice.

A patient with moderate, progressive exophthalmos or a longer time to parturition may require enucleation or protection of the globe(s) by performing a permanent tarsorrhaphy (Figure 10-15). After sedation and application of local and topical anesthesia, the eyelid margins are trimmed off and discarded. The lids are closed using 3-0 to 4-0 absorbable sutures in the fibrous tissue layer of the eyelid (the tarsal plate) and also in the subcutaneous tissues and skin, taking great care that no sutures penetrate the full thickness of the lids and touch the cornea. If exophthalmos is severe or rapidly progressive, enucleation (Figure 10-16*A*) or exenteration (Figure 10-16*B*) is indicated if the cow is to be maintained comfortably until she can give birth.

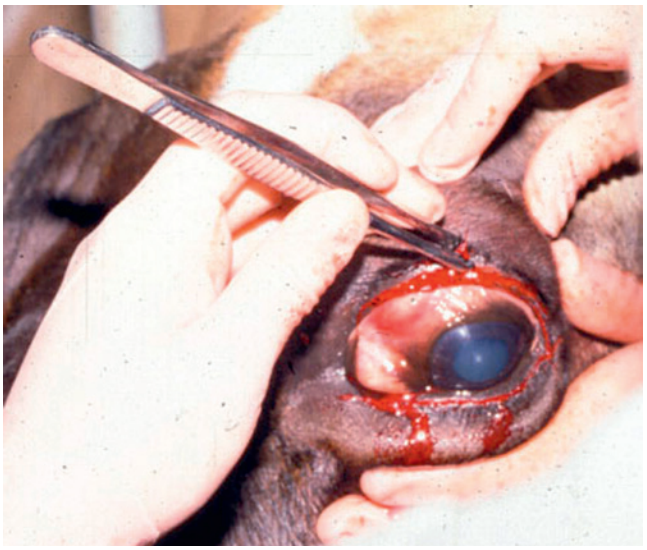


Figure 10-15 Permanent tarsorrhaphy on an 8-year-old Jersey 3 weeks prepartum.

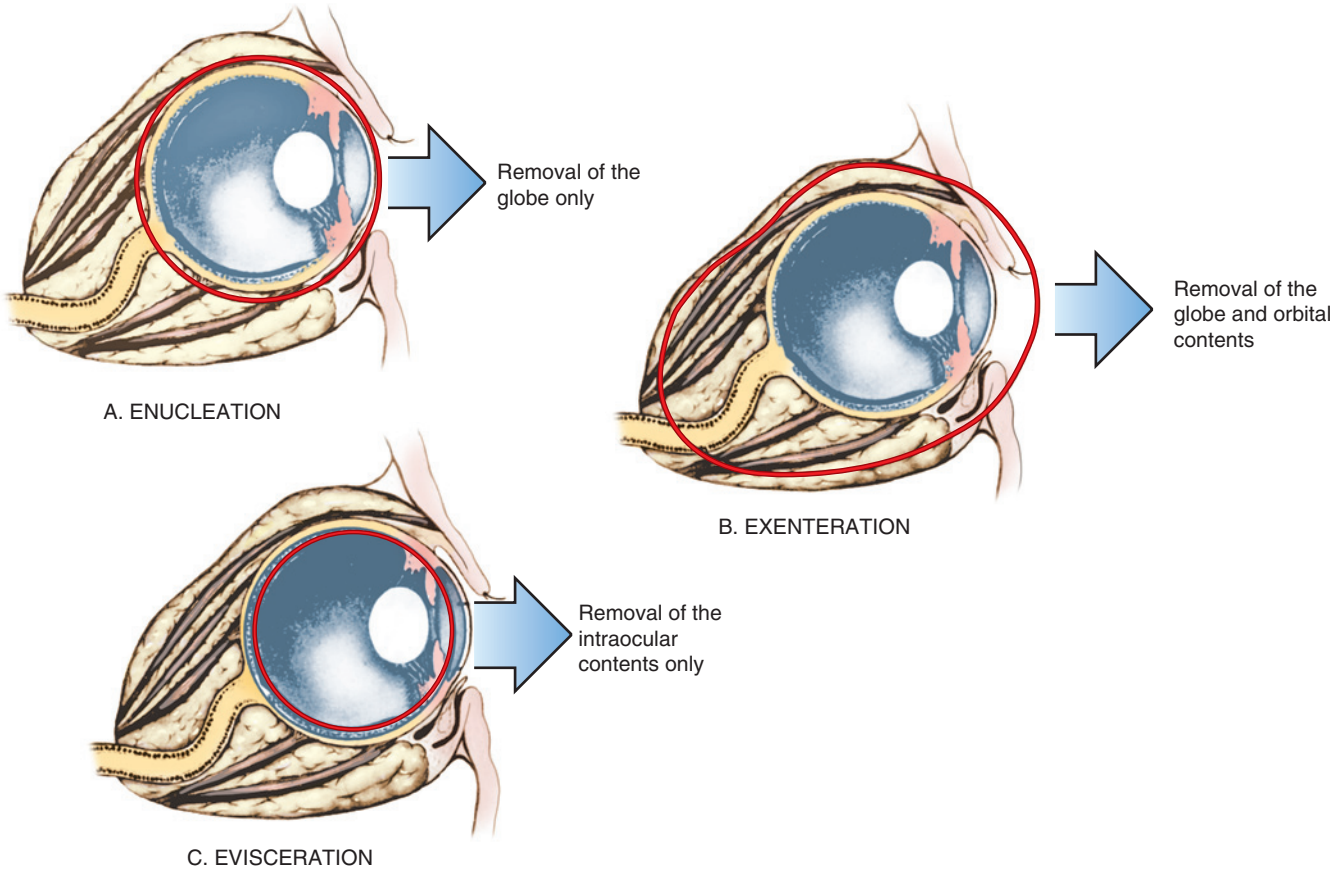


Figure 10-16 *A*, Diagrammatic representation of enucleation; *B*, exenteration; and *C*, evisceration. (Reprinted with permission from Slatter D: Fundamentals in veterinary ophthalmology, ed 3, Philadelphia, 2001, WB Saunders.)

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GENERAL SURGICAL TECHNIQUES

All advanced ocular surgeries can be performed in farm animal species, but this chapter discusses only the most common. For numerous reasons, including financial constraints, one of the most common ocular surgical procedures performed by many large-animal veterinarians is enucleation, and every large-animal veterinarian should be comfortable performing this surgery because it can be life changing (when a chronically blind and painful eye is removed) or life saving (in cases of invasive tumors confined to the periocular tissues). Indications for enucleation include extensive, uncontrolled inflammation infection or trauma, painful blind eyes from glaucoma or any other cause, invasive ocular or orbital tumors, or congenital defects that result in exposure damage to the cornea and chronic pain. In large-animal surgery, the transpalpebral technique is the most commonly performed enucleation technique although subconjunctival enucleation is ideal when removing an eye with glaucoma. Removal of the eye and orbit contents (exenteration) is a significantly more invasive procedure. During enucleation, exenteration, or other orbital surgeries in farm animals, the surgeon should review the orbital anatomy of the species in question in advance to be able to avoid, for example, damaging the very thin-walled caudal extension of the maxillary sinus present in adult cattle (the lacrimal bulla) as well as review critical vascular and neural structures passing through the orbit to supply other parts of the face. Following any surgical procedure on the eye, flunixin meglumine (1 mg/kg) is recommended preoperatively and for at least 2 postoperative days to decrease postoperative pain and inflammation.

Preparation of Periocular Tissues

Individual surgeons may have personal preferences for the type of tissue cleansing and preparation done before surgery, but some basics about periocular surgical preparations should be emphasized. Of utmost importance are protection of the healthy eye and remembering to use prep solutions that do not cause irritation or damage to either eye(s).

Sterile artificial tear ointments are used to protect the cornea before preparation procedures. However, ointments should never be used perioperatively if an intraocular procedure is planned. If artificial tear ointments are not used during preparation, an anesthetized patient's eyelids should be manually closed whenever they open, and sterile saline or collyrium should be applied frequently to the cornea to prevent corneal desiccation.

Removal of hair from any surgical field is standard presurgical protocol but requires particular care near the eye. Some surgeons do not remove any hair at all before intraocular surgery because of their concern that small pieces of hair may not be completely rinsed from the conjunctival fornices and may enter the open eye during surgery. Other surgeons clip only the long or dirty periocular hairs using scissors but do not use electric clippers or razors out of concern for damage and irritation of the sensitive skin of the eyelids. Using care and sharp clipper blades, an experienced surgeon can clip periocular hair without trauma to the patient. Chemical depilatories must not be used near the eye; waxes may cause eyelid swelling and irritation and damage to the eye surface if carelessly applied.

Extreme care must be taken to ensure all hair particles are removed from the conjunctival sac after clipping if the eye is to be opened during a planned intraocular surgery or laceration repair. A 20- to 22-gauge, 5- to 7-cm soft, flexible catheter can be attached to a 12- to 20-cc syringe filled with sterile saline and used to repeatedly lavage all of the recesses of the conjunctival sac and the bulbar surface of the membrane nictitans. The author uses the same syringe to thoroughly flush the upper and lower nasolacrimal puncta and ducts, flushing normograde to ensure that tear duct debris does not enter the conjunctival sac. A significant amount of exudate and debris residing within the nasolacrimal duct system can reenter the conjunctival sac during surgery and should always be flushed away before and after any eye surgery.

Surgical prep detergents, such as povidone-iodine detergent scrubs, alcohol, hydrogen peroxide, and chlorhexidine diacetate, should never be used near the eyes or anywhere there is a chance they could drip or run into the eyes. Chlorhexidine diacetate in particular can cause severe ocular disease and should be avoided. Povidone-iodine solutions (20% solution in sterile saline or sterile water) are acceptable sanitizers for the periocular skin. Five or more centrifugal scrubs beginning at the eyelid margins and circling outward are performed, alternating with sterile saline scrubs or rinses. Finally, the povidone-iodine solution should be applied and left in place for several minutes.

They are many acceptable choices of surgical drapes: the eye can be draped with a standard four-drape technique, a fenestrated drape, or specialized, nonfenestrated, fully self-adhesive eye drapes such as 3M Ioban incise drapes.[5] The latter are highly recommended for any type of intraocular surgery because their fenestration can be customized and the adhesive drape adheres beautifully to the lids and periocular facial skin and hair. For standing surgeries, once the patient's head is secured, fully adhesive 45 × 60-cm incise-type plastic drapes,with or without ionophore impregnation, have proven to be very useful. These thin, translucent drapes eliminate the need for bulky cloth or paper drapes, which can blind and frighten the standing animal and which often become dislodged if patient movements occur. The adhesives on the 3M incise drapes are excellent and maintain the drapes in place throughout most head movements. As long as the eyes are completely protected during application, a cyanoacrylate skin adhesive can be used before drape placement to ensure even better skin to drape adhesion.

Basic Ophthalmic Surgical Instrumentation

Minimal investment is needed to purchase the few additional instruments necessary to perform the surgical procedures discussed in this chapter that would not be found in a standard soft tissue surgical pack.

A basic ophthalmic instrument set (Figure 10-17) suitable for eyelid, conjunctival, and simple corneal surgery includes small towel clamps such as Schaedel's; a Bard-Parker #9 blade handle; small Mayo scissors; general suture scissors; small stitch scissors (Westcott); forceps such as Adson or Brown-Adson suitable for eyelid surgery in large ruminants; Allis tissue forceps useful during entropion and enucleation surgery; forceps such as fine Bishop-Harmon suitable for eyelid surgery in small ruminants; 4 Hartman curved mosquito hemostats; four 6-inch Kelly hemostats; a Derf or other small needle holder; large, curved utility scissors with serrated blade (enucleation in adult cattle); small curved and straight Metzenbaum scissors; small ophthalmic scissors such as a Stevens or Westcott tenotomy scissors; a small needle holder appropriate for 5-0 to 6-0 or smaller sutures such as an 11-mm, nonlocking, curved Castroviejo needle holder; small tissue forceps suitable for cornea and conjunctiva, such as a 0.4-mm Colibri-type 1 × 2 or delicate 1 × 2 Bishop-Harmon; double-ended Martinez corneal dissector; Snellen or Desmarres lid forceps with solid lower plate;

[5]3M Ioban™ 2 Antimicrobial Incise Drapes, 3M Europe N.V./S.A., Hermeslaan 7, B-1831 Diegem, Belgium. http://solutions.3m.com.

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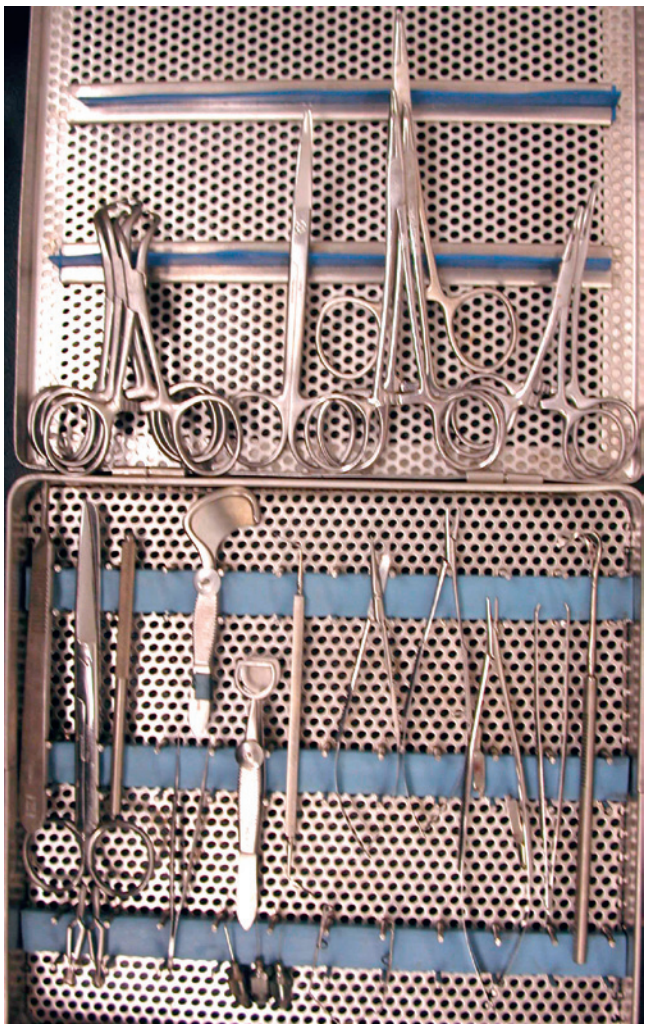


Figure 10-17 A basic ophthalmic instrument set.

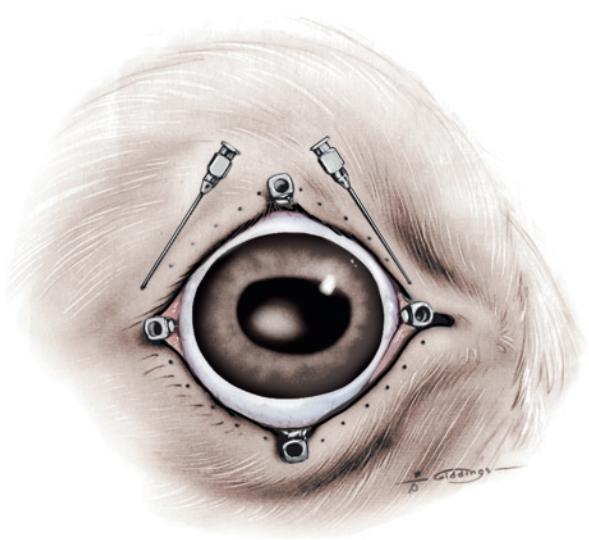


Figure 10-18 Injection sites for local anesthesia before transpalpebral enucleation in cattle. Five to 10 mL of lidocaine is injected at each site to produce anesthesia and proptosis. (Reprinted with permission from Slatter D: Fundamentals in veterinary ophthalmology, ed 3, Philadelphia, 2001, WB Saunders.)

simple eyelid speculum, such as a 20-mm Barraquer; Desmarres lid retractors (2); and nonlinting sponges.[6] A binocular magnifying loupe is extremely useful for eye surgery in the field or hospital if better magnification systems are not available. Suture material appropriate for eye surgery should be available, including 5-0 and 6-0 absorbables for eyelid surgeries, 4-0 silk used for stay sutures and procedures such as tarsorrhaphies. Synthetic absorbable sutures, 6-0 to 7-0, with reverse cutting needles are suitable for corneal repair.

Anesthesia

In most instances, common ocular surgeries can be done in a standing, sedated large farm animal. However, general anesthesia is certainly advantageous when a cow is fractious, has a severe lesion such as a penetrating corneal wound, or cannot be locally anesthetized or for humane concerns.

If the surgery is to be done standing, adequate restraint with local and topical anesthesia is essential, and supplemental sedation is helpful. The adult bovine should be placed in a chute or stanchion and the head tied snugly to the side in a position comfortable and safe for the patient and convenient for the surgeon. The face is clipped and prepared for aseptic surgery. Local anesthetic is first injected circumferentially around the lids, 2 to 3 cm from the eyelid margins, with additional anesthetic injected at the medial and lateral canthi. To anesthetize the globe itself there are several options, including the Peterson block discussed previously. Retrobulbar blocks can be performed in adult cattle by depositing 15 to 20 mL of 2% lidocaine into the retrobulbar space, within the cone of the periorbita connective tissue, using an 8.75-cm ($3\frac{1}{2}$-inch) 18-gauge needle. This block should be avoided unless experience is first obtained on a cadaver head. The author prefers in all cases to perform a 4-point block, using a gently curved, 22-gauge, $3\frac{1}{2}$-inch spinal needle, directed through the conjunctival fornix and along the sclera (not penetrating the globe) at 10 o'clock, 2 o'clock, 4 o'clock, and 8 o'clock (Figure 10-18). The 3:00 and 9:00 positions should be avoided. At each site, the needle is inserted to a depth of 6 to 10 cm (according to the size of the patient) and 5 to 8 mL of 2% lidocaine is injected. Alternately, the needle may be directed through the closed lids, inserted near the orbit rim, directed toward the orbit apex for 6 to 10 cm (according to the size of the patient). This block carries increased risk of anesthetic being deposited within the globe itself and not into the retrobulbar tissues. The globe and retrobulbar tissues are usually completely anesthetized when the extraocular muscles are paralyzed, the globe can no longer move, the pupil is widely dilated, and the corneal reflex is absent (all parameters should be assessed). Pupil dilation has been reported to be a sufficient indication of a properly performed block but in some cases the pupil may be dilated yet the patient will still feel pain during enucleation. *Patient welfare mandates full anesthesia before proceeding with surgery. If the patient becomes fractious or repeatedly vocalizes during surgery it is usually because pain is being felt.* Although beef cattle may behave differently, a dairy cow with complete orbit and periocular anesthesia will usually stand quietly throughout an entire enucleation. If she moves, it generally indicates that she hurts; the surgeon should stop the surgery and administer additional local anesthesia as needed.

[6]Weck-Cel, Solan Ophthalmic Products, Xomed Surgical Products, Inc., Jacksonville, FL, US.

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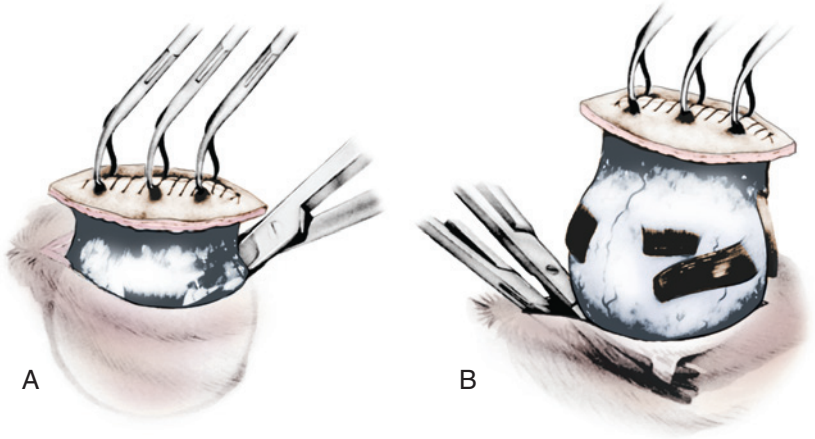


Figure 10-19 *A*, A periocular incision is made, extraocular muscles are transected, and dissection continued toward the orbit apex. *B*, The optic nerve and associated vessels are transected. (Reprinted with permission from Slatter D: Fundamentals in veterinary ophthalmology, ed 3, Philadelphia, 2001, WB Saunders.)

Enucleation: Transpalpebral Approach

After appropriate preparation and thorough nasolacrimal duct lavage, the eyelids are sutured or clamped together. A circumferential incision around the eyelid margins is made through the skin, into the subcutaneous tissues of the eyelid but not through the tarsal plate (the connective tissue layer of the lids) or conjunctiva (Figure 10-19). This incision should be 1.5 to 2.0 cm from the lid margins to avoid the large angularis oculi vein dorsomedially and to ensure sufficient eyelid remains to close over the orbit. The lateral and medial canthal ligaments securing the eyelids to the orbit bones will be encountered deeply subcutaneous; they are very broad and dense, and their attachments extend well into the interior of the medial and lateral bony orbit, as well as on the exterior bony surfaces and should be transected using a blade or Mayo scissors. Once these ligaments are transected, forward traction is applied to the freed eyelids, and dissection is continued caudally toward the orbit rim, taking care to stay external to the tarsal plate (connective tissue sheet in the deep eyelid). The conjunctival sac should remain closed during this dissection. As dissection approaches the orbit rim, the scissors should be directed perpendicular to the plane of the skin and the tarsal plate should be penetrated. Further dissection in this direction should expose the sclera. The four rectus and two oblique extraocular muscles are then identified and incised one by one, through their tendon of insertion on the sclera. However, in cases of panophthalmitis or when enucleation is necessary because of severe orbital cellulitis, the extraocular muscles and the other soft tissues within the periorbita should be excised as widely as possible, or a transpalpebral exenteration should be performed. Significant bleeding will occur in these cases. In animals in which infection of the sclera and posterior eye is not a concern, intraoperative bleeding is considerably lessened if each rectus muscle is transected at its tendon of insertion on the sclera. As each muscle is encountered, one blade of a Metzenbaum scissor is inserted between the muscle and sclera, and the scissor is pulled anterior toward the limbus before cutting, thus ensuring that the transection occurs through muscle tendons, which bleed much less than the muscle belly. The dorsal and ventral oblique muscles have very short tendons of insertion; they are transected close to the sclera and will bleed. After rectus and oblique muscle transection, additional anterior and medial traction is applied, and the retractor muscles that form a cone around the optic nerve can be easily palpated from the lateral side of the orbit. *Traction on the globe should be as little as possible to decrease vagal nerve stimulation and to avoid potential damage to the optic chiasm.* The surgeon should attempt to "strum" this cone of tissues extending posterior from the globe (retractor bulbi muscle unit surrounding the optic nerve) because the cone is rarely visualized directly because of variable amounts of orbital fat and hemorrhage. Once the locations of the retractor muscle cone and nerve have been confirmed, the surgeon's nondominant index finger should remain on the cone while the dominant hand directs the blades of a large, curved, serrated utility scissor along the finger until the blades reach just beyond the fingertip. Two to three carefully placed cuts at this location will sever the muscle and optic nerve; as soon as the nerve is severed the globe "gives way." Holding the lid-conjunctiva-nictitans-globe unit in one hand, the remaining medial attachments on the globe are severed and the globe and attached tissues are removed and set aside. Care should be taken to palpate throughout the excised tissues, attempting to feel for the cartilage of the third eyelid to ensure it has been completely removed. To eliminate any possibility of postoperative lacrimocele formation (rare in ruminants), all secretory tissue must be removed from the orbit. This includes the eyelid margins, the lacrimal caruncle, the conjunctiva, and the gland of the third eyelid. Some surgeons remove the main lacrimal gland, but because its ductules have been destroyed, this is not mandatory. The latter is located within the periorbita of the dorsolateral orbit, ventral to the orbit rim.

Meticulous hemostasis during enucleation is time consuming and in most cases is not necessary. In the enucleation technique described previously, bleeding is generally minimal unless severe inflammation is present. Severe bleeding during enucleation surgery usually occurs when the surgeon blindly cuts tissues located in the ventral, ventronasal, and caudal orbit. The majority of dissection should therefore occur dorsal and dorsolateral where tissues are more easily identified before they are cut. When ventral dissection is needed, the surgeon should try to identify tissues before cutting them. Note that in the surgery as described previously, no attempt is made to clamp or ligate the optic nerve and retractor muscle cone because doing so may create dangerous traction on the optic nerve (which in smaller farm animals and other species can blind the remaining eye) and because the bleeding from these tissues is minimal. In

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Figure 10-20 Closure of the surgical site following enucleation in a cow.

addition, optic stalk sutures usually slip off, traction during their placement may increase vagal stimulation, and the sutures themselves can act as a deep orbital foreign body, continuing an orbital inflammatory or infectious process if one was preexisting. In fact, the author has never ligated nor clamped the optic stalk in any enucleation procedure in any species. Instead, following removal of the globe and inspection of the remaining orbit contents, the orbit is packed with sponges and gentle pressure is applied as closure commences. Of course, all sponges are removed before the first tissue plane is closed. If sufficient periorbital connective tissue remains, this layer should be closed first, followed by subcutaneous tissue closure. An absorbable or nonabsorbable suture is used in the skin according to the surgeon's preference and the patient's demeanor (Figure 10-20). Using elastic adhesive bandage material and a thick pad of gauze over the incision, a pressure bandage is ideally applied for 24 hours. Drains are not necessary unless there is preexisting infection. Antibiotics and analgesics should be given for 5 to 7 days after surgery. If possible, feed sources should be elevated for 2 to 3 days.

Enucleation: Subconjunctival Approach

A simpler, much less traumatic procedure that is indicated for removal of glaucomatous, phthisical, or other noninfected globes, subconjunctival enucleation begins by placing an eyelid speculum or sutures to maintain the lids in an open position. The dorsal conjunctiva is incised 1 cm posterior to the limbus, and this is continued 360 degrees around the globe. The extraocular muscles are incised at their tendons of insertion on the sclera, as described previously. Working from the dorsolateral aspect of the orbit, the optic stalk is isolated and incised as described previously. Bleeding is very minimal to this point. Once the globe is removed, the palpebral conjunctiva is located and dissected fom the inside of the lids. The entire nictitans and its conjunctiva are completely excised, palpating to ensure the entire cartilage and the secretory gland or glands surrounding the cartilage have been removed. The lid margins are excised and bleeding controlled. Closure is as for transpalpebral enucleation.

Orbit Exenteration

Exenteration removes the globe and as much of the orbit contents as possible. For exenteration surgery, the dissection is done outside of the periorbital connective tissue cone; thus all the connective tissues and muscles surrounding the globe are removed (see Figure 10-16*B*). For extensively invasive squamous cell carcinoma (SCC) in cattle, this is the preferred procedure.

The surgery commences as in the transpalpebral approach described previously. As the orbit rim is reached, the plane of dissection remains against the bony orbit walls. All extraocular eye muscles are removed along with a substantial portion of the optic nerve, using caution to avoid traction transmitted to the optic chiasm that might damage the contralateral optic nerve, as discussed previously. Closure is as already described. A drain may be necessary for 48 to 72 hours.

Evisceration with Intrascleral Prosthesis

Evisceration is the removal of the contents of the globe, leaving the cornea, sclera, extraocular muscles, and adnexal structures in place (see Figure 10-16C). Following evisceration, a silicone prosthesis is inserted into the remaining corneoscleral shell. The result is a painless eye with a hazy gray-white cornea and a moderately cosmetic appearance after 6 to 8 weeks of healing. This surgery is usually reserved for those select cases where enucleation might ordinarily be recommended but where the owner desires a better cosmetic result. In general, prostheses are placed to benefit the owner or the public, who may prefer the presence and appearance of a gray-white "eye" to an empty orbit. When the surgical site has healed, the patient appears to still have an eye present, lids that still blink, and a globe that still moves but is blind.

Evisceration with prosthesis should never be performed in any eye with preexisting infection, significant corneal disease, or any corneal ulceration, or when there is any possibility that intraocular neoplasia may be present (ultrasound examination should be performed on the globe preimplant if the intraocular structures cannot be fully assessed during an ophthalmic examination).

Indications for the procedure are conditions such as chronic glaucoma, uveitis, or any other blinding painful ocular disease where neoplasia and infections have definitely been ruled out and where the cornea remains relatively healthy. Perioperative antibiotics should be administered. The procedure is easiest if performed under general anesthesia. After a routine clip, prep, and nasolacrimal lavage, an eyelid speculum is placed or stay sutures or hand-held retractors are used to retract the eyelids. Stay sutures of 4-0 silk are placed at 3 and 9 o'clock in the limbus, with care taken so that they do not penetrate the globe. The dorsal conjunctiva is sharply incised dorsally at the 12 o'clock position anterior to the equator and approximately 0.5 to 1.5 cm from the limbus (increasing the distance from the limbus according to the size of the globe). The conjunctival incision parallels the limbus and is continued from the 12 o'clock to the 2:30 o'clock and 9:30 o'clock positions on the globe so the final incision encompasses 140 or more degrees. The sclera is incised in a similar manner, using a #11 blade followed by Metzenbaum scissors or with thermocautery. Care must be taken to avoid transecting any rectus muscles or a globe with strabismus will be the final result. Care should also be taken to avoid carrying this incision to the 3 o'clock and 9 o'clock positions, as critical vascular structures are present there. As soon as the sclera is incised, vitreous and aqueous humours will exit the wound, thus collapsing the globe. Hemorrhage will increase and can be suctioned, as needed, *avoiding touching the cornea with the suction tip.* If care is taken at this point to incise only sclera and not the underlying choroid, bleeding will be less. Suction and pinpoint cautery can be used as needed for hemostasis.

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Bleeding will be significant as the choroid is removed from the eye, and suction, always directed caudally in the globe to avoid the cornea, is highly recommended. A small blunt spatula, such as a lens or cyclodialysis spatula, is inserted between the sclera and choroid and directed forward to carefully separate the choroid from its scleral attachments in the area of the iridocorneal angle, again avoiding any corneal touch. The choroid is then bluntly separated from the sclera and from the region of the optic nerve. If the choroid is not removed with suction, two-tissue forceps can be used to grasp and remove the choroid from the eye in a hand-over-hand manner. The choroid may tear during removal, with remnants inside remaining attached to the sclera. These will continue to bleed and should be removed as completely as possible using suction and blunt dissection. Complete hemostasis, however, is impossible.

A silicon ball implant is then placed inside the corneoscleral shell. The implant size should be determined preoperatively and several sizes made available before surgery. According to Severin's guidelines, the implants available should be within 1 to 2 mm of the horizontal diameter of the cornea of the normal eye. If neither eye is normal, measuring the normal eyes of an animal of the same species can provide an approximation. The preferred implants are black silicon balls, which should be thoroughly cleansed, sterilized, and rinsed again before placement. Implants less than 30 mm in diameter can be introduced via a Carter Sphere Introducer.[7] Larger implants require placement of four to six stay sutures around the wound margins. These are used to elevate the cut edges of the sclera up, out, and over the ball as the ball is pushed gently through the wound. The sclera is closed with 4-0 to 6-0 synthetic absorbable sutures in a simple interrupted pattern; suture size varies according to the size of the globe and patient. The sclera is oversewn with the same suture in a simple continuous pattern. The dorsal rectus muscle should be inspected, and if it has been severed, it should be re-apposed using 6-0 synthetic absorbable sutures. The conjunctiva is closed with 5-0 to 6-0 suture in a simple continuous pattern. A temporary tarsorrhaphy is placed in the lids as described previously.

Postoperative discomfort should be controlled, and nonsteroidal antiinflammatories are indicated preoperatively and postoperatively; systemic and topical antibiotics should be continued for 10 to 14 days. A considerable amount of tissue swelling will result, and cold packs are recommended four times a day for 24 to 48 hours. They are followed by hot packs as needed.

Client education is important during the postoperative period. The eye will appear to be filled with blood for several weeks. The red blood will gradually degrade over 2-3 weeks to a greenish color, similar to the color changes seen in a bruise. Beginning at 5 to 7 days, a 360-degree interstitial vascular keratitis develops as the cornea accommodates itself to the silicon inside, the lack of nutrition provided by the aqueous humour, and the disruption of the scleral blood flow caused by the incision. Because of this vessel ingrowth, by 4 to 6 weeks (time varies with corneal diameter), the cornea will appear markedly red and will be heavily vascularized. At approximately 8 weeks the cornea will begin to clear to its final dark gray marble appearance. Very rarely, central corneal ulceration (which is actually central corneal necrosis) develops. This requires reinforcement with a corneal graft and conjunctival flap or extrusion of the implant, and infection may occur. If central corneal necrosis does occur, the author recommends enucleation rather than further salvage attempts because such attempts are usually unrewarding.

[7]Storz Instruments, Bausch & Lomb, 400 Somerset Corporate Blvd., Bridgewater, NJ 08807 USA. http://www.bausch.com/ecp/our-products/surgical-instruments/storz-ophthalmic-instruments#.VeDVzpfBs1I.

SURGICAL TREATMENT OF SPECIFIC CONDITIONS

Acute Head Trauma with Eye Injuries

Traumatic injuries to the head, orbit, or globe are common in the ruminant. Serious head, ocular, and orbital trauma is always an emergency. After injury, the patient's head is restrained, if possible, to avoid additional, self-induced injury that occurs from rubbing the eye and periocular area against the chute, stanchion, stall, wall, or forelimb. Examination or manipulation of the ocular or periocular tissues is avoided until adequate restraint and tranquilization are completed.

Blunt Trauma to the Eye without Laceration or Rupture

Trauma patients should receive a careful physical, neurologic, and ophthalmic examination, including fundus examination and evaluation of direct and consensual pupillary light reflexes. The eye may appear normal or have any combination of injuries. Indirect ophthalmoscopy may be needed for fundus examination through cloudy media. In addition to a routine ophthalmic examination, careful examination of the sclera for occult ruptures should be performed as far posterior on the globe as possible, concentrating especially in the equatorial region. Occult ruptures can lead to phthisis bulbi. Extensive corneal lacerations, corneoscleral avulsions, or scleral ruptures require immediate surgical repair, best performed by a specialist. Hyphema is often present acutely. If more than half of the anterior chamber is filled with blood or if spontaneous intraocular recurrence of bleeding occurs, the eye has a very poor prognosis and phthisis bulbi often results. An initially normal-appearing cornea should be monitored carefully for several days after any blunt traumatic injury because it can slough its epithelium a few days later as a consequence of the contusion and corneal ulceration is the result.

Orbital and Periorbital Fractures

Orbit fractures, common in the equine, are seen much less commonly in ruminants. The dorsal (frontal bone) and temporal (temporal and zygomatic bones) regions of the bony orbit are most commonly injured. Clinical signs include edema, swelling, pain, blepharospasm, chemosis, subconjunctival hemorrhage that may be accompanied by lacerations, contusions, or other injuries of the face or lids. Subcutaneous emphysema with or without orbital emphysema may be present if the frontal or maxillary sinuses have been fractured, and abnormal ocular or nasal discharge may be present. Palpable disruption of the bony orbit rim may be evident if fracture fragments are displaced. The globe may be normally positioned or may be exophthalmic or enophthalmic or have strabismus. Upper eyelid function may be impaired because of tissue swelling or trauma to the palpebral nerve. Rule-outs include orbital cellulitis, orbital extension of sinus disease, orbital neoplasia, and orbital foreign body.

Diagnosis of orbital fractures is generally straightforward if a known traumatic event has occurred. Palpation of the affected area and digital examination of the inside of the orbit rim through the palpebral fissure should be performed once the patient is safely tranquilized and topically anesthetized. Swelling, pain, and the temperament of the animal may prevent complete palpation. Skull radiographs are

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helpful because orbital fractures are generally much more extensive radiographically than what is evident by palpation. Any combination of skull radiographs, computed tomography, ultrasonography, and magnetic resonance imaging may be necessary for full diagnosis.

Eye motility should be thoroughly evaluated by moving the patient's head dorsally, ventrally, laterally and in small circles while simultaneously observing for normal, conjugate vestibular eye movements, but this may be difficult to accomplish when significant periocular swelling exists. Assessing normal eye movements is important because extraocular muscle entrapment is an indication for surgical repair. Forced ductions of the globe may be necessary for complete evaluation. Forced ductions are performed after moderate sedation and topical anesthesia or under general anesthesia. The limbal conjunctiva is grasped at one or more sites sequentially with small tissue forceps, and the globe is "forced" through all planes of motion.

Symptomatic treatment—including cold compresses, analgesics, and antiinflammatories—is acceptable in cases with normal ocular motility and without fracture fragment displacement. Systemic corticosteroids are used with caution and, because of the risks inherent with their use, are not recommended unless optic nerve damage is suspected. These include a depressed immune system and the risk of inducing premature parturition. Hot compresses may be used after the first 24 hours for 5 to 10 minutes every 2 to 4 hours. Systemic antibiotic therapy is indicated in open fractures, sinus fractures, or skin wounds. Frequent (eight times or more per day) topical eye lubricants to prevent corneal desiccation are mandatory with any impairment of eyelid function or eyelid integrity. A temporary tarsorrhaphy may be placed to keep the globe protected. Symptomatic treatment alone is not sufficient if there is significant sinus compromise, displacement of fracture fragments, or marked facial deformity, or whenever there is any displacement of the globe or impairment of normal globe movements. Fracture repair is needed urgently in cases of optic nerve compromise.

Fracture repair is most easily accomplished within the first 24 to 48 hours if the condition of the patient permits general anesthesia. Repair may sometimes be accomplished by digital manipulation and bony traction. Many times replacement of the bones close to the original anatomic configuration without fixation is sufficient. If the fractures are unstable more orthopedic manipulation and instrumentation are required, such as figure-eight wiring of the bony fragments (see the oral section in Chapter 14 for details on wiring technique).

Eyelid and Membrana Nictitans Diseases

Eyelid anatomy varies somewhat across species but there are many common features. Both eyelids should conform and contour perfectly to the globe from the lateral canthus up to the medial $\frac{1}{6}$ of the lids where a small separation of lid to globe occurs because of the presence of the membrane nictitans or third eyelid. The nictitans should likewise conform perfectly to the globe, providing a "squeegee" to the corneal surface with its every excursion. Cilia or eyelashes are present on the upper lids with fewer and smaller lashes present on the lower lids. As the eye is approached from the lashes a flat, hairless lid margin is present that should be perpendicular to the corneal surface over its entire length with no hairs on the lid margin surface (distichia). No eyelid hairs should touch the cornea at any point (trichiasis). If either lid margin is rolled outward from the cornea, ectropion is present, unsightly but not usually irritating or painful to the patient. If either eyelid (usually the lower) is turned inward, entropion is present and surgical intervention is indicated.

Ectropion

Ectropion should be corrected if concurrent ocular disease is attributable to the eyelid deformation, such as chronic conjunctivitis, keratoconjunctivitis, blepharitis, or facial tear scalding. Ectropion in ruminants is usually secondary to scar tissue formation (*cicatricial ectropion*) but may occur from other causes. True conformational ectropion such as that seen in dogs is extremely rare in all large animals. Ectropion may occur in combination with entropion and other eyelid or conjunctival irregularities. A number of corrective procedures have been described, depending on the etiology and degree of disease. Ophthalmic surgical texts should be consulted for details of the surgical procedures. Correction of ectropion can be much more complicated than an entropion correction and may necessitate referral to a specialist.

Entropion

Entropion can be congenital, may be associated with dehydration (particularly in newborns), may occur secondary to microphthalmos, or can develop at any age as a result of squinting from eye pain (*spastic entropion*) or secondary to eyelid scarring (*cicatricial entropion*). Entropion is self-perpetuating and must be corrected for patient comfort and corneal and ocular health. Uncorrected entropion can lead to severe keratoconjunctivitis, corneal ulceration, and scarring or possible corneal perforation. Entropion in some breeds and in some herds of sheep and goats may have an inherited predisposition and affected animals should be noted, not bred, or culled. Many affected individuals of any species may, in addition to entropion, appear to have overly long eyelids because of tissue swelling, but the lids are not actually elongated in these individuals (Figure 10-21*A*).

Mild cases of entropion in any species and at any age can be corrected by using a variety of techniques. Newborn animals less than 24 hours old with entropion may respond to frequent (every hour or more often, as needed) manual eversion of the eyelid margins in combination with heavy topical lubrication to prevent eyelid spasm and correcting the dehydration and nutritional status of the infant. If the entropion does not correct within 48 hours, or if *any* corneal disease develops, additional corrective measures must be taken. Short-term options to effect mechanical eversion of the eyelid margins in cases without corneal disease include injections of saline (very short-term correction) or injections of long-acting antibiotics (3-5 days of eversion). These are administered through 22- to 25-gauge needles placed subcutaneously in the eyelids, very close to the lid margins, with care taken to protect the globe during needle placement and injection. A sufficient volume is injected to swell, tense, and evert the eyelid out and away from the cornea (usually 1-2 mL).

Entropion of longer duration, spastic entropion associated with corneal disease, or entropion in animals that may not be able to be monitored daily (some newborn sheep, goats, or calves) necessitate corrections that will maintain longer term eversion. Several options are recommended. If only one or two animals are to be treated, one or two modified horizontal mattress-type "tacking" sutures of size 3-0 to 4-0 may be placed. The first suture bite is placed through the skin of the face over the palpable ventral orbit rim, needle directed toward the eye. The second bite, 4-5 mm long, is placed 2 mm away from the eyelid margin, split-thickness in the lid (never penetrating the full thickness of the eyelid!), and *parallel* to the eyelid margin. The final bite is directed away from the eye and placed in the facial skin over the orbit rim, 5 to 6 mm from the first bite. As the suture is tightened, the lid margin should be guided outward, away from the cornea, before the suture is knotted. The suture ends are trimmed short, and care is taken to ensure that they cannot touch the

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Figure 10-21 *A*, A 15-hour-old doeling Boer goat with severe entropion of the superior and inferior right eyelids. Severe keratitis is present. *B*, Marked improvement in the corneal disease is noted 6 days after wound clips were placed to correct the entropion. A small lateral canthal relaxing incision was performed to relieve lid tension and further relax the lids. *C*, The eye looks grossly normal 11 months later. (Images courtesy of Dr. Mary C. Smith, Cornell University.)

cornea. If absorbable suture material is used, the sutures will fall out in a few weeks.

Because suturing is not practical where a large number of animals must be treated and because suture placement carries some risk of the needle injuring the eye of a struggling newborn or youngster, skin staples or wound clips can be used in such cases with good success (Figure 10-21*B*). The patient is restrained and a fold of skin parallel to the lid margin is pinched up using fingers (preferred) or Allis or other tissue forceps. Michel wound clips[8] of size 7.5, 11, or 14 mm (according to the size of the patient) are then secured in the skin fold as shown (see Figure 10-21*B*). If a clip or staple is improperly placed or appears ineffective, it should be immediately removed and corrected. *The staples or clips must not be able to touch the cornea*. Sufficient staples (usually two to four) are placed to correct the length of turned-in lid margin. The clips will fall out in a few weeks or can be removed. Concurrent corneal or ocular disease may require treatment with topical or subconjunctival medications. The patients have no detectable lid scarring when this procedure is performed properly (Figure 10-21C), and even severely inflamed corneas return to normal appearance (see Figure 10-21*B* and C).

The author has never seen a calf, lamb, or kid up to a year of age with entropion that was not resolved by suture tacking or wound clip eversion and thus has never in farm animals needed to resort to any form or variety of skin removal techniques to correct entropion, such as the Hotz-Celsus procedure or other procedures described in small-animal ophthalmology textbooks. The exception is entropion caused by scar tissue formation. Skin removal techniques should never be performed until more conservative procedures have been tried and have failed, because skin removal procedures carry increased risk and discomfort for the patients and expense for the owner.

Temporary Tarsorrhaphy

Regardless of the species, any animal presenting unable to close its eyelids (lagophthalmos) due to trauma, tissue swelling, exophthalmos from any cause, facial nerve paresis, or paralysis such as seen with listeriosis or other conditions *should be considered an emergency* because corneal ulceration will usually develop in these cases in less than 24 hours without treatment, and these exposure ulcers may progress rapidly. In every case, in addition to medical therapy and frequent lubrication of the eye (minimum six times per day), a temporary tarsorrhaphy is immediately indicated. Although these need to be placed carefully, they are simple to perform. First, all of the patient's eyelashes should be trimmed flush with the skin, using petrolatum-coated scissor blades (the petrolatum will collect the lashes as they are trimmed). Using 3-0 or 4-0 sutures (ideally smaller, and according to the patient's size), one or two horizontal mattress sutures are placed split thickness through the eyelid margins. In most cases, to ensure that the suture ends hang ventral to the globe, the first suture bite should enter skin 5 mm from the central lower lid margin, tunnel subcutaneously, and exit *just anterior to the lower lid margin, taking care that the*

[8]Steele Supply Company, 3413 Hill Street, Saint Joseph, MI 49085 USA.

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suture is not full thickness at any point. Crossing to the upper eyelid, the needle enters the lid margin of the upper eyelid through a tarsal gland opening, travels subcutaneously a short distance, and exits approximately 5 mm from the margin. Reversing direction, the horizontal mattress is completed and tied slightly tighter than simple apposition, ensuring before it is knotted that no hairs or sutures are in contact with the cornea. If it is anticipated that these sutures will need to remain in place more than 5 to 7 days, stents should be used. The recommended stent is a 4- to 5-mm length of a 3- to 4-mm–wide rubber band. Sutures are placed through the rubber *before entering the lower lid* and again after exiting the upper lid, with the final result being stents that cushion the suture in both lids. Buttons or tubing are *not recommended* as stent material because they irritate most patients and will accumulate excess ocular discharge, thus increasing the bacterial load around the eye. Likewise, the smallest possible suture should always be used to close the lids (nothing larger than 3-0). If the lids need to be opened for daily examinations the suture can be tied in a shoelace knot: loosen the knot, slide the rubber piece along the suture ends as the lid is opened, and when closing the lids again, the traction of the suture through the rubber bits will serve to hold the suture in place while the shoelace knot is retied.

The temporary tarsorrhaphy is a useful procedure but is reserved for cases that require temporary corneal protection (a few days to a few weeks, at most). The procedure requires careful attention by the caregiver to ensure that suture ends do not rub the cornea, and that suture loosening, a common complication as initial swelling of eyelids decreases, is negligible. A large amount of ocular and suture-induced exudate may accumulate on the sutures over time and should be carefully removed because not only is it esthetically displeasing but also the exudate may cause ocular or skin irritation and increase the likelihood that the patient will cause self-trauma to its eye. Temporary tarsorrhaphy sutures may cause undue lid inflammation and should be removed if this occurs. They will usually necrose through the eyelid skin within 2 to 3 weeks.

Reversible, Split-Lid Tarsorrhaphy (Figure 10-22)

If the lagophthalmos or complete inability to close the eyelids is due to facial nerve paralysis, and if nerve function has not returned within 3 weeks, a long-term, split-lid, reversible tarsorrhaphy is recommended. This is an extremely useful procedure in cases with unilateral or bilateral eyelid paresis or paralysis that can be left in place permanently or that can be opened gradually as facial nerve function returns, whether that is in 6 weeks or 4 years. Because the eyelid margins are not removed in this procedure, when the lids are reopened there is minimal lid scarring, excellent cosmesis, and excellent lid function. The author's 30 years of experience with facial paralysis cases is that, given sufficient time, almost all of them will regain facial nerve function unless the nerve has been severed (complete facial nerve function has returned after as long as 3 to 4 years in some equine cases). If a reversible split-lid tarsorrhaphy has been performed to protect the cornea, rather than a permanent tarsorrhaphy or, worse, an enucleation, then full lid function and a normal-appearing eye can be restored when nerve function returns.

General anesthesia or standing, heavy sedation, topical anesthesia, and local nerve blocks are required. *Eyelid margins should never be removed in these cases.* Holding the lids taut, a #15 Bard Parker blade or a #64 Beaver blade is used to split the eyelids in one or more sites, very carefully, to a depth of 4 to 6 mm, along a line immediately caudal to the tarsal gland openings, such that two layers form, the outer being the skin, orbicularis muscle, and some tarsal glands and the inner being conjunctiva and some tarsal gland (the glands are divided as the incision is made). *The inner lid layer (upper or lower lid) must not contain any hairs or hair follicles because the inner layer will be everted toward the cornea after closure.* Using 5-0 or 6-0 absorbable suture such as Vicryl (never Vicryl Rapide), one to two simple interrupted sutures are placed in the apex of each opposing incision and knotted, taking care that sutures do not penetrate the conjunctiva at any point. When these are knotted, the upper and lower lids become firmly apposed and the outer skin-muscle layer will evert outward, while the conjunctival layer will evert toward the cornea. Suture ends are trimmed very short. An additional two to three horizontal mattress sutures are placed in the now-everted external lid margin layer to further secure the wound edges together. When healed, the final result will look like a Caslick's procedure has been performed on the eyelid (Figure 10-22*B*).

Initially, the eyelids normally look overcorrected or may be almost completely closed due to tissue swelling. This subsides in a few days, and if the eye is otherwise normal, the patient will regain forward vision. If a corneal ulcer is present in the eye, a transpalpebral lavage catheter (see previous discussion) should be placed before the lids are closed. Eyelid manipulations must be minimized, or preferably avoided entirely, for 3 weeks postoperatively. If medications are required and a lavage catheter has not been placed, the owners should be shown how to apply medications through the medial lid opening without placing tension on the wound.

When facial nerve and eyelid function returns, the thin intermarginal membrane that forms after healing can be gradually snipped opened following topical anesthetic administration and sedation as needed. In some cases, mild lid paresis will remain; in these cases the temporal 5 to 10 mm of the lids should be left adhered together.

Nasolacrimal Duct Lavage

Nasolacrimal duct obstructions or some foreign bodies within the nasolacrimal duct can be relieved by nasolacrimal lavage. Nasolacrimal duct lavage can be performed normograde or retrograde (see Figure 10-1*A* and *B*), but in most food animals normograde lavage is easiest. The lacrimal puncta are located just inside the eyelid margins, in the conjunctiva adjacent to the mucocutaneous junction, 8 to 10 mm from the medial eyelid commissure in adult cattle and approximately 3 to 4 mm in diameter. The upper puncta is most easily cannulated. Holding ones thumb adjacent to the medial upper lid margin, gently evert the lid margin while applying gentle upward traction. The opposite hand gently advances an open-end tomcat catheter, 18- or 20-gauge IV catheter (with stylet removed), or 5 French feeding tube into the puncta as far as possible until resistance is met, at least 2 to 3 cm. Unless a culture is indicated (in which case sterile saline is used), a syringe filled with 20 cm^3 of very warm tap water (most patients greatly dislike cold solutions passing through their nasolacrimal ducts) is attached to the catheter hub, and gentle, pulsing lavage is performed until fluid is noted from the lower eyelid puncta. Then, using finger pressure, occlude the lower puncta. With additional gentle lavage, fluid should flow from the nose. Staining the lavage solution with fluorescein will aid visualization of this fluid. If patency is not achieved, wait a few minutes and try again, but never forcefully flush the nasolacrimal ducts. If patency is not achieved, the next step is to flush retrograde (see Figure 10-1*B*). The position of the nasal orifice of the nasolacrimal duct is quite variable across species; thus some exploration may be needed. In most cattle, the nasal orifice is found on the ventral surface of the rostral

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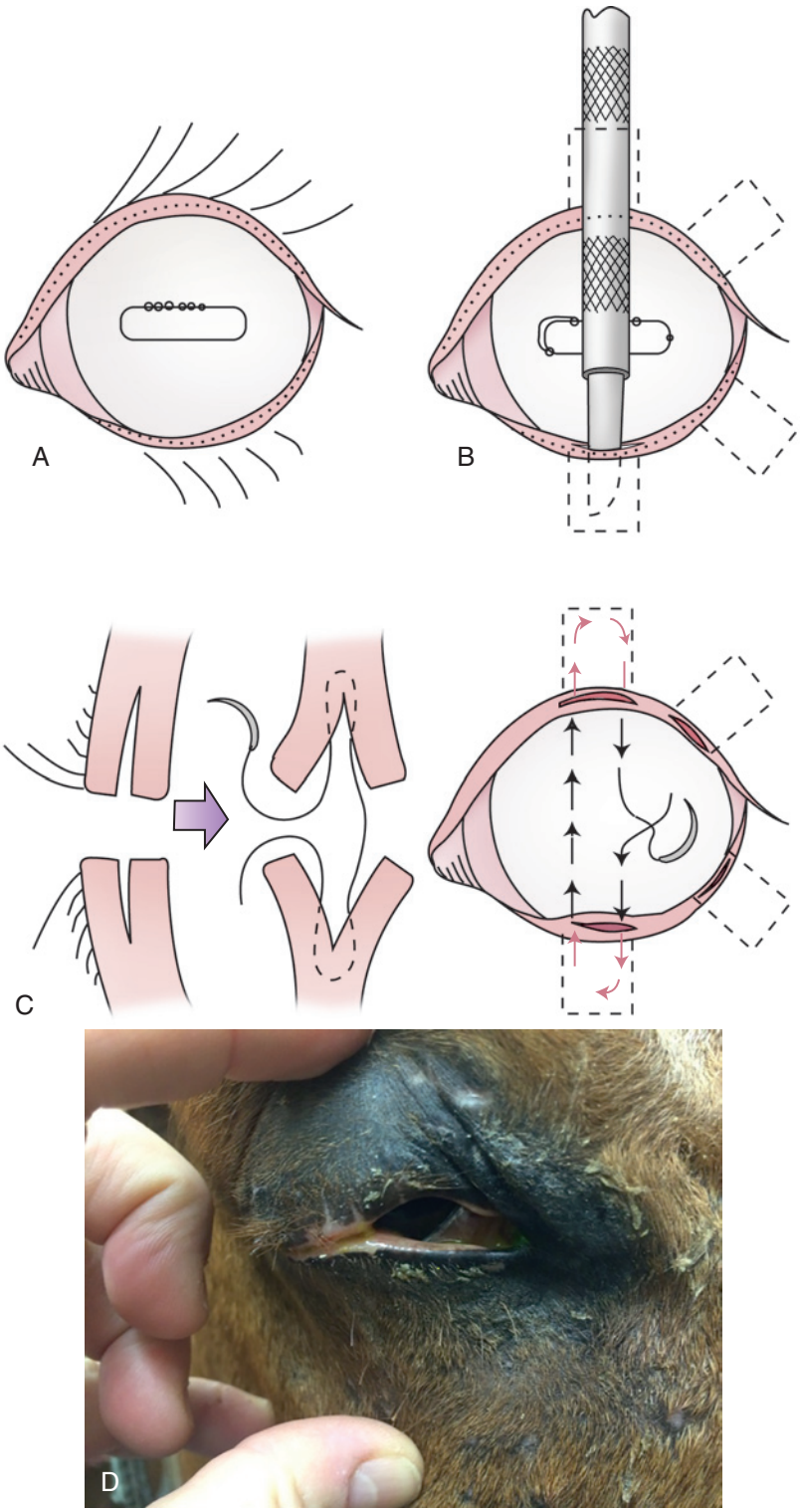


Figure 10-22 Reversible split-lid tarsorrhaphy (RSLT). *A*, Illustration of upper and lower lid margins slightly everted to show the "dotted line" of tarsal gland openings. *B*, A no. 64 Beaver blade is used to incise just inside the tarsal gland openings, splitting the lid to a depth of 5 to 7 mm into 2 layers: a skin-orbicularis muscle–tarsal plate layer externally and tarsal plate–conjunctiva layer internally. Four incisions are made at two apposing sites on each lid as shown or one longer incision can be used in each lid instead. C, Using 5-0 Vicryl, simple interrupted sutures are preplaced into the apex of each opposing incision. After bites have been placed in the superior and inferior lid they are tied securely to ensure that the knots are well buried in the lid tissues. For extra security, or in lids with normal tone, additional horizontal mattress sutures are placed through the now-everted external lid margins (not shown). *D*, RSLT placed 10 days previously in a patient with right-sided facial paralysis of several week's duration. The upper and lower lids have healed together. The eyelid margins remain, thus allowing the lids to be reopened if facial nerve function returns.

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Figure 10-23 A catheter is in place in the nasal orifice of the nasolacrimal duct of a donkey with bloody nasal discharge. To locate this opening in donkeys, evert the lateral alar fold and inspect the everted surface carefully (the opening is not on the floor of the vestibule as it is in horses).

portion of the alar cartilage, most easily seen by looking dorsally in the nasal passage, about 6 to 8 cm beyond the nasal opening (see Figure 10-1*B*). In donkeys and some mules, the duct is usually found on the medial surface of the lateral alar fold; pull the nostril laterally and inspect the everted surface (Figure 10-23). Note that swine lack a lower lid puncta.

Periocular Fat Pad Hypertrophy in Pot-Bellied Pigs

Entropion in the Vietnamese pot-bellied pig can be extremely difficult to correct and commonly recurs days to months later, particularly in cases with excess, hard periocular fat and conformational enophthalmos. In some cases, true entropion is not actually present, because the lid margin is in normal position. In these cases, the periocular fat pads become thickened, hypertrophied, hardened, and heavy, and placing pressure on the eyelid results in a functional entropion and vision impairment. Affected pigs are unable to open their eyelids and because of this develop a wide range of related behavioral and physical changes including lethargy, apprehension, aggression, loss of interactive capabilities, fear biting, dermatitis, and weight gain. The modified Hotz-Celsus procedure and other skin-removal procedures can be used in the lower eyelid but are almost uniformly unrewarding in the upper eyelid if there is a heavy dorsal fat pad present or if the lids are not pliable.

The periocular fat pads are most severely enlarged dorsally and most prominent on the dorsolateral aspect of the orbit. Andrea and George reported that most of the dorsal fat pads measured 2 to 4 cm in width and 4 to 6 cm in length. A few pigs also have fat accumulation along the ventral aspect of the orbit. In the report of Andrea et al., attempts at controlling the condition with dietary management and exercise were unsuccessful, in part because affected animals were reluctant to move or exercise. Andrea et al. and this author have had good results performing a partial resection of the hypertrophied fat pad and redundant skin.

The pig is positioned in sternal recumbency under general anesthesia. The periocular skin is prepared for aseptic surgery. To prepare the area, the fat pads need to be lifted so that the underlying skin can be thoroughly cleansed; the tenacious greasy exudates hidden in the heavy thickened folds are very difficult to remove but must be cleansed away.

A sharp skin incision is made in the cleavage line at the ventral aspect of the fat pad, beginning just rostral to the base of the ear, extending rostrally, crossing the upper eyelid, and redirected dorsomedially to the midline dorsal to the nose. The incision continues toward the midline, crossing the upper eyelid, until it meets the corresponding incision from the other side. The resulting large flap of forehead skin is elevated from the frontal bone, incorporating the fat pad but taking care to avoid the muscles of the face—including the parotidoauricularis, the frontoscutularis, and the levator anguli oculi muscles. In some cases the fat is so dense and firm that the skin cannot be manipulated. In these cases, the dorsal flap is everted as much as possible using penetrating towel clamps, and slices of subdermal fat (2 to 4 mm at a time) are removed until the bases of the hair follicles in the overlying skin are visible. Once the skin is freed and all dermal fat debulked to the level of the dorsal plane of the ears, the skin flap is put back into place and the now-pliable excessive skin of the brow is trimmed to create a snug fit between the undermined skin flap and the ventral wound edge. The skin is sutured in an interrupted pattern with 0 or 2-0 polypropylene suture material. In some pigs it will be necessary to remove an ellipse of additional redundant skin and fat ventral to the eye and over the bridge of the nose. Perioperative antibiotics and nonsteroidal antiinflammatory drugs are indicated.

Pretreatment of local skin fold dermatitis and yeast infections are required in many cases before considering surgery because wound healing would be compromised otherwise. Andrea et al. noted a favorable outcome in all cases, with minor postoperative discomfort, and that has been the author's experience as well. Vision was restored in all animals, and all owners reported favorable outcomes.

Eyelid Lacerations

Eyelid lacerations usually occur because the individual has caught the upper or lower eyelid on a hook, nail, or other pointed object; the apparent laceration is usually an avulsion or rupture of the tissue that occurs as the patient pulls the head away; thus the damage is often more than is apparent at first glance. Some apparent lid lacerations are actually a result of blunt compression or crushing, and in such cases tissue trauma may be very extensive.

The diagnosis is usually obvious. The wound may be a simple laceration perpendicular to the lid margin, a flap of eyelid hanging from a pedicle, or a laceration that has removed the lid margin. The wound is usually edematous and bloody, with tears and mucoid to mucopurulent ocular discharge apparent in the periocular area. The individual is usually in mild to moderate pain. A fluorescein dye test must be performed to assess the integrity of the cornea. A complete ocular examination, including intraocular examination, should be performed as soon as possible. Any corneal or other ocular injury should be treated appropriately. The eye is lubricated and protected from self-trauma before, during, and after the examination. If the etiology is unknown, skull radiographs may be indicated to rule out metallic foreign bodies and periorbital fractures.

Simple lacerations may only require cleaning and topical antibiotics. Any eyelid laceration where the lid is unable to close completely or completely cover the cornea should be repaired as soon as possible, depending on the health status of the patient, to ensure normal eyelid function and future corneal health. Many eyelid lacerations in ruminants can be repaired under sedation and local anesthesia, but general anesthesia may be needed for the best cosmetic and functional result and for extensive injury cases. Owners may be

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inclined to treat eyelid lacerations by simply trimming away the thin flaps of tissue hanging from the remaining eyelid. This should *never* be done. Seemingly redundant eyelid tissue or flaps of eyelid margins should be incorporated into the closure. No other tissue in the body can substitute for missing eyelid margin, and removal of these thin strips of tissue can result in a lifetime of chronic discomfort for the animal because of irritation from hairs present at the edge of the wound that will become the new eyelid margin. Removal or improper repair of an eyelid margin leads to chronic corneal disease from irritation by eyelid hairs (trichiasis), exposure keratitis due to improper spreading of the tear film over the cornea, and chronic keratoconjunctivitis due to an inability of the eye to properly cleanse itself.

Perioperative antibiotics are indicated. Lid lacerations can be repaired under local anesthesia and sedation if the patient is cooperative and the repair is a simple one. General anesthesia should be used in all cases of complicated repairs or if the patient is difficult to manage. In either case, repeated topical anesthetic applications may be helpful during surgery. Clipping the lid hair around the wound may be necessary but can be troublesome because the small cut hairs are difficult to eliminate from the wound. Coating the wound before clipping with petrolatum or a water-soluble, sterile gel may prevent hair contamination, but the lubricant must be washed carefully away during wound preparation. The periocular tissues should be thoroughly cleansed with 10% povidone-iodine solution with sterile saline rinses. The wound should be checked carefully for any foreign bodies. Wound debridement should be extremely minimal to preserve as much eyelid tissue as possible, and the eyelid margin must be conserved whenever possible. Tissue that appears hopelessly desiccated, inflamed, and/or infected may heal well if properly repaired. Wound debridement is best performed by simply rubbing with dry gauze until bleeding is noted, but wounds that are more than 24 hours old may require scarification with a #15 scalpel blade, taking care not to remove tissue, only to restore a liberally bleeding surface.

Full-thickness wounds should be closed in two to three layers using 3-0 to 5-0 absorbable sutures according to the size of the patient and thickness of the eyelid. The fibrous tarsal plate and orbicularis oculi muscle should be incorporated in the deep layer and the subcuticular tissues in a second layer. Careful examination of the deeper layers of the eyelid may be needed to identify the thin connective tissue layer of the eyelid, the tarsal plate, but *this is the most important layer to incorporate in the deep sutures*. The first suture placed is the most important; it should appose the eyelid margins perfectly. Figure-8 sutures buried in this fibrous tissue layer near the margin are very useful and often recommended because they allow excellent wound apposition and position the knot well away from the eyelid margin. This suture is tightened but not tied. If its placement is not exact and apposition is not perfect, the suture must be replaced or corneal ulceration may result. This suture may be preplaced to facilitate placement of other sutures. Additional deep sutures are placed as necessary, depending on the length of the laceration. Skin closure is routine, but the ends of skin sutures placed near the eyelid margin must be secured well away from the lid margin to prevent corneal irritation. Synthetic absorbable sutures (4-0) can be used successfully in the skin and do not require removal. *Regardless of the suture pattern chosen, the surgeon should always ensure that sutures do not penetrate the full thickness of the eyelid at any point, and suture knots and ends must be well buried inside of the wound or they will touch the cornea and corneal ulceration will result.*

Severe lacerations may need stent support during healing. Eyelids can be successfully stented to the opposing eyelid via tarsorrhaphy, using split-thickness horizontal mattress sutures in the eyelid margins. If the eyelids must be closed, a transpalpebral lavage apparatus may be preplaced for administration of topical medications (if needed) before the lids are closed (see Transpalpebral Ocular Lavage Apparatus and Figures 10-4 and 10-5), or a sufficient opening should be left at the medial or lateral canthus to allow instillation of medications. Lacerations in the area of the medial canthus require careful assessment of the nasolacrimal system. If the canaliculi have been lacerated and full restoration to function is desired, such as in show animals, microsurgical repair is indicated as soon as possible after the injury.

Postoperative medical management should include warm compresses, if possible, for 10 minutes every 2 to 3 hours for 2 to 3 days. Topical corticosteroids should be avoided. Topical broad-spectrum antibiotic six times a day for 24 hours, then four times a day for 7 to 10 days is indicated if excessive tissue injury is present or if corneal integrity is in doubt but otherwise is not necessary. If the cornea is injured, topical medications are chosen more judiciously and administered more intensively. Caretakers should be advised to avoid placing unnecessary tension or stress on the eyelid during the application of topical medications. If this is not possible, topical ophthalmic antibiotic solutions may be sprayed onto the cornea via medication in a tuberculin syringe with the needle hub attached but with the needle broken off the hub. This makes a very effective, simple, medication squirt gun. Systemic antibiotics are indicated for 5 to 7 days; systemic antiinflammatories are indicated if excessive inflammation or discomfort is present. Self-trauma should be prevented, and the periocular area should be cleansed as often as exudates and discharges accumulate. After cleansing and drying, the area of the face beneath the eye should be coated with a film of petrolatum jelly to prevent hair loss from irritation by ocular secretions. The eye should be examined daily to ensure normal eyelid function and no suture irritation.

Palpebral Nerve Paralysis

The palpebral nerve is a branch of the auriculopalpebral branch of the facial nerve. Palpebral nerve paralysis and the resultant inability to blink the eyelids in one or both eyes is usually of traumatic origin, often as a result of stanchion or chute trauma. Chronic otitis media or brainstem diseases should be ruled out, especially if the entire facial nerve is involved. The absence of a palpebral reflex is diagnostic.

The initial clinical sign is ptosis of the affected eye(s) followed subacutely by tearing, and soon exposure keratitis and corneal ulcer(s) will develop. Exposure ulcers are usually central to ventrotemporal on the cornea and may be superficial to deep. Characteristically, ulcers secondary to exposure keratitis may not appear to be as deep as they actually are because the adjacent cornea in these cases swells very minimally and, in fact, may be somewhat desiccated. If possible, a slit lamp examination should be performed daily in these cases until the ulcers heal and in all cases careful monitoring is indicated.

Acute treatment includes antiinflammatories, hot compresses, topical dimethyl sulfoxide or topical nonsteroidal antiinflammatory drugs at the site of trauma and systemic steroids unless contraindicated. Topical ophthalmic lubricants should be applied at least four to eight times daily until lid function returns. Topical antibiotics are given four or more times daily in cases that have corneal ulcers. Even if the cornea can be medicated and lubricated very frequently, a temporary tarsorrhaphy (see previous discussion) should also be performed in every case as soon as possible, ideally

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within the first 24 hours, and should be replaced with a reversible split-lid tarsorrhaphy (see previous discussion) if nerve function has not returned by 3 weeks.

Eyelid Tumors

Eyelid masses often are seen in cattle but are less common in other ruminants or pigs. Papillomas (warts), benign skin masses of probably viral origin, are commonly seen periocularly in cattle but are also seen in sheep and goats. They are usually self-limiting, and spontaneous regression is likely. Papillomas that involve the eyelid margins, or are of sufficient size in the periocular area to cause irritation to the eye, should be removed. Small ruminants with self-limiting wart-like masses should be evaluated for contagious ecthyma, a zoonotic disease.

Depending on the type of tumor, its location, and the equipment available, the tumors may be removed surgically, or cryotherapy, hyperthermia (see Figure 6-24*A*), or radiofrequency modalities can also be used.

The most common eyelid tumor seen in cattle is squamous cell carcinoma (SCC). It can involve the eyelid(s) (Figure 10-24), the membrane nictitans (Figure 10-25*A* and *B*), conjunctiva (Figure 10-26), or cornea (Figure 10-27). The tumor is locally aggressive in almost all cases and has metastatic potential. Precursor lesions (Figure 10-28) (e.g., carcinoma in situ) can resemble papillomas (Figure 10-29*A*), granulomas, or epithelial inclusion cysts. The diagnosis is based on the appearance of the tumor and is confirmed by histopathological evaluation of the scraping or biopsy of the lesion.

Many therapeutic modalities are used to treat squamous cell carcinomas. Different therapeutic approaches are used in feedlot cattle compared with those used in valuable breeding or pet animals. Early recognition of small tumors less than 2.0 cm in diameter allows consideration of some less invasive therapeutic techniques for SCC; any chronic non-healing sore or scab on the eyelids should be considered a possible SCC.

Small tumors of the eyelids may be removed by sharp excision if sufficient functional lid margin remains (see Figure 10-29*A* and *B*). If lid margin is to be excised and direct closure is planned then the tumor should be less than 1.5 cm in diameter in an adult bovine or $\frac{1}{4}$ of the length of the lid or less in most species (larger tumors may be removed and lower eyelid function restored using an H-plasty procedure). Although a "wedge" excision of the eyelid is described in many older references as appropriate to remove lid margin tumors, a wedge removal should not be used because a wedge maximizes the length of eyelid marginal tissue removed. A tent-shaped excision is preferred because it maximizes the amount of eyelid preserved (Figure 10-30). After routine preparation of the eye and periocular tissues, the eyelid is first inspected carefully to confirm the extent of the tumor. A lid forceps or clamp with a solid lower plate such as a Snellen entropion forceps or Desmarres chalazion forceps, if available, is placed around the lesion and tightened to gently compress the lid tissue. The use of such clamps is a significant aid to hemostasis, and the solid lower plate provides a firm surface for incision. Two sharp incisions are made with a #15 Bard-Parker scalpel blade, one on either side of the tumor, and as much eyelid margin as possible is conserved. These incisions are perpendicular to the eyelid margin and extend into the affected lid just beyond the base of the tumor (see Figure 10-30). These two incisions are then connected in a V so the excised piece of lid is shaped somewhat like a house, with the lid margin being the base of the house. The wound is closed as described for lid lacerations, with a figure-8 suture preferred in the connective tissue layer. Postoperative management includes cold compresses if needed for 24 hours and topical antibiotics three times a day. The eye should be examined daily for increased squinting, tearing, clouding, redness, or pain. If



Figure 10-24 Squamous cell carcinoma of lower eyelid in a cow.

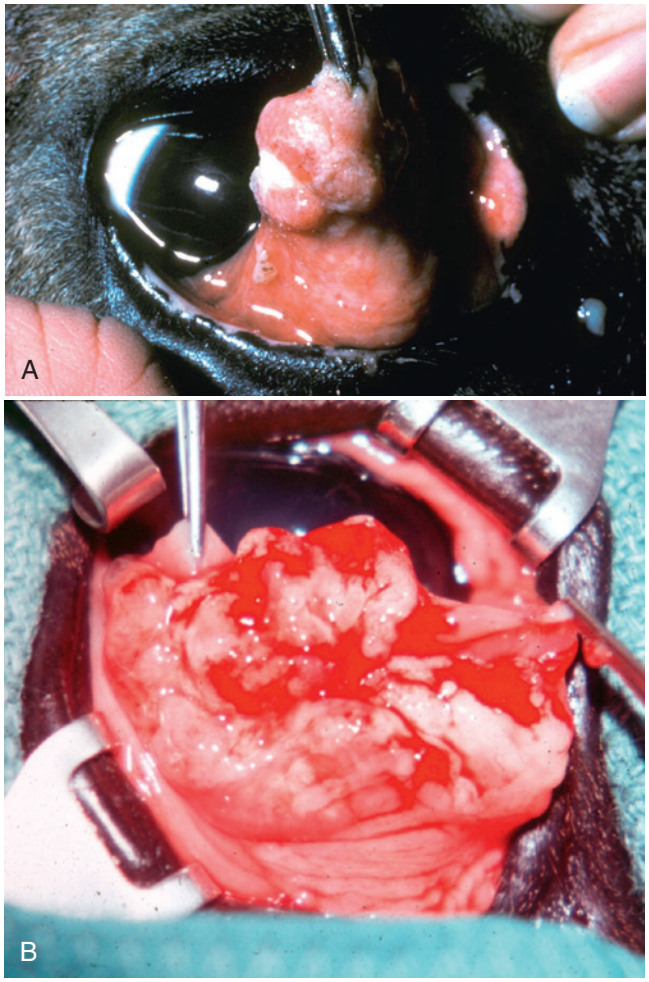


Figure 10-25 *A*, Squamous cell carcinoma (SCC) of the membrane nictitans suitable for a standing nictitans excision. Note the wide border of normal nictitans below (and above) the lesion. *B*, More extensive SCC nictitans and conjunctiva lesion, which require more dissection, thus making the lesion unsuitable for a standing surgical procedure.

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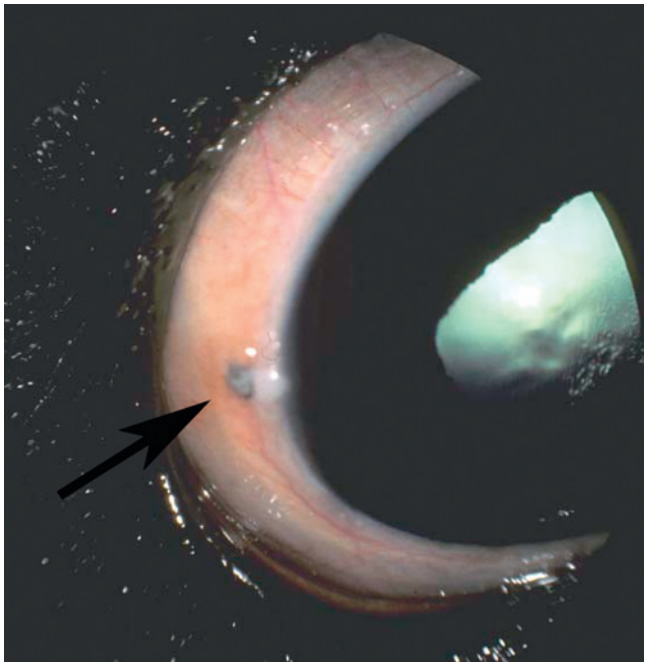


Figure 10-26 Squamous cell carcinoma (*black mass at arrow*) of the conjunctiva in a cow.

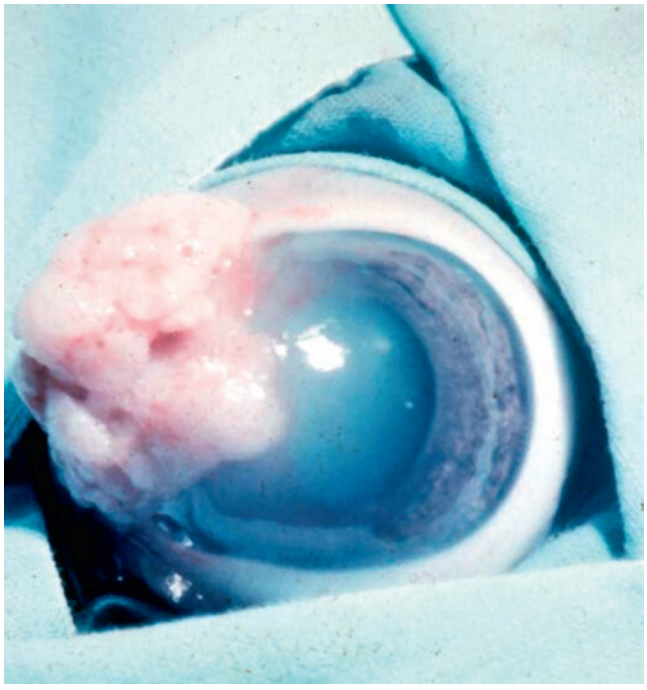


Figure 10-27 Squamous cell carcinoma of the cornea in a cow.

these occur, veterinary attention will be needed. Suture irritation should be ruled out.

Cryosurgery can be appropriate for small lesions (2.5 cm or less in diameter). The animal is sedated and restrained and the surgical site desensitized with a local (and/or topical) anesthetic. The area to be frozen is identified. Adjacent areas are protected by petroleum jelly. The eye itself is carefully covered with a cryoprotective shield. Two

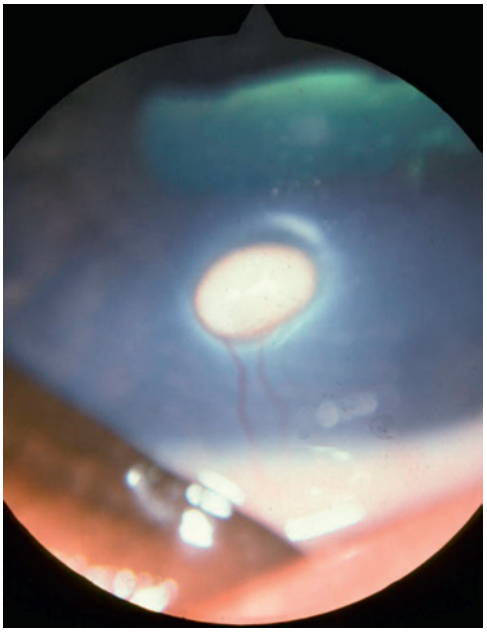


Figure 10-28 Corneal dyskeratosis—a precancerous lesion in a 2-year-old bull.

freeze-thaw cycles using liquid nitrogen (nitrous oxide is insufficiently cold) are performed using a probe, cup, or spray. The periphery of the lesion should reach –40.0°C. Effective time of cryodestruction is 10 to 20 minutes once temperature equilibrium has been reached. To maximize results with cryosurgery, the operator strives for two quick-freeze/slow-thaw cycles. Frozen tissue sloughs in 7 to 14 days; new hair growth often is white. The eye should be monitored carefully for 2 to 3 weeks afterward to ensure that sloughing tissue does not cause corneal irritation. Topical antibiotics may be needed for 7 to 14 days.

Radiofrequency hyperthermia[9] can be used for small tumors that can be debulked before application of this device. Penetration is only 0.5 to 1.0 cm; therefore it is not an appropriate procedure for larger masses, and multiple treatments may be necessary.

As is the case with many carcinomas, SCC is a radiosensitive tumor. Very small lesions less than 2 mm in depth can be treated with 150 Gy of β radiation via a strontium 90 applicator[10] (Figure 10-31*A* and *B*). However, β particles do not penetrate deeply and a strontium probe is not useful for treating larger mass lesions. Other radiation treatments such as implanted radon seeds (brachytherapy) may be effective, but radiation laws limit their availability. Electronic brachytherapy treatment units may hold promise, but their use has not been well validated at this time.

Membrana Nictitans Excision

SCC also commonly develops on the membrana nictitans. If the tumors are less than 2 to 2.5 cm in diameter and involve only the free margin of the nictitans like the mass shown in Figure 10-25*A*, they can be successfully removed using a

[9]Hach RF 22A Thermoprobe Device, Hach Chemical Co., Loveland, CO, USA.
[10]AmerSham International, AmerSham Laboratories, White Lion Road, Bucks, UK, or the American subsidiary, American Corporation, 2636 Clearbrook Drive, Arlington Heights, IL, USA.

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Figure 10-29 *A*, Papilloma on the lower eyelid of a calf. *B*, Calf after surgery to remove lower eyelid lesion. An elliptical incision was made and the skin closed primarily. (Courtesy Dr. Norm G. Ducharme; Cornell University.)

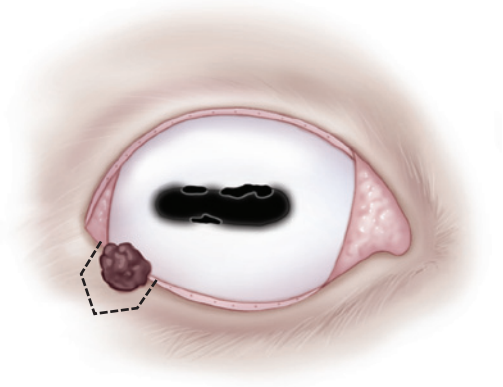


Figure 10-30 Schematic diagram showing the placement of incisions for removal of larger eyelid tumor.

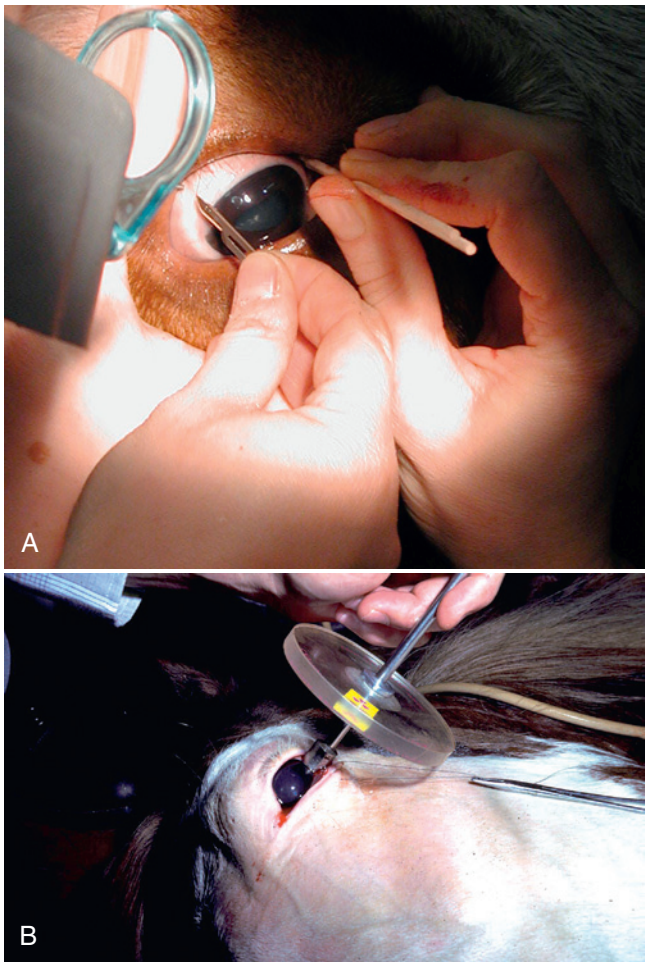


Figure 10-31 *A*, Magnifying loupe and no. 15 blade used to excise squamous cell carcinoma from the lateral limbus in a cow before beta irradiation. Q-tips are used in the opposite fornix to position and stabilize the globe in this sedated cow. *B*, Use of the strontium applicator.

4-clamp technique by excising the entire nictitating membrane with the animal standing. Although this procedure can result in keratoconjunctivitis sicca in a dog or cat, large-animal species depend less on the secretions of the membrana nictitans gland, and it can usually be removed without consequence. Tear test measurements should be performed before excision and weekly for several weeks afterward.

The patient should be premedicated for 24 hours with topical antibiotics and flunixin meglumine (1.1 mg/kg) administered preoperatively. Following sedation, the eyelids are paralyzed and topical anesthesia applied. The conjunctival sac is lavaged with sterile saline. The eye is retropulsed, and the nictitans is grasped using a hemostat on the free margin, not on the tumor. The nictitans is everted, and the extent of the tumor on the bulbar surface of the nictitans is confirmed. The surgeon should ensure sufficient normal nictitans tissue and conjunctiva are present dorsally and ventrally to allow complete tumor removal. As the nictitans is stretched across the cornea toward the lateral canthus, curved Kelly hemostats are clamped across the folds of normal nictitans conjunctiva dorsal and ventral to the tumor so their curves follow the curve of the eyelids and their tips are within a centimeter of each other medially at the base of the T cartilage. Scissors, or a scalpel blade held in the

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fingers, are used to cut along the clamps, *leaving the clamps on the patient*. A fourth clamp is then placed across the base of the T cartilage and the remainder of the nictitans excised, leaving the clamp on the patient. The clamps should remain on the patient for at least 10 minutes, longer if possible, and then removed with care to *ensure that the crushed conjunctival edges remain apposed*. The eye and lids must not be manipulated after the procedure is completed except to remove the clamps.

Complications are uncommon but include incomplete excision, excessive hemorrhage, and, rarely, orbit fat prolapse. Incomplete excision should not occur if the clamps are carefully applied. If clear margins sufficient for clamp placement beyond the tumor are not available, the procedure should be aborted and removal under general anesthesia planned. Hemorrhage and orbit fat prolapse occur rarely if the clamps remain in place for at least 5 minutes. Hemorrhage can be controlled by manual direct pressure or a pressure bandage applied to the head and left in place for 24 hours. Orbit fat prolapse is of more concern, and if it develops, it will worsen as the patient wakes up and retracts the eyeball. In this case the clamps should be replaced and the conjunctiva oversewn with 5-0 synthetic absorbable sutures. Prolapsing fat should not be removed because chronic enophthalmos will result. General anesthesia may be required to replace severe fat prolapses.

Postoperatively, flunixin meglumine should be administered once daily for 3 days. Topical antibiotics should be applied four times a day for 5 days but *must be applied without causing pressure on the lids or globe or orbit fat prolapse could result*.

Other Conditions Involving the Membrana Nictitans

Other than SCC, major diseases of the nictitating membrane are rare. Lacerations of the nictitans can occur and, if extensive, should be repaired or the nictitans can be excised as described previously. Traumatized nictitating membranes require careful examination of the palpebral and bulbar surfaces to ensure the cartilage is not exposed, which will cause chronic corneal irritation.

Orbital fat may prolapse into the nictitans (or elsewhere deep to the conjunctiva) and will resemble a neoplastic swelling; lymphosarcoma should be ruled out in these cases. The lacrimal gland surrounding the cartilage at the base of the nictitans can become hypertrophied. This may resolve with topical or intralesional steroids or may require excision and biopsy. Normal tear function should be ascertained before this procedure. The nictitans is a very common site for seclusion of foreign bodies (usually plant material), and the bulbar surface of the nictitans must be examined in all cases of refractory corneal ulcers or refractory conjunctivitis. A small fold of conjunctiva is present centrally on the bulbar surface and requires examination using magnification. In sheep and goats, intense follicular hyperplasia of the nictitans may occur with conjunctivitis caused by *Chlamydophila* sp. *Mycoplasma* sp., *Moraxella ovis*, *Colesiota conjunctivae*, *Listeria monocytogenes*, *Acholeplasma oculi*, and *Thelazia* spp. have also been associated with severe keratoconjunctivitis in sheep and goats.

Conjunctival and Corneal Diseases

Dermoids are a common congenital defect affecting the eyes (Figure 10-32). In cattle, they are usually readily diagnosed because they appear as a piece of haired skin attached to the cornea, conjunctiva, sclera, lacrimal caruncle, eyelids, or any combination thereof (Figures 10-33 and 10-34). In other species, notably the horse, dermoids may be nonhaired and the diagnosis in these cases is a bit more challenging.



Figure 10-32 Young Holstein heifer with bilateral dermoids.



Figure 10-33 Epiphora and chronic conjunctivitis in the right eye of the same patient.

Affected animals may be asymptomatic for a short time after birth if the dermoids are small or nonhaired. Most cases quickly develop chronic conjunctivitis, epiphora, blepharospasm, and ocular discomfort. Corneal ulceration or scarring may occur as a result of poor distribution of the tear film. Large dermoids of the cornea may cause visual impairment or blindness. Given the chronic irritation and discomfort associated with the dermoid, excision is warranted if the affected animal is to be kept. Dermoids may be associated with other intraocular anomalies, and a careful ophthalmic examination concentrating on the anterior chamber, iris, and lens is warranted, particularly if surgical removal is planned. A slit lamp biomicroscopic (Figure 10-35) examination by a trained individual may be helpful in these cases.

Dermoids that do not involve deeper layers of the eye may be removed by lamellar superficial keratectomy using conventional sharp excision or removed via CO_2 or excimer laser ablation. CO_2 lasers can cause extensive damage to normal

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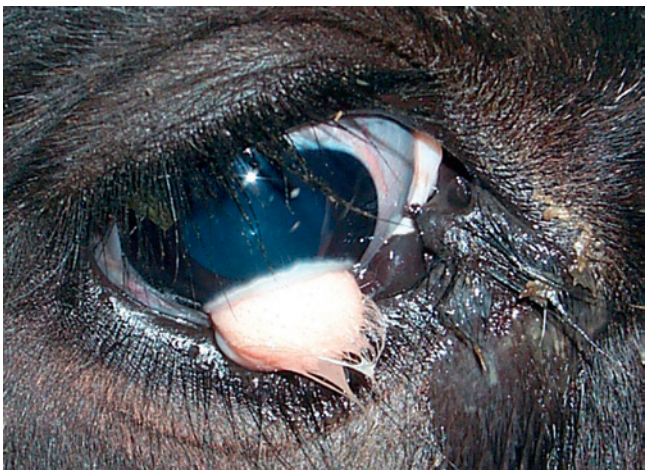


Figure 10-34 Large, white dermoid on the left cornea of a Holstein calf. Note the malformed medial eyelid commissure—additional smaller dermoid masses are present there and also on the membrana nictitans.



Figure 10-35 Slit lamp biomicroscopic examination of temporal limbal squamous cell carcinoma.

corneal tissue and should be used with great caution. Cryosurgery is not recommended because of the potential for extensive damage to adjacent corneal endothelial cells with resultant chronic corneal edema.

A superficial lamellar keratectomy is most easily performed with an operating microscope but when one is not available can be done using a simple magnifying loupe. Specialized instrumentation—including an operating microscope—allows a quicker, more precise surgery with less postoperative scarring. Minimal instrumentation should include an eyelid speculum or retractors, 1 × 2-mm toothed Bishop-Harmon or Colibri forceps, a #64 Beaver blade or #15 Bard-Parker blade, a Castroviejo needle holder, and a Stevens' tenotomy scissors. A Martinez corneal dissector is highly recommended to facilitate undermining the lesion by lamellar corneal separation.

General anesthesia or 4-point or other retrobulbar anesthesia is strongly recommended because precise, controlled corneal incision and dissection is extremely difficult to perform on an eyeball that is moving. In some adult cattle, the globe may be gently proptosed manually to stabilize it. The proptosed globe will remain proptosed in most cases until replaced, or a towel clamp can be carefully placed through the lid margins to ensure this. The cornea is incised partial thickness, circumlesionally; extreme care is used to avoid incising too deeply and breaching the anterior chamber. This can be prevented by use of a restricted depth corneal knife.[11] Hand stability is much improved if the surgeon is sitting with forearms supported. The base or sides of the surgeon's palms should be resting on the patient's head whenever the cornea is incised or held. Most dermoids are quite superficial and involve the epithelium and very superficial stroma; the initial circumlesional incision should extend to the superficial stroma. If a restricted depth blade is not used, incisional depth can be difficult to judge without an operating microscope, but a good guideline is to carry the incision just deep enough to see a clear separation of the wound edges. The beginning surgeon usually makes too shallow an incision so only the epithelium is incised and the wound margins do not separate even though the incision is visible. When the epithelial basement membrane and the most superficial stroma are incised, the wound edges relax because of the looser intracellular connections present in the stroma.

If the dermoid extends beyond the limbus, the surrounding conjunctiva should be incised using tenotomy scissors. After the initial incision surrounds the whole lesion, the corneal wound edge to be removed is grasped with a small-toothed tissue forceps and elevated slightly while the corneal dissector is introduced. If a Martinez dissector is not available, a #64 Beaver blade can be used to undermine the lesion, but extra care should be taken to maintain a plane of dissection parallel to the corneal surface and no deeper than the original incision to avoid full-thickness penetration of the cornea. Note that Beaver blades are much sharper than dissectors. The corneal dissector is gently rotated while it is advanced beneath the lesion and separates the corneal lamellae; it should advance easily if it is in stroma. Once the dissector has been introduced and the lamellar dissection begun, the surgeon should take care to keep the dissection in the same plane. If the corneal dissector does not advance easily, the dermoid may extend into the deeper corneal tissues or the initial plane of dissection may be too shallow. As dissection progresses, bleeding may be encountered if the lesion is encountered or if the dissection crosses the limbus and the corneal dissector will fail to advance easily. Tenotomy scissors or scalpel incision may be necessary to remove the remaining lesion. The wound bed is inspected to ensure complete removal; any excess bleeding from the conjunctiva and sclera can be controlled with gentle pressure applied for a minute or so or with a spray of 1:10,000 epinephrine. The cut conjunctival edge may be secured to the limbus by using a simple continuous pattern of 5-0 synthetic absorbable suture with the knots trimmed short. If, during surgical excision, the lesion is found to be deeper than expected, the cornea may require reinforcement with a conjunctival flap.

The eye is treated postoperatively as for a corneal ulcer by using 1% atropine bid-tid to control the uncomfortable ciliary muscle spasm that occurs with corneal disease and topical broad-spectrum antibiotics four times a day. The eye should be inspected daily for a few days to ensure the cornea is stable and infection or corneal malacia does not develop. Recheck at 1 week should reveal that a lesion initially 1 cm

[11]Item 72-031, Surgical Specialties, 355 Burrard Street, Suite 1100, Vancouver, BC, Canada V6C 2G8.

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in diameter is no longer retaining fluorescein stain; larger lesions will heal in 10 to 14 days in almost all cases.

Lacerations and Ruptures of the Cornea and/or Sclera

If any suspicion of laceration of the cornea or sclera exists, the owner should be instructed not to touch or attempt to examine it and to prevent the patient from causing self-trauma to the eye. Examination of the eye or periocular area by the owner or veterinarian should not be performed until the patient has been heavily sedated and the eyelids paralyzed. Failure to follow these guidelines can result in a simple laceration becoming a hopeless evisceration. Instruct the owner that not even eye medications should be applied to the eye until the examination has been completed. No ophthalmic ointment should be placed in a lacerated eye during the examination, preoperative preparation, or surgery because it can cause chronic intractable inflammatory disease if it gets inside the eye.

The diagnosis of a corneal laceration is usually obvious with a corneal and/or scleral defect of variable size that is usually plugged with fibrin, iris, or other uveal tissue. The globe may appear smaller than normal because of leakage of aqueous humour from the eye, and the anterior chamber, if visible, may be shallow or collapsed. Small to large amounts of fibrin, hypopyon, and/or hyphema may be present in the anterior chamber. Fluorescein stain should be applied to determine wound leakage (a clear stream of aqueous humour in fluorescein-stained tears) and to assess for other corneal damage; fluorescein will stain the wound margins and may cause fluorescence of the aqueous humour if the wound is not yet sealed. During the examination, it is important to assess the nature and extent of the eye injury and to evaluate for neurologic or other injuries elsewhere on the body. A complete extraocular and intraocular examination of both eyes should be attempted, but examination of the inside of the affected globe can be difficult if fibrin, hyphema, miosis, severe corneal edema, or anterior chamber collapse is present. A focal, very bright light should be used to assess the consensual papillary light response. The dazzle reflex (a subcortical response of partial, bilateral blinking of the eyelids in response to a quick, very bright light stimulus) should be assessed because it can indicate an intact visual pathway to the level of the midbrain. Transpalpebral ultrasonography can be performed to evaluate lens integrity and position and to assess and characterize posterior segment damage and can be a valuable supporting tool for prognosis in many cases but should only be performed under very heavy sedation or general anesthesia. If the animal is awake and resistant to the procedure, ocular movements or retractor bulbi contractions can cause further prolapse or distortion of intraocular contents. A heavy coating of sterile ultrasound coupling gel should be applied to the closed lids, and a transpalpebral scan should be performed with no pressure whatsoever applied to the globe. Gel must not enter the palpebral fissure. A stand-off pad is not recommended because its use applies further weight/pressure to the eye.

All lacerations of the globe have a guarded prognosis because of the possibility for infection, but certain lacerations carry a guarded to grave prognosis, and enucleation or intrascleral prosthesis placement instead of repair should be discussed with the owner. Restoration of a visual eye is extremely unlikely in these cases, and many will develop phthisis bulbi, a shrunken and often painful eye. Any laceration associated with proptosis, 50% or greater hyphema, or lens rupture/dislocation, or as a result of severe blunt trauma carries a very guarded prognosis. Cases with ruptured lenses require phacoemulsification to remove all lens cortical material or chronic uveitis results in most cases. Lacerations of greater than 24-hour duration with a flat anterior chamber have a guarded prognosis. An eye ruptured from blunt trauma carries a grave prognosis because the intense blunt force required to rupture the eye usually results in multiple, severe intraocular damage. Extensive laceration with prolapse of intraocular contents other than aqueous or iris tissue carries a poor prognosis, but the examiner should be sure that suspected vitreous prolapse is not just clotted aqueous humour. Lacerations that extend across the limbus into the sclera have a poor prognosis if a large amount of uveal tissue has prolapsed through the scleral wound. Prolapsed uveal tissue in these cases usually includes the ciliary body, and damage to the ciliary body results in decreased aqueous humour production, hypotony, and phthisis bulbi. The uveal tissue prolapse through the sclera can occur beneath an intact overlying conjunctiva, and if the conjunctiva is swollen or hemorrhagic, the prolapse can be difficult to confirm by visualization. Because many of these types of injuries develop phthisis bulbi, if the client wants to preserve the appearance of a somewhat normal eye, an intraocular prosthesis can be placed through the wound at the time of the initial surgery after complete removal of intraocular contents or as a second procedure performed immediately upon recognition of shrinkage of the globe. Lacerations that are heavily contaminated or are caused by a perforating injury have a high likelihood of infection and are not candidates for prosthesis placement.

Lacerations with a fair or good prognosis include those that are not full thickness, those with a formed anterior chamber, and those with only a small amount of hemorrhage or fibrin in the anterior chamber or on the surface of the cornea. Iris may protrude through and close the wound, but there is minimal distortion of intraocular structures. Full-thickness lacerations require immediate surgical repair under general anesthesia. Wounds that are not full thickness but with margins separated by more than 2 to 3 mm also need surgical repair under general anesthesia. Referral to a veterinary ophthalmologist is recommended for all but the simplest cases. Surgery should not be attempted unless standard ophthalmic surgery instruments and appropriately sized sutures are available (6-0 or smaller). The repair is usually more difficult than anticipated. Magnification is essential, but only a few specialized instruments are needed, most of which are described in Conjunctival and Corneal Diseases for lamellar keratectomy.

Repairs should always be performed under general anesthesia. Ketamine is to be avoided for general anesthesia or induction, and muscle relaxants are sometimes needed as part of anesthetic protocol to eliminate nystagmus. The eye must be protected during induction so that further injury and tissue prolapse do not occur. After preparation of the surgical field, the wound should be cultured.

The eye should be gently lavaged and cleansed, and any healthy-appearing prolapsed uveal tissue (usually iris) should be replaced into the anterior chamber in acute injuries. Necrotic, desiccated, macerated uveal tissue is carefully excised in all cases. The surgeon must understand that postoperative uveitis is proportional to the degree of uveal damage/handling. A rule of thumb is to always excise uveal tissue that is clearly contaminated or that has been prolapsed longer than 24 hours. Uveal excision can result in severe hemorrhage. Battery-operated bipolar microcautery[12] devices are extremely helpful in these cases. The anterior chamber is irrigated and then reformed with balanced salt solution or

[12]Acuderm, Inc., 5370 NW Terrace, Ft. Lauderdale, FL, USA, www.acuderm.com, or Aaron Medical, 7100 30th Avenue North, St. Petersburg, FL, USA.

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lactated Ringer's. The lens is inspected if possible. Viscoelastic substances are critical to assist chamber formation and dissection of uveal tissue but may require removal before complete wound closure or postoperative ocular hypertension can result.

Wound apposition should be precise and is greatly improved if binocular magnification is used. Appropriate suture size varies somewhat with the size of the patient; 7-0 or 8-0 polyglactin 910 ophthalmic suture may be the most practical because it does not require removal. Sutures should be placed 1 to 1.5 mm apart—as deep as possible in the stroma—but must not be full thickness; entry and exit points of the suture should be perpendicular to the corneal surface and wound edge, respectively. Sutures should be tightened just to the point of tissue apposition; overly tight sutures can cause gapping of the deep wound edges. The chamber is reformed after wound closure with lactated Ringer's or balanced salt solution through a 27- to 30-gauge needle inserted at the limbus. Wound integrity should be confirmed by applying fluorescein to the corneal surface and applying gentle external pressure to the globe. Unstable, irregular wounds or repairs may be reinforced with a conjunctival flap, but this is not usually necessary unless the security of the wound closure is in doubt. Conjunctival flap placement almost always results in a denser, more opaque corneal scar postoperatively. Ophthalmic texts should be consulted for details on conjunctival flap placement. A transpalpebral lavage device could be placed at this time if desired. The eye should not be covered by a tarsorrhaphy or membrana nictitans flap except during the immediate postoperative and recovery period unless there is a strong indication for the procedure. Nictitans flaps and temporary tarsorrhaphies can cause corneal irritation. Furthermore, nictitans flap placement can increase intraocular pressure, thus resulting in wound leakage, and both nictitans flaps and tarsorrhaphies preclude direct examination of the globe, which is important postoperatively.

The eyes should be monitored daily or more often for 7 to 10 days postoperatively. Profound secondary uveitis is common and will require management; endophthalmitis may develop. Postoperative treatments are greatly facilitated by placement of a transpalpebral lavage apparatus while the patient is under general anesthesia, as discussed in the introduction. Topical 1% atropine solution should be used to effect or up to three to four times a day, to facilitate pupil dilation and cycloplegia and to stabilize the blood aqueous barrier. Topical broad-spectrum antibiotic solutions should be used every 1 to 2 hours for 24 hours, then every 2 to 4 hours for 3 to 7 days, and then every 4 to 6 hours, depending on the condition of the eye, for 3 or more weeks. Systemic broad-spectrum antibiotics with a good gram-positive spectrum are indicated; systemic nonsteroidal antiinflammatory agents may be indicated in some cases to help control postoperative uveitis. Topical nonsteroidal medications may be used with caution if needed, but the eye should be observed daily for progressive keratomalacia.

Superficial nonpenetrating, nongaping lacerations can be treated as corneal ulcers and monitored carefully every 1 to 2 days for secondary infection, particularly if plant matter caused the laceration. Medications should include topical 1% atropine once or twice a day or more often to effect to maintain pupil dilation, topical broad-spectrum antibiotics every 2 to 4 hours for 3 days, and then four to six times a day, depending on the condition of the eye. Systemic nonsteroidal antiinflammatories may be needed occasionally until the wound is healed and any associated uveitis controlled. The wound should be monitored for enzymatic digestion by tissue collagenases or proteases, which would cause the cornea to develop a jelly-like or mucoid consistency. Topical autologous serum or 10% acetylcysteine should be added every 2 hours to the treatment regimen if in doubt.

Some corneal injuries result in deep flap wounds of varying thickness, with flaps of tissue still attached to the cornea; these should be repaired as lacerations. Flaps that have minimal edema can be carefully replaced over the wound bed by rolling a cotton swab over the flap to press it firmly in place and remove air bubbles. After this, the flap can be secured at the wound edges with points of tissue adhesive or sutures. If the flap subsequently detaches it may need to be excised, but corneal tissue should be preserved whenever possible. Very thin flaps are best excised immediately.

Corneal Foreign Bodies

Corneal foreign bodies are found frequently in food animals with painful, irritated eyes and are usually foodstuffs, although other plant material, hairs (eyelash or tail), metallic, glass, shot, or other substances have been found. Rebhun (1995) reported corneal foreign bodies commonly occurred after windstorms and associated with tail switching. In such cases, hairs can be embedded in the cornea or intraocularly. If a corneal foreign body is suspected, the owner should keep the patient quiet and prevent self-trauma to the eye.

Clinical signs initially include squinting, tearing, and photophobia; a mucopurulent ocular discharge may develop after 1 to 3 days in some cases that develop secondary infection. Signs can vary with the size, location, nature, and extent of the injury and the type of foreign body. The patient may rub the affected eye, blink it frequently and forcefully, and have frequent extrusions of the membrana nictitans. Ocular examination with a focal light source and magnification is usually diagnostic if the foreign bodies are embedded in the cornea. Sedation, eyelid block, and topical anesthesia may be necessary for diagnosis because most affected animals are in a lot of pain with intense blepharospasm. Corneal or ocular foreign bodies may be readily visible or very small and difficult to see, even with good magnification and lighting. The depth of the foreign body should be assessed carefully. The iris and anterior chamber are examined very delicately for evidence of foreign body penetration—including aqueous flare, fibrin, hyphema, and so on. These may be obvious to very subtle. Fluorescein stain should be applied to determine the extent of associated corneal ulceration and to assess aqueous humour leakage in the case of deep stromal foreign bodies (leaking aqueous humour appears as a clear stream in the fluorescein-stained tears). Foreign body penetration into the anterior chamber has a guarded prognosis. The examiner should also use care examining anything that appears as a black foreign body in the cornea, because what appears to be a foreign body may be a piece of iris or corpora nigra that is sealing a corneal perforation. These are approached with caution because disturbing the lesion may cause aqueous humour to leak. Careful anterior chamber and iris examination should be diagnostic as anterior synechia is usually obvious if the anterior chamber is examined from the sides. Cases with large, deep, or penetrating foreign bodies or corneal perforations require general anesthesia before removal and may need referral to a specialist trained in microsurgical technique who is capable of managing a potential perforation.

All foreign bodies should be removed as soon and carefully as possible to prevent further patient discomfort and penetration of the object through the corneal layers. Regardless of the type of correction used, it is critical to make certain all foreign material is removed. This requires a very bright focal light source, magnification, time, and patience. Superficial foreign bodies can often be removed by using a strong spray of sterile saline from a syringe directed

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tangentially at the foreign body through a 20- or 22-gauge needle hub while the eyelids are held open. If the lids cannot be kept open, a palpebral nerve block should be performed. If spraying does not dislodge the offending material, topical anesthesia can be applied and a 25-gauge needle or small, toothed forceps (e.g., Bishop-Harmon 1 × 2 mm, Colibri or other) can be used to gently remove the material. All foreign particles should be sent for bacterial and fungal culture and sensitivity. Postoperatively, the eye is managed topically as a complicated corneal ulcer, including four- to six-times-daily broad-spectrum antibiotics and topical atropine twice per day to effect pupil dilation.

Prognosis is fair if all foreign material can be removed and no severe secondary infection is found. Prognosis for penetrating foreign bodies is guarded because of the high incidence of secondary endophthalmitis, particularly if the perforation was caused by plant material or hair.

Corneal Ulcers Requiring Surgical Intervention

Corneal ulcers seen in cattle and small ruminants most commonly occur from trauma, foreign bodies under the lids or nictitans, or primary or secondary infectious agents. The corneal disease in cattle caused by *Moraxella bovis* and other organisms is certainly the most economically significant disease in the world in veterinary ophthalmology; *Chlamydophila* spp. (Figure 10-36), *Mycoplasma* spp., and *Rickettsia* spp. can also cause serious individual or herd problems with resultant economic losses to sheep and goat producers or owners. *Listeria monocytogenes* infections should be suspected in animals fed silage. Corneal ulcers require immediate veterinary attention, frequent topical and often systemic medications, and careful follow-up. Fortunately, the ruminant eye is very forgiving and subjectively heals better than that in some other species. Veterinary ophthalmology textbooks or species-specific medical texts should be consulted for the details of proper medical management of corneal ulcers.

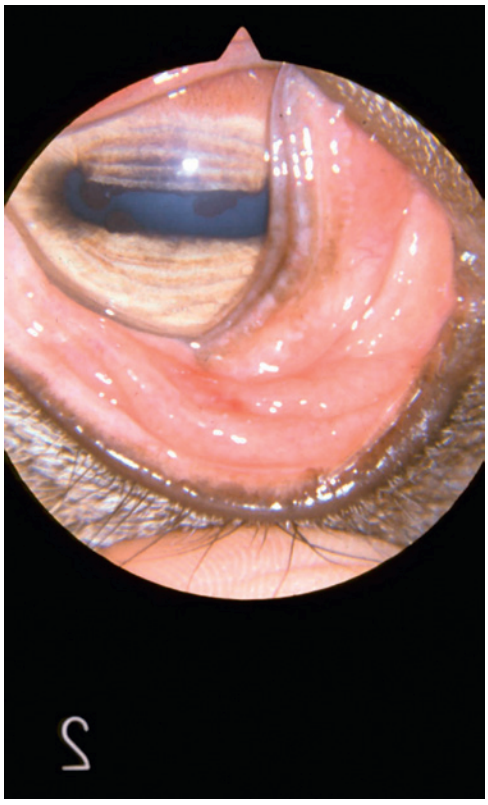


Figure 10-36 Acute conjunctivitis in the right eye of a young goat; the problem was bilateral.

Corneal ulcers that are extremely large or deep on initial examination (e.g., descemetoceles), do not respond, or worsen with medical therapy may require surgical intervention. A simple procedure that provides some protection and support to the healing cornea is the membrana nictitans, or third eyelid flap, which secures the nictitans to either the dorsotemporal bulbar conjunctiva or to the upper lid. Both procedures can be performed under heavy sedation, topical anesthesia, and eyelid akinesia, but for best results and to reduce the risk of rupturing a deep ulcer, general anesthesia may be necessary. The preferred techniques are described by Severin. Although securing the nictitans to the bulbar conjunctiva may provide more support and less movement of the nictitans against the healing corneal epithelium, the preferred procedure in large-animal patients is to secure the third eyelid into the fornix of the upper eyelid. Although there is more movement of the eye independent of the nictitans and potentially less direct corneal epithelial support with this procedure, there is much less risk of a suture penetrating the globe during placement and of corneal irritation from the suture. This type of flap can be left in place for a longer time than those secured to the bulbar conjunctiva.

To perform the procedure the nictitans is grasped at the free margin and stretched across the cornea to determine the normal direction of movement for that patient. In general, most flaps will be secured to the dorsotemporal fornix, but occasional cases are best secured laterally, according to the anatomy of the individual patient. The preferred suture is 3-0 to 4-0 silk because of ease of handling and knot security, but silk must be removed at a later date. Bovine surgeons may prefer 1-0 to 2-0 suture, commonly chromic catgut, which will dissolve over time and loosen the flap without suture removal but they may leave irritating suture ends during the process. Two horizontal mattress sutures are placed and bites spaced accordingly. The surgeon should remember to first place each suture through a stent of tubing or other material if the flap is to be left in place for several weeks. The upper lid is grasped and pulled away from the globe as the needle is passed first through the skin and conjunctiva approximately 5 cm from the lid margin. During needle passage in the standing animal, the cornea should be protected with a lid plate or with the operator's fingers. The next bite is a horizontal mattress-type bite through the palpebral or front surface of the nictitans, 2 to 3 mm from the free edge. The bite may partially penetrate the cartilage—but not the caudal or bulbar surface of the nictitans—and should not be placed around the base of the T-shaped cartilage. The suture is completed by passing it back through conjunctiva and skin so that the final bite is 3 to 5 mm from the first. Three sutures are preplaced. Before tying, the bulbar surface of the nictitans is inspected and mucus and exudates are washed from the eye. The sutures are pulled in unison as the nictitans is guided under the upper lid. The free margin of the nictitans should be tucked well under the upper lid before knots are tied on the outside of the eyelid. Sutures should be slightly overtightened before knotting if there is excessive tissue swelling to ensure the sutures remain tight and well away from the cornea as swelling decreases.

Although unsightly for owners to look at, third eyelid flaps cause minimal discomfort to the patient, can be a useful adjunct to healing, can reduce pain, and can prevent further injury (e.g., from exposure), but they are not without problems. One of the most serious concerns is that a flap precludes daily examination of the eye, which is critical in rapidly deteriorating corneal ulcers. If the flaps are placed improperly or the sutures loosen or pull out, additional or

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worsening corneal ulceration may result. The flaps should be removed immediately for careful eye examination if increased rubbing, squinting, exudates (pus, mucus, or tears), pain, fever, or depression is noted.

Conjunctival flaps are the treatment of choice for many rapidly deteriorating or deep corneal ulcers and may be indicated after some keratectomies. They support the ulcer, provide immediate blood supply, release beneficial blood components over its surface, provide a source of fibrovascular tissue to reinforce the healing wound, and increase the concentration of systemically administered drugs that reach the site. They should be used judiciously and only when necessary for ulcers located in the central cornea because the resulting scar can be quite dense and permanent in some cases and will impair vision. Conjunctival flaps are also useful to reinforce the cornea after laceration or foreign body removal.

Many types of conjunctival flaps have been described including 360 degrees (total), hood, bridge, pedicle, rotational, peripheral, advancement, tongue, and others. The type of flap used varies with the location, depth, and etiology of the ulcer; the available instrumentation, proper lighting and magnification, and experience of the surgeon are other variables that should be considered before surgery.

A fornix-based, total (360 degree) flap is the simplest of the described procedures and requires the least instrumentation. Conjunctiva is dissected as described here, 360 degrees around the limbus (leaving a 2-mm rim of conjunctiva attached at the limbus because corneal stem cells are located there). Using care to keep the conjunctival dissection superficial in order to avoid cutting the extraocular muscles (see below), the dissection is extended a sufficient distance toward the equator of the globe to allow conjunctivae from the opposing hemispheres to be sutured together centrally, using mattress sutures of 4-0 to 6-0 synthetic absorbable suture. Corneal sutures are not usually placed, and the procedure does not necessarily require use of a microscope or magnifying loupes. All of the other described flap procedures require 6-0 to 8-0 accurately placed corneal sutures, mandating good magnification.

A properly performed conjunctival flap dissects only the conjunctiva and does not incorporate the thick, underlying, somewhat gelatinous, and quite elastic Tenon's capsule. Conjunctiva is extremely thin and almost transparent. During proper dissection of the conjunctiva one should be able to clearly visualize the tips of the scissors at all times—not just imagine their presence or see their impression through the tissue. Tenon's capsule is hard to exclude from the dissection, but care should be taken to do so. A too-thick flap is ultimately harder to place, harder to secure, more likely to retract after placement, and will eventually result in a denser scar that can be blinding in the central visual axis. A subconjunctival injection of sterile saline before dissection may make the tissues easier to separate. Care must be taken at all times during dissection to avoid severing any of the extraocular muscles deep in the Tenon's capsule and superficial to the sclera.

Some disadvantages of the 360-degree flap are the same as for a nictitans flap, and include prevention of a complete examination of the cornea and other structures inside the eye due to obstruction by the total flap being the most significant. In addition, the 360-degree flap is often much thicker and more opaque than other types of flaps, and corneal scarring may be more severe. In most cases, the pedicle or rotational flaps are strongly preferred, the details of which can be found in any ophthalmology text. Whenever possible, the flap should be positioned so the nictitans can move smoothly over the flap pedicle rather than bumping against the flap edges. The appearance of the final scar can be improved if pigmented conjunctivae can be transposed.

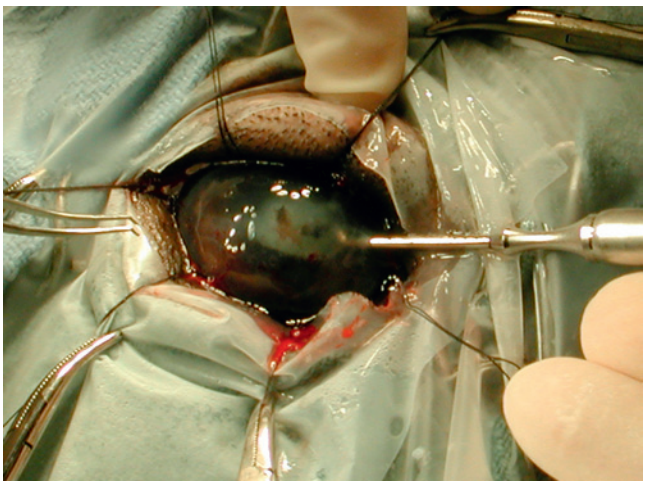


Figure 10-37 Phacoemulsification of a cataract in a water buffalo.

Corneoscleral transposition, lamellar keratoplasty, and penetrating keratoplasty are additional surgical procedures that can be used in some cases of corneal ulcers, abscesses, or some degenerative diseases. All of these procedures require highly specialized instrumentation and operating microscopes and may require referral to veterinary ophthalmologists trained in the procedure(s).

Cataract Surgery

Cataracts are not reported as commonly in food animals as they are in horses and small animals, but they do occur. Cataract removal may be indicated in select cases and is performed with phacoemulsification (Figure 10-37). Replacement intraocular lenses suitable for food animals are not available and moderately severe hyperopia may result, but successful cases show marked improvement negotiating what should be a controlled environment. The surgery is best performed at specialty referral centers.

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CHAPTER 11

Postmortem Examination

Josepha DeLay

Postmortem (PM) examination provides a mechanism for practitioners and producers to understand the cause of disease and/or death in animals. Most commonly, the goal of the examination is to control and prevent disease in a herd or flock. PM examination may also be required to document lesions or the cause of death for legal or insurance purposes, recognize surgical complications or surgical improvements that can be made, or address animal welfare concerns. The maximum amount of information will be gleaned from an examination conducted in a thorough, systematic manner. A key to efficiency is to incorporate PM examinations into daily practice, making the method as routine as physical examination of a live patient. Once the procedure itself becomes automatic, the practitioner can concentrate on lesion detection and interpretation. Each practitioner should establish a PM examination routine that is comfortable for him or her and use this method consistently.

A problem-based approach to PM examination contributes to efficiency and directs focus during the examination to specific organ systems based on clinical differential diagnoses. Establish a list of differential diagnoses before beginning the PM examination, based on clinical signs and epidemiologic features of the disease. During the examination, search out and evaluate lesions that would support these differential diagnoses, and identify other lesions that could expand the list. The examination should be as thorough as possible, as valuable but unexpected lesions could be overlooked if the examination is incomplete. Renderer's requirements may influence the extent of the PM examination; however, this need must be balanced with the benefits of conducting a thorough examination.

Frequent participation in PM examinations allows a practitioner to create a mental catalog of the normal appearance of various organs and artefactual PM changes, to better recognize significant lesions when encountered. Changes in organ size, color, texture, and symmetry are important to note, as well as more obvious lesions such as abscesses, necrotic foci, fibrinous exudate, and rupture of an organ. Many lesions encountered during a PM examination are abnormal but are not considered significant to the animal's demise. Postmortem tissue autolysis will contribute to color (green/brown/red) and textural (friability) changes. Lividity (that is, postmortem blood pooling) results in color change, most notable as dark red-black discoloration in the down-side lung in animals dying or left lying in lateral recumbency. Scavenging by predators will cause various injuries unaccompanied by hemorrhage, as the lesions were produced after death.

BIOSECURITY AND BIOCONTAINMENT

Field PM examinations should be located in a low-traffic area that is relatively contained, to prevent pathogen dissemination to other animals and physical locations on the premises. In many geographic locations, seasonal conditions will affect where the PM examination is conducted, and the extent of cleaning and disinfection that will occur following the examination. PM examinations are inherently untidy procedures, and significant risk of contamination is possible if the practitioner and producer are not cognizant of contamination of people and equipment at the site. An area close to on-farm composting or rendering collection bin locations is ideal. In hog barns, the outside end of the loading chute is a common site for PM examination and limits the potential for pathogen spread back into the barn. Any heavy equipment used to transport or support the body during the examination, and all instruments used for the examination, should be thoroughly washed and disinfected at the end of the procedure. All footwear should be similarly cleaned and disinfected.

PERSONAL PROTECTIVE EQUIPMENT (PPE) AND ERGONOMICS

Disposable gloves, coveralls, steel-toed boots and safety glasses comprise the minimum PPE required for field PMs. Kevlar gloves should be considered for the nonknife hand. These are comfortable and reusable and can prevent cuts from knives, scalpels, and bone, especially transected ribs. Safety glasses are beneficial both to reflect flying bone shards and to prevent ocular and oral contamination by blood splashes and intestinal content. When performing PM examinations on animals with suspected zoonotic diseases, practitioners should also wear double gloves and appropriate respiratory protection (such as disposable respirators masks) and face shields.

As with other facets of food animal practice, PM examination presents many ergonomic challenges that can be difficult to accommodate in the field. In diagnostic laboratories, examinations are conducted with the body on a hydraulic table that can be adjusted throughout the examination to accommodate the height of the prosector and the region of the body that is being examined. In field situations, the animal is often on the ground and the practitioner must adjust his or her body to the animal's location. Wherever possible, use external appliances such as the bucket of a loader tractor or large bales covered with disposable plastic tarps to raise the body to a comfortable level. The various methods used will be influenced by biocontainment issues discussed previously and will require some degree of imagination on the part of both the practitioner and the producer.

Enlisting an assistant such as an animal health technician or the producer to help during dissection, and as a set of clean hands for sample collection and photography, will streamline the PM procedure and increase safety for the practitioner, especially during dissection of mature cattle. Recommendations for PPE, ergonomic guidelines, and biocontainment apply to all individuals participating in the PM examination.

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EQUIPMENT

A dedicated PM kit contributes to the efficiency and ease of the procedure. A combination of common surgical instruments and veterinary supplies and tools obtained from hardware, garden, and restaurant supply stores complete the kit. Scalpel handles and disposable scalpel blades, scissors, and tissue forceps are necessary for organ dissection and sampling. A large, sturdy kitchen knife with a plastic handle and a hand-held manual knife sharpener are invaluable. A sharp knife dramatically increases the ease of dissection, and tips for maintaining a sharp blade are provided elsewhere. Aviation-type tin snips make excellent bone cutters for young and smaller animals. Large tree pruners are suitable as rib cutters for medium-sized animals. A cordless rechargeable oscillating saw, hacksaw, sturdy cross-cut saw, or axe can be used to cut ribs and skull bones in mature cattle. Note that oscillating saws should not be used in animals with suspected zoonoses because of potential aerosolization of pathogens.

Sterile sealable plastic bags in various sizes are required for sample collection for microbiologic and toxicologic testing. For histopathology, containers of 10% neutral buffered formalin should be of a size appropriate to provide a 1:10 ratio of tissue to formalin. If needed, use multiple containers rather than compromising tissue fixation. Small 30- to 60-mL sterile sample containers with screw caps are useful for collection of intestinal content and urine. Sterile swabs, syringes, and needles and serum tubes can be used for collection and storage of various fluids, including synovial fluid, urine, and body cavity effusions. A permanent marker is needed to label all sample containers and bags. A camera or smart phone for digital image capture is advantageous for recording and later reviewing lesions at all stages of the PM examination. Images of gross lesions can also be forwarded to the veterinary pathologist performing histopathology, to allow correlation between gross and histologic findings. A method for voice or written recording of gross lesions is desirable.

SAMPLING AND ANCILLARY TESTING

The PM examination provides a one-time opportunity to collect a range of tissue samples that can be used for ancillary tests carried out at a veterinary diagnostic laboratory. Most laboratories publish recommendations for sampling and test selection that are specific to these facilities. As part of the problem-based approach to PM examination and based on the antemortem differential diagnoses, a list of ancillary tests and appropriate samples should be established before beginning the PM examination. This list can be mentally adjusted as the examination progresses, based on the lesions encountered. Histopathology, various microbiologic tests, and toxicologic assays are valuable adjuncts to gross PM, especially if the cause of death is not evident from gross examination alone. In cases where the diagnosis can be made on gross examination, ancillary testing can provide a specific etiologic diagnosis that can guide vaccination programs or other methods for disease prevention and control. As a general rule, duplicate fresh and formalin-fixed samples of tissues with lesions should be collected. Fresh tissues are suitable for the vast majority of microbiologic tests, including bacterial culture and various polymerase chain reaction tests. Formalin neutralizes most pathogens (excluding prions), and as a result, formalinized tissues are not suitable for microbiologic tests such as bacterial culture and antigen enzyme-linked immunosorbent assay. Some polymerase chain reaction assays can be performed using formalin-fixed tissues; however, the method is not routine at most laboratories, and test sensitivity can be negatively affected by nucleic acid fragmentation resulting from formalin exposure.

Fresh tissues for microbiologic tests should be collected as aseptically as possible. Examination of intestine should be carried out near the end of the PM examination, to limit contamination of other tissues. The notable exception is in cases of neonatal diarrhea, where immediate formalin fixation of intestinal samples from very recently euthanized animals is important. Each fresh tissue sample should be collected into a separate sterile, sealable plastic bag and labeled with tissue and animal identifiers using permanent marker. A 2- to 3-cm^3 sample is adequate for most microbiologic and toxicologic tests. For intestine, 3- to 5-cm segments are appropriate for microbiology. Collection of intestinal content into sterile containers (plastic screwtop, not glass) is suitable for various bacterial and viral polymerase chain reaction testing, as well as for parasitology tests. Sterile swabs are useful for sampling joint surfaces and body cavities in cases where effusions are detected.

Tissue samples in formalin should be sufficiently small to allow rapid fixation and optimal preservation for histologic examination. Approximately 1-cm^3 samples from solid organs and 2- to 3-cm intestinal segments opened longitudinally are appropriate. For most organs, a single sample incorporating normal and lesional tissue is adequate. Include serosal surface or organ capsule in the sample. Kidney samples should include both cortex and medulla in one piece. Lung samples should include cranial, middle, and caudal lobes. One section from each level of the gastrointestinal tract should be included (forestomachs, abomasum, duodenum, jejunum, ileum, cecum, spiral colon, descending colon). In cases with enteric disease, multiple intestinal samples from affected levels will increase the probability of identifying diagnostically useful lesions, because many infectious and noninfectious enteritides have a segmental distribution.

A concise history with pertinent clinical details and gross PM findings is an important part of all submissions for ancillary testing. Signalment and epidemiologic features of the disease condition should be included in the clinical differential diagnoses. The objective features of gross lesions are most important. The practitioner's subjective interpretation of these findings may also be included.

PM examinations should be conducted as soon after death or euthanasia as is feasible. Tissue autolysis begins immediately after death, as do overgrowth of commensal and contaminating bacteria. Both situations will negatively affect the results of gross and histologic PM examination and can adversely influence results of microbiologic tests. Ideally in a disease outbreak situation, and especially in neonates, euthanasia and immediate PM examination of two to three acutely affected, untreated animals will provide optimum samples for all ancillary tests and the best chance for reaching a useful diagnosis.

PM PROCEDURE

1. *External examination*. Record identification tags, tattoos, and brands; digital images are useful. Note body condition, muscle mass, condition of hair coat, and hydration status of the animal. Examine oral, ocular, and genital mucous membranes for color (that is, evidence of anemia, jaundice, etc.), ulceration, vesicle formation, or other lesions. Examine oral cavities and teeth for wear and other changes and to corroborate age. Identify any external cutaneous lesions, including lacerations, and

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ulcerations at mucocutaneous junctions and coronary bands. In cases of unexpected death, note the physical location and position of the animal. Check for evidence of fracture. Evaluate joints for evidence of swelling and, if present, aseptically aspirate joint fluid and store aliquots in blood tubes with ethylenediaminetetraacetic acid (for cytology) and without additives (for microbiology). Multiple joints of both forelimbs and hindlimbs should be incised to allow evaluation of synovial fluid and articular surfaces.

2. *Ventral midline incision, skin back right side of body, disarticulate right coxofemoral joint, and incise shoulder girdle.* With the body in left lateral recumbency, make a ventral midline skin incision extending from the mandibular symphysis to the anus. In male animals, extend the incision parasagittally around the prepuce. In females, similarly circumvent the mammary gland. Begin with a stab incision over the sternum, to avoid puncture of abdominal viscera. Extend the incision by directing the knife subcutaneously (with blade outward, to avoid dulling the knife) cranially and caudally from the initial incision. Grasp the edge of the upper (right) side of the skin incision, and while applying traction cut through subcutis and retract the skin covering the right side of the abdomen. Extend the incision through the axilla and serratus ventralis muscle while elevating the right forelimb such that the limb is reflected over the dorsal aspect of the body. Retraction by an assistant of a rope tied around the pastern can aide in this step. Similarly with the right hind limb, elevate (abduct) the limb, and incise muscle at the medial aspect of the limb to the level of the coxofemoral joint. Incise the joint capsule, transect the ligament of the femoral head, and reflect the hind limb over the dorsal aspect of the body while cutting through muscle surrounding the greater trochanter of the femur.
3. *Expose the abdominal cavity.* Incise through and remove the muscle of the right abdominal wall extending from the spinal column to the ventral midline, just caudal to the last rib and cranial to the pelvis, and exposing the abdominal cavity. Examine the peritoneum and viscera in situ for lesions including peritonitis, peritoneal effusion, displacement, and rupture. Collect samples aseptically (fluid, swabs) if effusion or peritonitis is evident.
4. *Expose the thoracic cavity by removing the right lateral thoracic wall.* Puncture the diaphragm from the abdominal aspect, checking for evidence of normal negative intrathoracic pressure, observed as an inrush of air. Incise the outer circumference of the diaphragm at the margin with the rib cage. Make an incision through the muscle at the dorsal and ventral aspects of the right lateral rib cage, providing access for rib cutters. Cut the ribs along the incised line, avoiding the lateral vertebral processes and sternum at the dorsal and ventral margins of the thoracic wall, respectively. Remove the right thoracic wall by cutting through any remaining soft tissue.
5. *Examine thoracic contents in situ.* Evaluate for lesions including pleuritis, pleural effusion, pneumonia, and abscesses. Incise the pericardial sac for evidence of pericarditis. Collect samples aseptically (fluid, swabs) if pleural effusion, pleuritis, or pericarditis is evident.
6. *Remove the pluck (tongue, larynx, esophagus, trachea, lung, heart, and attached structures removed intact).* Cut through the mandibular symphysis using bone or rib cutters (in young animals), or remove the rostral aspect of the mandible using a hacksaw (in older animals). While retracting the tongue ventrally, incise its lateral margins adjacent to the mandible. Incise the dorsal and lateral aspects of the pharynx while continuing to apply traction, and disarticulate the hyoid apparatus by incising through the prominent epihyoid-ceratohyoid joints. Thoroughly examine the oral cavity, teeth, and tongue for evidence of ulceration or erosion, dental attrition, and other lesions. Incise soft tissue at the dorsal and lateral aspects of the trachea and esophagus while continuing to apply traction to the tongue. Similarly, incise the soft tissue at the thoracic inlet and dorsal and ventral mediastinum. Transect aorta, esophagus, and vena cava at the caudal aspect of the thorax, as well as pericardial attachments at the ventral aspect.

   Conduct a more in-depth examination of organs of the pluck by evaluating the thyroid glands for size and symmetry; incising the length of the esophagus and the trachea to evaluate mucosal surfaces; evaluating the thymus for size (taking the animal's age into account) and lesions; and examining the lung. If abnormal, estimate the percentage of the affected lung parenchyma for interpretation of clinical significance of pneumonia. Transect the lung lobes in several sites and evaluate the cut surface for evidence of bronchiolitis, necrosis, consolidation, or thrombosis. Examine the external surface of the heart for evidence of epicarditis, and evaluate the general shape of the heart for evidence of chamber enlargement. Make a transverse cut across the ventricles approximately ⅓ of the distance between the apex and heart base, and compare the thickness of the right to the left ventricular outer walls. In neonates, the ratio will be 1:1 or 1:2. In animals older than 4 to 5 days, the ratio should be approximately 1:3. Open both atria and ventricles to evaluate the atrioventricular, pulmonary, and aortic valves. Especially in neonates, in cases with abnormal ventricular wall ratios, and in cases of unexpected death, search for congenital lesions including atrial and ventricular septal defects and patent ductus arteriosus. Evaluate the endocardium distal to aortic and pulmonic valves for evidence of fibrosis (jet lesions).

   In many field circumstances, examination of thoracic organs in situ may be adequate and most efficient, and pluck removal will not be necessary. However, removal of these organs and examination outside the body allow complete visualization of both lungs and facilitates more thorough examination of the heart. Pluck removal is recommended in cases with pneumonia, potential cardiac disease, or other intrathoracic disease conditions and in cases of unexpected death. Removal of thoracic viscera also provides more space for manipulating abdominal organs and can be especially advantageous in mature cattle.
7. *Examine abdominal organs in situ.* Evaluate serosal surfaces for evidence of peritonitis. Assess displacement or torsion/volvulus of the gastrointestinal organs. Intestinal anatomoses should be assessed for evidence of leakage by pressuring content toward the suture line.
8. *Examine and sample solid abdominal organs (liver, spleen, kidneys, adrenal glands, pancreas) before opening the gastrointestinal tract, to prevent contamination of potential microbiologic samples.* Make several transverse incisions through the liver, checking for abscesses. Examine the caudal vena cava for evidence of thrombi. Sagittally section kidneys in situ, and examine the renal pelvis (for evidence of pyelonephritis or hydronephrosis) as well as the cortex and medulla. Transversely section the adrenal glands, evaluating the cortex and medulla. Incise the urinary bladder, examining the urine as well as bladder mucosa.
9. *Incise the gastrointestinal tract at various levels, exposing and evaluating mucosal surfaces and luminal content.* Gastrointestinal organs should be first examined entirely in

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situ to accurately assess the presence of displacement, torsion or volvulus, and serosal contamination/reaction. Thereafter the gastrointestinal tract may be removed for more thorough examination outside of the body. In cases where gastrointestinal disease was diagnosed clinically, and especially in larger or more mature animals (with a larger gastrointestinal tract), removal of the entire tract allows for easier examination. Whether examining in situ or externally, note key organs to provide anatomic orientation: the ileocecocolic junction, spiral colon, forestomachs in ruminants, and jejunum.

In mature cattle, reflect and exteriorize the entire small intestine and colon over the dorsal lumbar region of the body. Remove forestomachs by firmly grasping and pulling the rumen ventrally over the ventral body wall. Although peritoneal attachments of the dorsal rumen are minimal, some cutting may be necessary to initially free a large, full rumen from the abdominal cavity. Transect at the omasoabomasal junction, allowing the abomasum to remain attached to the reflected intestine. Make several transverse cuts through the spleen. Incise the rumen and measure the pH of fluid content. In a recently deceased animal, normal rumenal pH varies between 5.5 and 7.5. Examine and evaluate rumen content and mucosa. Normal rumen mucosa sloughs easily after death; acidosis and inflammation due to carbohydrate overload result in firmly adherent mucosa. Similarly incise and examine the reticulum and omasum.

Remove the intestine and abomasum from the abdominal cavity en bloc by transecting the rectum and cutting mesenteric attachments. Open the abomasum along the greater curvature, evaluating the content and mucosal surface. Similarly open and examine representative segments of duodenum, jejunum, ileum, cecum, spiral colon, descending colon, and rectum. Examine and incise multiple mesenteric and mesocolonic lymph nodes, with special attention to ileocecal nodes.

In small ruminants, calves, and pigs, examine the gastrointestinal tract in situ by similarly incising and examining the mucosa and luminal content at all levels and evaluating the mesenteric and mesocolonic lymph nodes.

10. *Examine skeletal muscle at multiple sites*. Incise several large muscle bundles of both thoracic and pelvic limbs and trunk. Examine for evidence of lesions including clostridial myositis or nutritional or other myopathy.
11. *Remove the brain*. Examination of the brain is important in cases with evidence of neurologic disease and in cases of unexpected death. Gross and histologic examination of the brain can reveal lesions in some situations in which neurologic disease was not evident clinically (for example, peracute meningitis in neonates), making the case for routine examination of the brain as part of the PM examination.

Two methods are suitable for brain removal under field conditions. The head should remain attached to the body with each method. Compliance with PPE recommendations is important, especially in cases where rabies, *Streptococcus suis* meningitis, listeriosis, or other zoonoses are suspected. Alternatively, the head can be easily removed and safely transported to a local diagnostic laboratory for brain removal and examination. To remove the head, disarticulate at the atlantooccipital joint and sever the junction of the caudal medulla (obex) and C1.

Brain removal method 1: This method creates a coronal or frontal section of the brain, allowing removal in separate rostral and caudal sections. Use a knife to incise skin and soft tissue at the right lateral aspect of the skull along a line extending dorsoventrally from rostral to the base of the pinna to just caudal to the mandible (Figure 11-1). With a hacksaw or crosscut saw, completely transect the skull along the same plane as the cutaneous incision. Using a scalpel or scissors, remove the rostral (cerebral cortex) and caudal (cerebellum, brainstem) brain segments by cutting the cranial nerves and transecting the brainstem at the obex, along with gentle digital manipulation.



Figure 11-1 Landmarks for brain removal by frontal section.

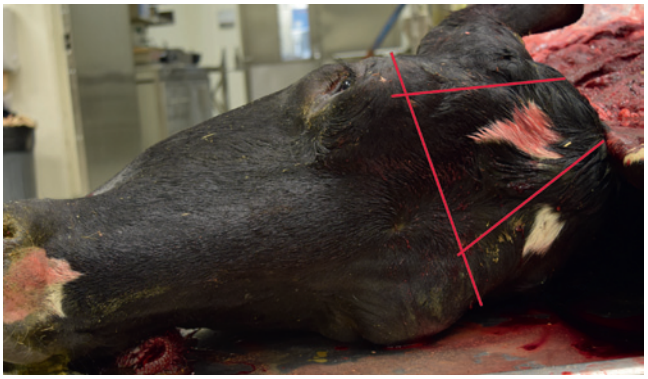


Figure 11-2 Landmarks for removal of calvarium and brain.

Brain removal method 2: The brain is exposed by removing the dorsal aspect of the skull. Reflect skin and muscle over the dorsocaudal aspect of the skull. Using a hacksaw, axe, or cordless reciprocating saw, cut and remove the dorsal calvarium along a roughly rectangular path extending rostrally from the level of the atlantooccipital junction (Figure 11-2). Note that oscillating saws should not be used for brain removal in animals with suspected zoonoses because of pathogen aerosolization. Pry the calvarium off, incising connections with the dura. Transect the junction of the caudal medulla and spinal cord and remove the brain, transecting cranial nerves.

Bone cutters may be used for the same procedure in neonatal animals. First remove the head by incising through the ventral aspect of the atlantooccipital

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junction, transecting the brainstem at the obex and cutting through the surrounding joint capsule and soft tissue. The calvarium is removed using the same landmarks as described previously, beginning with bone cuts at the 10 o'clock and 2 o'clock positions at the foramen magnum and extending the cuts rostrally to remove the calvarium.

Meninges may be swabbed for culture before brain removal at a site uncontaminated by PM instruments. The brain may be sagittally sectioned, with one half held frozen for potential additional tests and the other half fixed in formalin. It is important that the brainstem, cerebellum, and cerebral cortex be included among the samples submitted for histopathology.

12. *Remove the spinal cord, if warranted based on clinical history.* The vertebral column may be submitted intact to a local diagnostic laboratory for spinal cord removal. Alternatively, representative segments of cervical, thoracic, and lumbar vertebral columns may be removed with a hacksaw and submitted intact. The spinal cord may also be removed from these "chunked out" segments, if sufficiently short, by cutting the spinal nerve roots with a scalpel. The left lateral thoracic and abdominal walls and the head will need to be removed to access the vertebral column, regardless of the extent of further cord dissection. In very young piglets, lambs, and kids, the spinal cord may be moved by similarly dissecting out the vertebral column. Beginning at the cranial aspect of C1, the dorsal aspect of each vertebra is sequentially removed using bone cutters directed at the 10 o'clock and 2 o'clock positions of the spinal canal. This essentially results in a dorsal laminectomy that can be continued throughout the length of the spinal cord. The exposed spinal cord can then be removed by grasping the meninges at one end of the spinal canal with forceps and elevating the cord as the spinal nerves are sequentially cut. The dura should be opened longitudinally with scissors before fixation in formalin.
13. Mentally review gross lesions and correlate with clinical findings. Plan ancillary diagnostic testing based on these results.

RECOMMENDED READING

Griffin D: Field necropsy of cattle and diagnostic sample submission, *Vet Clin Food Anim* 28:391–405, 2012.

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PART II

BOVINE (ADULT)

CHAPTER 12

Surgery of the Bovine (Adult) Integumentary System

Catherine H. Hackett, Richard P. Hackett, Charles W. Nydam, Daryl Van Nydam and Robert O. Gilbert

WOUNDS

Richard P. Hackett and Catherine H. Hackett

WOUND HEALING

Wound healing is a complex orchestration of cellular and biochemical processes intricately balanced to achieve healing without potentiating tissue damage or causing excessive tissue proliferation. The cells that mediate wound healing include platelets, macrophages, neutrophils, epithelial cells, lymphocytes, fibroblasts, and endothelial cells. These cells interact, grow, divide, and migrate as directed by chemotactic agents, growth factors, and cytokines. The process of wound healing is a continuum of overlapping events described here as four stages: inflammation, debridement, repair, and maturation.

Inflammation

Inflammation is the body's attempt to arrest fluid loss, prevent infection, and initiate healing. When tissue damage compromises vascular integrity, platelet aggregation and the clotting cascade stop blood loss by forming a fibrin clot. Local cells simultaneously release catecholamines, histamine, cytokines, and prostaglandins. These mediators initially induce vasoconstriction to contribute to hemostasis. In response to chemical signaling, phagocytic cells enter the wound, resulting in the classic signs of heat, redness, swelling, and pain. Controlling pain and other negative effects of excessive inflammation is beneficial to the patient; however, elimination of the inflammatory response will prolong wound healing.

Debridement

Ultimately, the surface of fibrin clot formed during the inflammatory phase dries and becomes a scab. The scab protects the underlying tissue from injury and maintains a moist environment that is hypoxic and acidic, leading to bacterial-growth inhibition and stimulating fibroblast proliferation. Platelets and fibrin form a scaffold of proteins and chemotactic factors to attract neutrophils and macrophages, which remove necrotic debris, foreign matter, and bacteria.

Repair

Soon after injury, fibroblasts migrate across the protein lattice formed by the clot to bridge the damaged dermis with ground substance and collagen. This collagen forms scar tissue that is structurally altered and functionally inferior to the original dermis. By the process of angiogenesis, endothelial cells migrate and anastomose to revascularize the healing tissue. Epithelial cells at the wound margin begin to proliferate and migrate over the healing granulation tissue toward the center of the wound. Epithelialization is complete when apposing margins meet. Contact inhibition prevents further epithelial cell division. Wound contraction is the centripetal closure of the total wound area to reduce defect size. For contraction to proceed, select fibroblasts differentiate into myofibroblasts capable of contracting to pull the wound margins closer together. Contraction stops when the wound margins are apposed or when tension across the wound exceeds the potential strength of myofibril contraction.

Maturation

Remodeling of scar tissue occurs over the next several months. The collagen matrix initially produced by fibroblasts is converted from Type III collagen to Type I collagen. Reorganization and structural cross-linkage develops between the collagen fibers, increasing tensile strength of the scar.

Factors That Affect Wound Healing

Numerous factors affect the body's ability to repair itself. An adequate blood supply is essential for wound healing. Blood delivers nutrients, oxygen, neutrophils, and macrophages and removes cellular wastes. The presence of oxygen is necessary to meet the aerobic demands of metabolically active cells involved in healing. However, some degree of hypoxia stimulates wound healing by inducing multiplication of fibroblasts and secretion of growth factors to promote angiogenesis. Flap wounds, excessive local edema, and certain suturing techniques may disrupt effective local blood supply.

Devitalized tissue, foreign matter, and organic debris delay healing and increase the risk of wound infection. The presence of organic debris reduces the minimum number of bacteria necessary to cause infection. Pathogenic or opportunistic bacteria take advantage of the same binding sites and scaffolding used by neutrophils and fibroblasts to adhere to

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the wound. Some bacteria produce toxins that increase tissue damage and further the ability of bacteria to colonize and infect the tissue. Wounds located over joints or tendons are subject to excessive motion, which delays wound healing. Tension against the wound and recurrent irritation may cause chronic inflammation and exuberant granulation tissue development. Systemic factors such as starvation, hypoproteinemia, anemia, and drug effects are possible but very rare contributors to healing impairment or failure.

WOUND MANAGEMENT

Patient Assessment

Appropriate restraint, sedation, and local, regional, or general anesthesia are essential to effectively examine and manage any wound. Adequate assessment of the whole animal is an important step when treating wounds. An accurate history to determine approximate duration of injury, degree of fluid/blood loss, tetanus vaccination status, and musculoskeletal deficits/lameness will guide your choices in ancillary testing and procedures when the physical examination is completed.

Patient Preparation

Restraint of the animal in stocks, chute, stanchion, or tilt table will greatly aid in wound examination depending on the location of the wound and patient tractability. Ropes may be needed to provide further restraint and increase safety for the patient and examiner. Light sedation is often indicated. Disposable examination gloves should be worn by the practitioner for cleaning the region and during wound exploration. If entry into a synovial space is suspected, sterile examination gloves should be used during exploration of the wound but only after thorough cleansing of the wound. The hair around the injured region should be removed for assessment of the wound edges. This will reduce gross contamination with manure and dirt during the cleaning process. Water-based gel lubricant placed into the wound before clipping will facilitate removal of hair that enters the wound bed during the clipping process. In some cases, it may be helpful to shave the edge of the wound with a disposable safety razor or a scalpel blade held in a hemostatic forceps. The area should be cleansed with a mild neutral soap and water to remove gross debris followed by aseptic preparation with chlorhexidine or iodinated surgical scrub. Surgical scrubs are designed for preparation of intact skin so care should be taken to keep them out of the wound proper. Chlorhexidine scrub should be avoided when preparing wounds near the eyes as severe corneal ulceration may occur with inadvertent chlorhexidine exposure.

Anesthesia

Local anesthetics are irritating and can delay wound healing. Regional anesthesia should be thus used whenever possible. When local anesthesia is unavoidable, injections should be made through the wound and under the skin using the minimal volume necessary to provide adequate anesthesia.

Wound Assessment

Once the wound is thoroughly cleansed it should be examined carefully by visual inspection and palpation. The severity of local tissue injury and degree of remaining contamination should be noted. Skin flaps or muscle flaps should be examined to determine the degree of damage to their blood supply and contamination of their surfaces. Tissue loss may make it impossible to close the wound or result in excessive tension if it is closed.

Assessment of compound injury (injury that goes beyond damage to the skin and subcutaneous tissues) is important to determine an appropriate treatment plan and to render a valid prognosis. Damage to underlying muscle, bone, tendon, synovial structures, and vascular and nerve supply should be carefully assessed, initially by digital palpation. Complementary procedures including radiography, ultrasound, and distention of synovial structures with sterile isotonic fluid can be used to determine compound involvement. If body cavity involvement is a risk, radiographs and abdominocentesis or thoracocentesis may be indicated. Puncture wounds should be palpated to assess direction and depth using digital palpation and/or sterile probes, radiographs, or ultrasound if needed to determine the extent of deeper damage and help rule out the presence of foreign bodies. Contrast agents may be used if appropriate milk and meat withholding times are followed. A treatment plan can be formulated based on a thorough wound assessment and the financial and cosmetic goals of the owner.

Wound Lavage

Regardless of which technique is selected for wound management, removal of organic debris, necrotic tissue, and bacteria is essential. Lavage effectively removes contamination and decreases the inflammatory and debridement phases. To overcome the adhesive ability of bacteria and debris, irrigation fluid must be delivered at a minimum pressure of 8 psi. Forcing the irrigation solution through an 18-gauge needle attached to a 60-cm^3 syringe effectively attains this pressure. Pressure in excess of 15 psi increases the potential to separate facial planes and drive bacteria and contaminants deeper into the tissue.

Warm irrigation increases the circulation to the injured area, delivering vital nutrients and removing wastes. Ideally, lavage fluids should be 45°C. Fluids that exceed 60°C will cause tissue damage and delayed healing.

To prevent osmotic damage to healing tissues and cells, lavage solution should be isotonic. Lactated Ringer's solution or isotonic saline are ideal. The beneficial effect of lavage is mechanical so the larger the volume of lavage solution the greater the benefit. Antiseptics are sometimes added to the final liter of irrigation solution. Chlorhexidine solution at a 0.05% dilution (25 cm^3 of 2% stock solution in 1 L saline) has antibacterial effects without inhibiting wound healing. Chlorhexidine diacetate has a longer residual effect than povidone iodine and has shown greater efficacy in the presence of organic debris. Hydrogen peroxide should not be used to prepare wounds for closure due to limited bactericidal activity and local cytotoxicity.

Wound Debridement

In conjunction with lavage, thorough debridement is indicated to remove devitalized tissue and further remove foreign material and bacterial contaminants. The ideal is complete wound excision (en bloc debridement), sharp excision of the entire surface of the wound (except for the skin). This will effectively remove all tissue damaged by the wounding object and subsequently exposed to the environment from the wound, creating an ideal environment for successful healing. Simple debridement, the methodical removal of visually identified damaged tissue and foreign contaminants, is not as effective and should always be coupled with copious lavage. Scraping the tissue with a scalpel blade or abrasively scrubbing with gauze creates additional tissue damage and is not recommended.

Management Options

Choices for management of a traumatic wound are relative simple. You can suture the wound right away (or at least within several hours of injury) to use primary closure to achieve first-intention wound healing. You can wait a while

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to close the wound, using delayed primary closure within the first 4 to 5 days to still achieve first-intention healing or using secondary closure to achieve third-intention healing if a wound is closed after developing granulation tissue. Last, you may elect to leave a wound open to heal by second-intention healing (healing by contraction and epithelialization). The decision to leave a wound open or to suture the skin closed is based on the time interval since wounding, the degree of local tissue trauma, loss of tissue, the severity of contamination, the location of the wound, and the intended use of the animal.

Primary Wound Closure

With primary wound closure, the defect is closed by apposing and suturing skin edges. The best example is closure of a surgical incision. Primary wound closure provides the most rapid healing, the best cosmetic outcome, and the most normal return to function. It results in the most physiologically normal tissue and the least amount of scarification. Primary closure is normally used in wounds that are fairly recent, were caused by sharp incision, and have minimal contamination or soft tissue damage. It should be avoided in highly contaminated wounds even if a cosmetic appearance is desired (delayed primary closure should be used instead; see the next section, Delayed Primary or Secondary Closure).

Before closure, the wound should be made as clean as possible by thorough debridement and copious lavage. Wound edges are then apposed. Deeper tissues such as muscle or fascia may be closed in layers using absorbable sutures. The subcutaneous tissues are not normally closed. Skin is closed with either a monofilament nonabsorbable suture or, if suture removal will be problematic, may be closed with monofilament absorbable sutures. To minimize the inflammatory reaction, nonreactive suture materials and the minimum number of sutures necessary to close the defect are used.

Excessive dead space must be addressed either by placement of drains or by pressure. Fluid accumulation in dead-space cavities is a physical barrier to healing, increases tension on sutures, serves as an ideal medium for bacterial growth, and may exert pressure on adjacent tissues that reduces local blood supply. Drains are used in large wounds or wounds that are not amenable to pressure bandaging. One or more Penrose drains are placed in the deepest part of the wound and exited at the most dependent part of the wound. Drains should exit the skin through incisions separate from the sutured wound, not through the closure. Drains should be sutured proximally and distally and should be protected by a bandage or stent to minimize wicking of bacteria and contaminants into the wound. Drains normally are left in place for 24 to 48 hours or until drainage ceases. To minimize the risk of infection, dead space in limb wounds or other sites that can be placed under a bandage is best managed by this application of pressure rather than by the use of drains.

Most traumatic wounds are under tension during closure due to innate skin elasticity and local swelling. Tension is judged by the difficulty in bringing the skin edges back together either by pressing from the sides or by using two thumb forceps to pull the edges together. Skin closure must address tension and also provide precise anatomic apposition of tissues. Tension-relieving sutures are placed initially to bring the skin edges into contact. These are normally either pulley mattress (near-far-far-near or similar) or vertical mattress sutures placed at ≈3-cm intervals along the incision. In wounds under a lot of tension, penetrating towel clamps may be used to temporarily appose tissues during suture placement. For large wounds, especially those with muscle flaps,

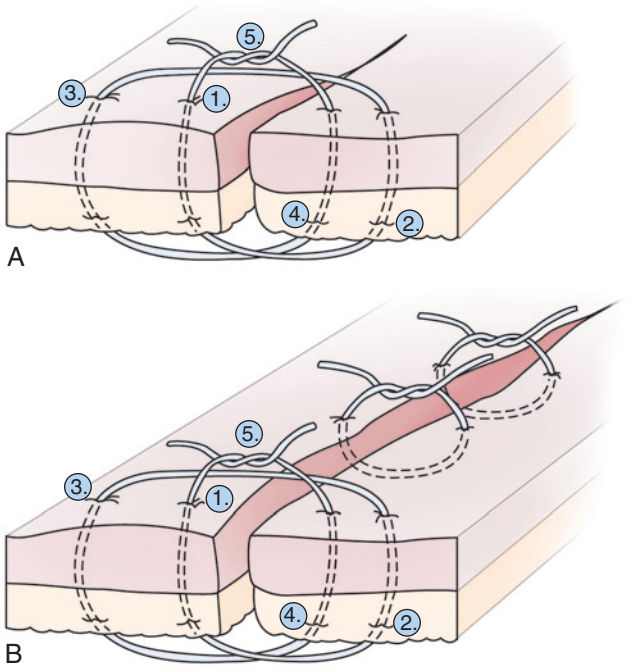


Figure 12-1 Primary wound closure using tension-relieving sutures placed at regular intervals to appose wound edges. *A*, Placement of a near-far-far-near tension-relieving suture, with *1-4* indicating the order the bites are placed and 5 indicating the knot. *B*, Two simple interrupted sutures placed next to a near-far-far-near tension-relieving suture.

rubber tubing stents, or "quills," may be placed on vertical or horizontal mattress tension sutures to help prevent tissue necrosis under the suture material. Simple interrupted sutures are then placed between the tension-relieving sutures to achieve precise edge-to-edge apposition of the skin (Figure 12-1*A* and *B*). A bandage, bandage cast, or cast may be applied over a closed limb wound to minimize contamination and restrict motion. Antibiotic therapy is indicated (see the following). Sutures are normally removed after 14 days. Quill tension sutures should be removed after 3 to 4 days.

Delayed Primary or Secondary Closure

These techniques may be used to manage wounds that have not lost any skin but were not suitable candidates for primary closure. This would apply to wounds that did not receive immediate attention or were so badly contaminated and traumatized at the time of presentation that primary closure was deemed inappropriate (Figures 12-2 and 12-3). These techniques are normally reserved for wounds of the lower limbs given the very good result normally obtained when allowing wounds of the upper limbs and trunk to heal by second intention.

In delayed primary closure the wound is sutured a few days after the injury but before granulation tissue develops at ≈5 days. By leaving the wound open during this period, wound drainage is optimal, the wound can be inspected and further debrided as needed, antimicrobials have an opportunity to exert their effects, and swelling in the area can be reduced, thus reducing the tension of wound closure. If the wound is closed before the appearance of granulation tissue at ≈5 days (that is, during the inflammatory phase of wound healing), healing is still considered to be primary wound healing, the same as if the wound had been closed shortly after it occurred. Wounds being managed by delayed primary

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Figure 12-2 Metatarsal wound in a 2-year-old Holstein heifer of several hours' duration. Substantial contamination, tissue trauma, and swelling make this wound a good candidate for delayed primary closure.



Figure 12-3 Metatarsal wound in a cow following closure with a combination of near-far-far-near and simple interrupted sutures.

closure are initially cleaned up as thoroughly as possible using cleansing, lavage, and debridement techniques as described previously. The wound is covered with wet gauze sponges (wet to dry dressings) and placed under a pressure bandage. This will help with both wound cleansing and with removal of edema from the limb, thereby facilitating wound closure. The patient is ideally treated by a combination of systemic antibiotics and antibiotics delivered by regional limb perfusion. The bandage is changed daily, and any persistent damaged tissue or foreign material is removed by debridement and lavage. In 2 to 4 days, when the wound surfaces appear healthy with no remaining devitalized tissue or foreign material, small amounts of nonmalodorous drainage, and limited local edema, the wound is ready for closure. Closure and aftercare are as described under Primary Wound Closure.

In contrast, secondary closure is used to close a wound that has been allowed to form a healthy bed of granulation tissue, a week or many weeks following injury. This may be employed in wounds that were not treated in a timely fashion or even as a second chance at closure if dehiscence of a wound initially managed by primary or delayed primary closure has occurred. The benefits of closing these wounds are several: all damaged tissue has been biologically debrided from the wound; granulation tissue is very resistant to infection so there is minimal risk of infection after secondary closure; there is little if any persistent local edema in the area. The downside is that there is often substantial fibrosis of tissues adjacent to the wound in these older wounds so closure is challenging to effect and there is substantial tension on the sutures after closure. To achieve secondary closure, excessive granulation tissue is sharply excised to



Figure 12-4 Tarsal wound in a Holstein heifer due to wire. Shredding and loss of tissue prevent closure of this wound so it will be managed as an open wound.

remove the physical impediment to apposition of the wound edges. Conservative undermining of the wound edges might be somewhat helpful but often produces little effect. The skin edges must usually be temporarily brought together with towel clamps while tension sutures are placed and tied. Most of the closure is effected with tension sutures, supplemented by simple interrupted sutures as needed for good apposition. Due to the substantial tension in these closures, immobilization is necessary to protect them from failure. A cast or bandage cast is strongly recommended. A pressure wrap bolstered by polyvinyl chloride splints provides less immobilization but might work in some situations. A soft bandage alone is not recommended.

Second-Intention Healing

Second-intention healing, also termed *healing by contraction and epithelialization*, occurs in wounds that are not sutured. This process may be elected in wounds with a high risk of infection due to heavy contamination or excessive soft tissue damage or have skin loss making closure impossible (Figure 12-4). It is also commonly used for deep penetrating wounds and wounds in dependent locations (axilla, inguinal area) as it promotes maximal drainage. Wounds healing by second intention require greater time to heal and may be unsightly and disturbing to the owner during the healing process. The final outcome is often surprisingly cosmetic in appearance and normally allows return to acceptable function.

Wounds to be managed by second-intention healing should be as thoroughly cleansed as if they were going to be sutured. The wound is cleansed, debrided thoroughly, and lavaged. Systemic antibiotics are normally used until there is a covering of granulation tissue. Topical treatments are not necessary. A bandage is applied to wounds of the lower limbs. If the injury lies over a highly mobile location on a limb, immobilizing the area with a splint, bandage cast, or cast may be necessary. Wounds elsewhere are left uncovered and petroleum jelly applied to the skin ventral to the wound to help prevent serum scald. Wounds are further debrided and lavaged as needed to remove damaged tissue or debris.

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This is not necessary after the wound surfaces are covered with granulation tissue (5 to 10 days).

In second-intention healing, the wound bed fills with granulation tissue and the skin is healed by the complementary processes of contraction and epithelialization. Wound defects healed by contraction are covered by normal skin. This is due to centripetal pulling of full-thickness skin around the wound over the granulation tissue by specialized myofibroblasts. This process starts approximately 1 week after injury and will continue until the wound is healed or until tension in the surrounding skin exceeds the centripetal pull of the myofibroblasts, a process that may take many weeks in larger wounds. As expected, contraction is most effective in healing of wounds with looser, more redundant skin and is more effective in wounds of the upper limbs, trunk, and neck than in wounds of the lower limbs and face. Quite often, though, contraction is remarkably effective in covering wounds, even in species and in anatomic locations that appear to have little skin laxity.

If tissue contraction is insufficient to close the wound, the final healing occurs by epithelialization, movement of epithelial cells at the wound margin across the granulation bed. This is a much slower process than contraction and results in a conspicuous scar—an epithelial coverage with no hair follicles or skin pigment that is mechanically weaker than normal skin and hence more prone to recurrent injury. If a large defect remains after contraction, skin grafting or reconstructive surgery may be necessary to achieve final healing.

Bandaging

When properly applied, bandages promote wound healing by reducing edema, assisting debridement, preventing drying of tissues, increasing local temperature, preventing contamination, and limiting motion. For the limbs, a three-part bandage consisting of a contact layer, an intermediate layer, and an outer layer are normally used. The contact layer lies in direct contact with the wound. The middle layer is a substantial bulky absorbent layer of roll cotton, sheet cotton, quilted wraps, or a combined roll, compacted by brown gauze or similar roll dressing. The outer layer must provide compression to the middle layer, so it must be elastic. Choices include elastic bandages, elasticized adhesive dressings, self-adherent cohesive bandages, or similar materials. Nonelastic dressings such as derby wraps or roll gauze are not adequate.

The contact layer is most commonly a simple nonadherent pad, but other dressings may be used depending on the wound's characteristics, particularly the need for further debridement, the amount of drainage, and the presence or absence of infection. Moisture-retentive dressings may be selected for wounds with light to moderate drainage. Hydrogel dressings promote debridement by providing a moist environment to enhance the body's natural ability to remove damaged tissues from a wound. Absorbent dressings such as hydrocolloids, alginates, and hydrofibers may be used for wounds with moderate to heavy exudate. Many other options for wound dressings are available but have not been widely adopted for use in large-animal practice due to expense and unfamiliarity. In practice, wet-to-dry dressings and nonadherent pads are most commonly used.

Wet-to-Dry Dressings

Adherent bandages may be used during the inflammatory and debridement phases of wound healing to promote removal of damaged tissue and foreign material. Moist mesh gauze sponges are used as the contact layer and slowly dry out (wet to dry) between bandage changes. Necrotic tissue and debris adhere to the gauze and are removed when the bandage is changed. Once granulation tissue develops debridement is no longer necessary, and adherent bandages are no longer used.

Semiocclusive, Nonadherent Dressings

Semiocclusive, nonadhesive pads are used once granulation tissue has developed. Being semiocclusive (permeable to gas and fluid), the bandage maintains hydration of the wound but retains some absorbency to prevent exudate buildup. Numerous nonadhesive pads are available commercially. They can also be made by coating gauze sponges with triple antibiotic ointment, povidone iodine ointment, or other topical ointments to prevent gauze adhesion to the wound.

Topical Medications

Topical medications are commonly applied to wounds to enhance wound healing, decrease further contamination, or repel insects. When choosing a topical therapy, one must select a treatment that will not inhibit healing.

Aloe Vera Extract

Aloe vera extract has been shown to have both antibiotic and antiinflammatory properties. In combination with allantoin, aloe vera extract has been shown to increase the rate of wound healing.

Triple Antibiotic Ointment

Triple antibiotic ointment of bacitracin zinc, neomycin sulfate, and polymixin B sulfate has been shown to increase reepithelialization by 25%.

Silver Sulfadiazine

Silver sulfadiazine is commonly used in human medicine to treat burn victims and promote wound healing.

Nitrofurazone

Nitrofurazone (a potential carcinogen) use in food animals is strictly prohibited by the Food and Drug Administration. Even topical administration has resulted in systemic detection of drug residue.

Povidone-Iodine Ointment

Application of povidone-iodine ointment decreases bacterial concentrations and infection rates, but it may also decrease the tensile strength of the wound.

Petroleum

Although commonly used in nonadherent bandages, petroleum has no apparent antibacterial properties and decreases the rate of wound contraction.

Systemic Medication

Tetanus Toxoid

Tetanus prophylaxis boosters should be administered to animals with significant tissue damage or penetrating wounds at risk of anaerobic bacterial growth. Tetanus vaccines should be used in accordance with manufacturers' directions and species specificity. If the animal has not been vaccinated before injury, tetanus antitoxin may be administered. However, anaphylactic reactions or acute hepatic disease (Theiler's disease in horses) are potential side effects of antitoxin.

Systemic Antibiotics

The use of systemic antibiotics in production animals is a topic of great debate. Indiscriminate use may propagate antibiotic resistance or upset the commensal flora of the skin or gastrointestinal tract. However, if the likelihood of systemic infection is high, such as with a penetrating wound or

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involvement of synovial structures, implementing systemic antibiotic therapy is certainly advisable. Regional limb perfusion with antibiotics has become a mainstay of traumatic wound management in horses. The distal limb is isolated by a tourniquet, and an antibiotic solution is administered into the cephalic or saphenous sodium veins to achieve exceptionally high concentrations of antibiotic in the isolated limb. This technique, adopted from the Bier block sometimes used for intravenous regional analgesia in cattle, is used commonly in wounds with severe trauma or contamination, wounds with open synovial structures, and as preparation for delayed primary closure. Antibiotic therapy in farm animals must take regulations for use of these drugs in food-producing animals into account.

Myiasis

The invasion of flesh wounds by fly larva can occur within 24 hours. Opportunistic species of maggots preferentially feed on necrotic tissue and may serve a reasonable benefit by facilitating debridement. However, these larvae may inadvertently damage the healthy tissue at the wound margins. Obligatory parasites, such as the larva of *Cochliomyia hominivorax* (New World screwworm), aggressively tunnel into the healthy subcutaneous tissue and exacerbate tissue damage. *C. hominivorax* infestations must be reported to state and federal authorities. Effective control against myiasis requires keeping the wound clean and dry, removing matted hair, and using topical insecticides or repellants. Recently systemic larvicides have shown potential benefits in controlling myiasis.

Ivermectin has been shown to be larvicidal to many common barnyard fly larva, including *Musca domestica* (housefly), *Musca autumnalis* (face fly), *Stomoxys calcitrans* (stable fly), and *Haematobia irritans* (horn fly). It has also been shown to directly prevent or eliminate subcutaneous infestations of *Chrysomyia bezziana* (Old World screwworm), *Cochliomyia hominivorax* (New World screwworm), and *Lucilia cuprina* (sheep blowfly) at a dose of 0.2 mg/kg. Infestation with screwworm larva was also effectively eliminated with doramectin. Other studies have not shown ivermectin as having the same efficacy to reduce larval infestations, and the potential for drug resistance to develop exists.

At a dose of 0.2 mg/kg, ivermectin did not affect the rate of larval infestation in goats. Empirical use of ivermectin in goats suggests a dose twice that labeled for cattle is necessary to attain the same effect. Ivermectin has not been approved for use in goats, and its administration must be deemed extralabel.

Exuberant Granulation Tissue (Proud Flesh)

Although exuberant granulation tissue is considerably more common in horses, excessive granulation tissue growth does occur on distal limb injuries of food animal species. This is a potential problem in any limb wound being allowed to heal as an open wound. Healing of wounds in the lower limb is less efficient than in other body locations due to innate problems such as lower blood flow, limited skin laxity, high motion, and propensity for environmental contamination. Bacterial infection, especially with *Actinomyces bovis*, may lead to a bacterial granuloma resembling exuberant granulation tissue. The instability and excessive movement of a lacerated flexor or extensor tendon may lead to overproduction of granulation tissue as well.

The most effective management of exuberant granulation tissue is prevention. Limb wounds should be thoroughly cleansed of devitalized tissue and debris as described previously. Application of pressure bandages or a cast will promote healing and help prevent development of exuberant granulation tissue by keeping the wound clean, decreasing movement, applying pressure, and maintaining a warm, moist environment.

If exuberant tissue does develop, it first must be removed. Tissue that is raised above adjacent surfaces is an effective barrier to both wound contraction and to epithelialization. Exuberant tissue is normally removed by sharp excision; exuberant tissue does not have a nerve supply so no local block is necessary. An alternative technique is the use of chemical cauterization with copper sulfate ($CuSO_4$) or potassium permanganate ($KMnO_4$). Care must be taken to avoid chemical injury to healing epithelial cells. To prevent recurrence of granulation tissue, it is critical to identify and eliminate inciting factors such as wound infection or excessive movement. Additionally, corticosteroids may be applied topically to granulation tissue to inhibit production, but these should not be used until a healthy bed of granulation tissue has developed, because they inhibit macrophages and neutrophils and delay wound healing. Corticosteroids will inhibit wound contraction. Silicone gel sheets have been used successfully to help prevent exuberant granulation tissue formation in horses.

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SKIN GRAFTS

Richard P. Hackett

INTRODUCTION

Skin grafting is rarely used in cattle. However, this procedure may be occasionally indicated in wounds of the distal limb with substantial tissue loss or in large wounds of the trunk, particularly following full-thickness thermal burns, to accelerate healing over normal processes of contraction and epithelialization. Techniques for grafting acute injuries are described, but normally grafts will be placed onto a developed bed of granulation tissue. Typically the wound should be given ample opportunity for complete wound contraction to occur (often several weeks in larger wounds). In veterinary medicine, skin grafts that are harvested from one location and placed onto another location on the same animal (autologous free grafts) are normally used. Large sheets of skin, either full-thickness or partial-thickness sheets, can be harvested with a dermatome and grafted at a different location. More commonly, small pieces of skin (island or seed grafts) are used. Various configurations of island grafts

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include pinch, punch, stamp, and tunnel grafts. Each technique has advantages and disadvantages. The pinch-grafting technique is particularly applicable for use in the field because it is technically simple to perform, can be done in standing patients, and requires no special equipment. This procedure has a good rate of graft survival compared with other grafting techniques. The balance of this discussion will focus on the pinch-grafting technique.

PATIENT SELECTION

Pinch grafts are used in wounds on the distal limbs or trunk that have sustained substantial tissue loss. Grafting is performed when the wound has had an opportunity to fill with granulation tissue and to fully contract, often several weeks after the original injury. Deeper tissues such as exposed bone, ligaments, and tendons should be covered with granulation tissue before pinch grafting. This granulation tissue, the recipient bed, must be well vascularized and free of infection or exuberant tissue.

Graft Harvest

Patients are usually started on systemic antibiotic therapy before surgery and maintained on these for 5 to 7 days. Normally pinch grafting is done standing under appropriate restraint with or without sedation. In standing animals the lateral cervical area, perineum, and pectoral areas are potential donor sites. The donor site is prepared for aseptic surgery and blocked by infiltration with local anesthetic. The skin is tented using a small suture needle or hypodermic, and a #10 or #15 scalpel blade, held parallel to the skin surface, is used to excise a 4- to 5-mm-diameter graft. These grafts will be either full or partial thickness depending on the thickness of the skin at the donor location. Several grafts are harvested initially on a 1 × 1-cm grid and then are held in saline moistened gauze sponges until implanted. The donor site defects do not require closure and will heal quickly with minimal if any scarring.

Graft Implantation

Local anesthesia of the wound bed is not necessary as granulation tissue is not innervated. Pinch grafts are placed just below the surface of the granulation tissue on a 1 × 1-cm grid. Starting at the dependent part of the wound and working dorsally, a #15 scalpel blade is stabbed into the granulation bed in a ventral direction to make a 1-cm-deep pocket just below the surface of the granulation tissue. A pinch graft, with the epidermal surface most superficial, is inserted into the pocket using a hemostat or small thumb forceps. It is not necessary to orient grafts by the direction of hair growth because any regrowth of hair following this procedure is sparse. An alternative technique is to use a curved mosquito hemostat to push grafts into the granulation tissue without first making pockets (Figures 12-5 and 12-6).

AFTERCARE

Limb wounds are covered with a sterile nonadherent pad, and the limb is placed in a pressure bandage that is changed every 2 to 3 days. This bandage is maintained until the granulation bed is largely covered by epithelial cells. Instead of a pressure bandage, a cast or bandage cast should be used for the first 10 to 14 days following grafting of limb wounds over high-motion areas. Grafted sites elsewhere may be lightly covered with a stent bandage or left uncovered. Grafts initially cannot be seen under the granulation tissue or may

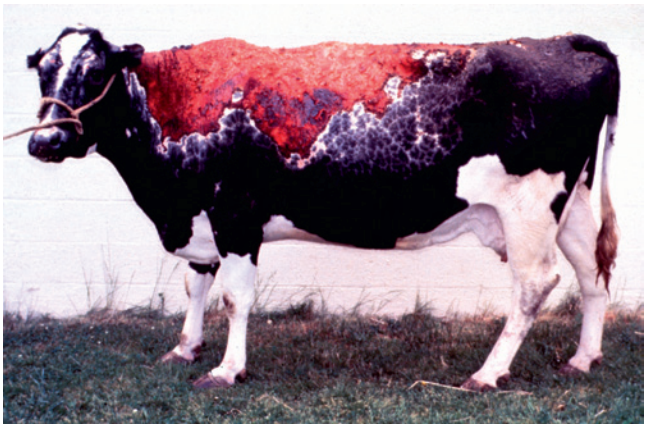


Figure 12-5 An adult dairy cow that survived a barn fire with a large granulating wound along the back.



Figure 12-6 The adult dairy cow shown in Figure 12-5 3 months after multiple pinch grafts.

appear as dark spots. Between 7 and 14 days, granulation tissue overlying the graft will lyse or slough, revealing pale, relatively inconspicuous grafts. By 3 weeks each surviving graft should be surrounded by a ring of migrating epithelium. These epithelial islands will rapidly coalesce with each other and with epithelial cells migrating from the wound margins to cover the wound with epithelial cells. Hair may begin to grow from the grafts by 2 months but will usually result in sparse tufts of erratic length and orientation.

OUTCOME

Graft survival is usually 50% to 75%. It may take 2 to 3 weeks to be certain how many grafts have survived. At that time, regrafting of areas with poor graft survival is indicated. Graft failure is most commonly due to infection, but a poorly prepared recipient bed or excessive motion at the grafting site may be factors as well.

Normally in large granulating wounds that have finished contraction, final healing is dependent solely upon migration of epithelial cells that form the wound margins across the granulation bed, a process that takes a very long time in large wounds. Pinch grafting provides many additional sources of epithelial cells because each surviving pinch graft sends new cells in all directions to merge with cells from other grafts and with epithelial cells from the skin margins, dramatically reducing the length of time necessary for wound epithelialization. Often, however, the cosmetic outcome is

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not substantially different from what would have been achieved had epithelialization from the skin margins been allowed to proceed naturally. The ultimate appearance is a weak epithelialized scar with little or no hair covering or, at best, scattered tufts of hair.

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DEHORNING/CORNUECTOMY

Daryl Van Nydam and Charles W. Nydam

HISTORICAL PERSPECTIVE

Dehorning is primarily an elective procedure, exceptions being cattle with fractured horns or osteomyelitis. As a surgical procedure, dehorning is one of the oldest and most common procedures done on cattle. Notwithstanding illustrations of cows in many children's books or on craft items such as cow saltshakers or towels, most cattle in countries with a developed bovine industry are dehorned. Although horns are useful to cattle in the wild state, dehorned cattle are safer for handlers and other cattle. Animal welfare concerns are decreased because cattle with no horns, especially when confined in relatively small areas, do not have the opportunity to gouge and bruise one another, either accidentally or on purpose as individuals seek dominance. Effective January 2001, Australia has excluded horned cattle from transport in the export market in an attempt to improve cattle welfare and economic efforts. Carcass losses from bruising are significantly lessened by dehorning, as is damage to other areas, such as the eyes. Market cattle are usually discounted at sale if horned owing to the likelihood of subsequent extra trim as well as more handling difficulty with the live animal. The incidence of infected lacerations and loss of blood from wounds is also lessened by removing horns. The same effect has not been seen with tipped horns.

Aside from some polled breeds (e.g., Polled Hereford and Polled Shorthorns), most beef and dairy cattle would have horns if they were not removed. Historically, some breeds, particularly Ayrshires, were prized for their horns, and much effort was put into training horns to shape for show purposes. Some beef breeds, such as Texas Longhorns and Scottish Highlands, still value horns. Pictures of the ideal dairy cow shortly after World War II showed horned animals. In northern climates, cattle 18 to 36 months old often had their horns cut off on a cold winter day and were turned outdoors, perhaps after placement of a tourniquet across the poll, so the frigid air would help constrict spurting and dripping blood vessels to stem the bleeding. It is reputed some animals lost enough blood that they became weak but seldom died.

Cattle owners came to veterinarians for a procedure that could be done cleaner with less blood loss and fewer aftereffects owed to an onerous task. Veterinarians could provide analgesia and anesthesia as options. The horns were likely to be removed better to avoid regrowth of remnant horn tissue that might still allow infliction of trauma as well as be unsightly. For veterinarians in food animal practice the surgery is repetitive and not especially challenging. Over the years, dehorning gave the veterinarian a chance to get to know the farmer and his cattle operation better, thus providing an opportunity to talk about other bovine production and health matters that the veterinarian could favorably affect. With the increase in large herds and development of newer and easier dehorning methods, the job has often been taken over by lay help. There is opportunity for veterinarians to instruct the lay help on effective dehorning. In addition, there will often be some that "got away" and so grew larger horns than farm help wants to dehorn, and there will be smaller or niche farms, even hobbyists, who will want the veterinarian's attention for dehorning.

ANATOMY

Horns begin as buds in the newborn when modified epithelium grows outward from the skin. Until 2 months of age, the horn bud is not attached to the skull. Under the bud, the continuing outgrowth of the cornual process of the frontal bone connects it to the skull after 2 months. The bone is covered by a blood-bearing corium that is covered by cornified epithelium. Initially, the frontal sinus does not extend into the horn, but at 4 to 6 months of age the sinus opens into the horn and becomes larger as the horn grows with age. To keep a scur of horn from growing back after dehorning, a ring of skin tissue 1 to 1.5 cm around the base of the horn needs to be removed, because this is the origin of the germinal epithelium where horn growth occurs. If this entire area is removed, the surrounding haired skin will replace the defect, even a large opening, without producing a horn.

The horn blood supply is mainly from a branch of the superficial temporal artery, the cornual artery, which lies at the ventral side of the horn (Figure 12-7). It arises from behind the orbit, courses caudally along the temporal line, and branches into dorsal and ventral arteries just as it approaches the horn. A proper cut will expose these branches

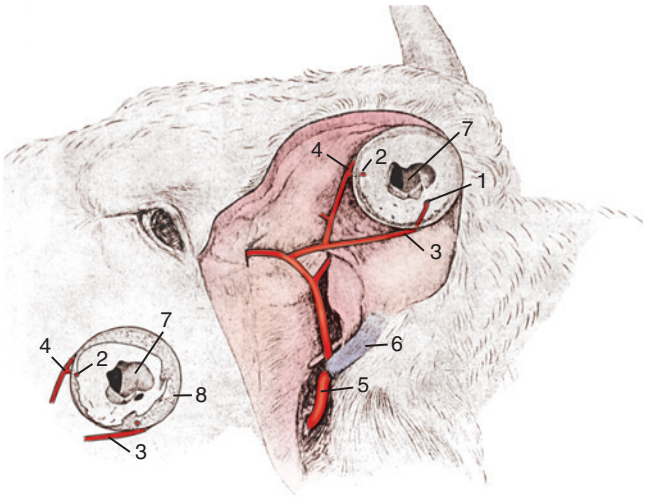


Figure 12-7 Schematic of mature bovine poll area and arteries of interest. 1, Intraosseous ventral branch of cornual artery; 2, intraosseous dorsal branch of cornual artery; 3, ventral branch of cornual artery; 4, dorsal branch of cornual artery; 5, external carotid artery; 6, ear cartilage; 7, frontal sinus; 8, horn matrix. (Reprinted from Williams WL: *Surgical and obstetrical operations*, ed 4, Ithaca, NY, 1919, William L. Williams.)

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on the edge of the bone. Some smaller arteries may also be exposed on the dorsal side of the horn.

The cornual nerve, a branch of the zygomaticotemporal nerve, innervates the horn area. It courses caudally from the orbit under the bony ridge of the temporal line to the horn, where it divides into two or more branches. The nerve runs with the cornual artery and vein below the temporal line.

RESTRAINT

Adequate restraint of the unwilling patient is crucial for rapid and efficient dehorning. Sufficient lighting facilitates the procedure, particularly if done surgically. Young calves can be straddled and handheld. Ideally, a wooden stake, stanchion, or a head gate on a chute, along with a halter to secure the head snugly against the side of the restraint with room to do so in either direction, should be available for larger animals. Nose leads can be used in place of, or in addition to, a halter on cows and bulls. In reality, animals to be dehorned have been too often presented in poorly illuminated and cramped areas and fastened loosely by a tie-rail or tether, all of which make restraint and subsequent dehorning more of an effort than one would wish. However, with practice one learns to improvise and cope to still do a satisfactory job.

ANESTHESIA AND ANALGESIA

Anesthesia is one feature that veterinarians can add to dehorning. It increases the time needed, especially when calves loose in a pen have to be caught individually for anesthetic administration and dehorning. Some people debate the need for the extra time and handling trauma; they prefer the "brief grief" technique. This is particularly so for very young calves being dehorned by cautery. Nevertheless, United Kingdom law requires use of some form of analgesia when dehorning cattle, unless a caustic disbudding paste is used on animals younger than 7 days old. A study performed in Denmark on Holstein calves showed that the negative behavioral effects and rise in cortisol associated with dehorning were lessened by a cornual nerve block. Larger animals are more easily controlled, especially for hemostasis procedures, if local anesthesia is used.

In all cases, 2% (20 mg/mL) lidocaine can be given with an 18- to 20-gauge, 1- to $1\frac{1}{2}$-inch needle in quantities of 3 to 10 mL per side—needle size and volume depending on the size of the animal. Sodium bicarbonate added at a 10:1 ratio to the lidocaine will lessen the injection pain of the patient. The injection site to block the cornual nerve is just under the shelf of the frontal crest/temporal line halfway between the orbit and base of the horn. Loss of sensation generally begins in 2 to 10 minutes and will provide postprocedural analgesia for up to 5 hours. Occasionally, this technique fails to produce the intended anesthesia of the area. Reasons for this include 1) variation in the nerve's relationship to the bony temporal line; 2) aberrant innervation of the area by other nerves (supraorbital and infratrochlear); 3) a long nerve of the frontal sinus; and 4) premature division of the cornual nerve (see Chapter 5 for more details).

Oral meloxicam at 1 mg/kg results in plasma drug concentrations in an effective range for 3 to 5 days. This dose and route reduce the stress associated with dehorning irrespective of whether it is given before or at the time of the procedure and thus greatly increases the likelihood of administration if the patient has to be handled only one time. Giving it orally at the time of dehorning also avoids the vagaries of adding medication to feed, because it is prohibited without exception.

Xylazine hydrochloride can be given to large or unruly patients, particularly if facilities for restraining the head are less than desirable, at a dose of 0.1 mg/kg intramuscularly or 0.05 mg/kg intravenously (some subjects may be refractory to this dose and require more). Fifty to 100 milligrams of xylazine can be added to a 100-mL vial of 2% lidocaine; the resultant mix then is given as usual for dehorning anesthesia to better calm the animal. For example, if 100 mL of xylazine is added to 100 mL of lidocaine, the resulting mixture is a 1-mg/mL concentration. If the desired dose of xylazine is 0.1 mg/kg and one is dehorning a 60-kg calf, 6 mg of xylazine is indicated. Therefore administering 3 mL of the mixture to each side to be dehorned gives the 6 mg of xylazine. If xylazine is used, sedated animals should have adequate footing both during and after dehorning. One disadvantage to xylazine use is that some animals lie down and will not get back up for proper positioning. Another possible untoward effect is bloat if the animal becomes and remains recumbent too long. Furthermore, decreased blood pressure induced by xylazine at the time of dehorning may give a false sense of security about the level of hemostasis achieved. To reverse the effects of xylazine, tolazoline, an alpha-2 adrenergic antagonist, can be administered at a dose of 4.0 mg/kg (4 mL/100 kg). Onset of recovery usually becomes apparent within 5 minutes. Neither tolazoline nor compounding of lidocaine with xylazine is approved for use in cattle at this time in the United States. Consult AMDUCA (Animal Medicinal Drug Use Clarification Act) for usage guidelines of extralabel use of drugs and the Food Animal Residue Avoidance Databank (FARAD) for withdrawal times (see Chapter 5, Farm Animal Anesthesia).

METHODS

The main methods of dehorning cattle are chemical, thermal cautery, cutting, or genetic. The first two are done on younger calves and require no hemostasis. They also leave no sinus open to infection and can be done any time of year. With proper attention, small horns can also be removed in summer, but cutting horns during fly season, particularly when the frontal sinus is opened, is generally not recommended because of the greatly increased possibility of infection.

The various means of cutting horns also opens the possibility of transfer of bloodborne pathogens such as *Anaplasma* spp., *Babesia* spp., or bovine leukemia virus. Complete disinfection of the dehorner between animals would prevent this but is not very practical in real field situations. This is another reason to dehorn young cattle by cautery. Dropping the dehorner in a bucket of disinfectant (chlorhexidine) between each use is of some value for diminishing infections transmitted by dehorning (DiGiacomo et al., 1985).

Chemical Dehorning

For chemical dehorning, a caustic paste of potassium, sodium, or calcium hydroxide is applied to the horn button (Figure 12-8). For best results, it is imperative the paste be applied as soon as the horn button can be felt (that is, within 3-7 days of birth); otherwise all of the horn-germinating cells will not be destroyed and regrowth will occur. It does cause some discomfort to the calf, which must be monitored to ensure that the paste does not gravitate toward its eyes if the calf starts rubbing the buttons or is out in the rain. A 1920 text oriented toward farmers, *The Practical Stock Doctor*, recommends an old technique of clipping the hair off the

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Figure 12-8 Equipment for dehorning younger calves. From left to right: dehorning paste, rechargeable clippers, butane fuel, Portasol dehorner, Buddex dehorner, Roberts dehorner.



Figure 12-9 Instruments for dehorning bigger calves. From left to right: small Barnes, electric dehorner 1, electric dehorner 2, propane dehorner, large Barnes.

button to allow better paste contact and use of smaller amounts to lessen the chance of runoff, advice still pertinent for this relatively easy and low-stress method if it can be done in a timely matter.

Thermal Dehorning

Various means of thermal dehorning are available. In all cases, it is important to burn thoroughly enough to kill the germinal tissue surrounding the horn bud. This technique is restricted to calves small enough that the dehorner being used will fit entirely on the base of the horn button. It is helpful to clip the hair away first with scissors, a small clipper, or a rechargeable battery-powered clipper (see Figure 12-8). With small calves, straddling the calf and holding the head firmly against the thigh may be sufficient restraint; otherwise a halter snugged to a firm object is desired.

Portable

Small butane-powered dehorners have become a favorite of many veterinarians and herdsmen (see Figure 12-8). They, like other thermal cautery devices, operate at 500 to 600°C. These portable dehorners do not need a cord, heat fast, and work quickly by cutting through the skin to the bone in 5 to 10 seconds, depending on the size of the calf. They can be used on calves about 3 days to 2 months old, which makes them useful for scheduled herd health visits. No risk of transferring bloodborne diseases exists, and they can be used year round. Petrie et al (1996) substantiate this as a less stressful procedure in their report of a surge in cortisol 3 to 7 hours after scoop dehorning but not after thermal cautery. The authors' preference is to have herds accustomed to the thermal cautery dehorning because this seems to be the least traumatic method yet offers excellent dehorning results with usually less operator effort.

Rechargeable battery-powered dehorners for 7-day- to 2-month-old calves are available (see Figure 12-8). They need to be kept charged and occasionally discharged for recharging, and the power weakens between calves if used in too rapid a fashion.

Sufficient pressure must be applied to the skull of small calves when burning with thermal dehorners, best done while twisting the dehorner back and forth. It must be done long enough to see a complete white rim of bone at the base of the burn effort to ensure the blood supply to the horn bud is completely cut.

Corded

Several different types of corded electric dehorners can also be found (Figure 12-9). Some are large enough to be used on older calves up to 8 months old, but more contact time is needed with more tissue damage and the smell of burning hair and skin. It is best to perform the procedure in young calves. Adequate time must be allowed for the dehorner heating element to get a cherry red color so it is hot enough to use. The dehorner must be applied firmly and long enough to get a copper-colored ring all around the base of the horn. With some smaller units, the heating element may not stay sufficiently hot to do a number of calves quickly, particularly if they are large. Dehorners attached to a small propane tank or via hose to a larger tank are heated and used in the same way.

Some owners or operators working in confined areas find the smell of burning hair and skin from this method objectionable. This can serve as a teachable moment when one is trying to convince a producer to more adequately ventilate a housing facility because the smell and smoke should clear out more quickly in a well-ventilated facility.

Cutting Dehorning

If young stock are missed at a young age or an owner prefers the final look of a gouge dehorning, then cutting the horns off is an option. Several cutting dehorner devices exist for this, including gouging forceps and a saw. The cutting operation is easier and cleaner if the instruments are kept sharp.

Tube Dehorner

A tube gouge or Roberts dehorner makes a circular cut when twisted over the base of a horn bud on young calves (see Figure 12-8). Then a twist upward scoops out the horn. Hemorrhage is minimal, and pressure can be applied to the opening to arrest the bleeding.

Scoop/Gouge Dehorner

Once horns have erupted, scoop dehorners, such as various-sized Barnes dehorners, can be used on calves from 3 months to 1 year or more, as long as the dehorner fits over the base of the horn enough to remove a 1-cm ring of skin

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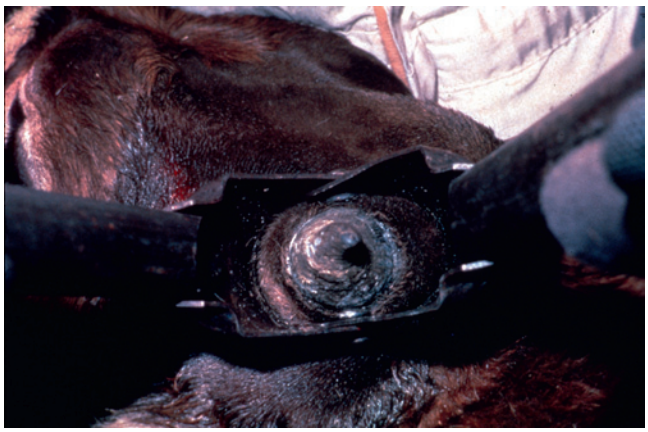


Figure 12-10 Large Barnes dehorner in place.

(Figure 12-10). By pushing down on the handles and forcing them apart, the sharp metal edges make an elliptical cut that removes the horn and exposes the cornual arteries. If conditions allow, one can tilt the head over to one side to cut the top horn and pull the head over in the opposite direction to cut the other horn, although both horns can usually be cut with the head tilted in just one direction by maneuvering the handles a little. The exposed cornual arteries and any available branches are grasped with hemostatic forceps and pulled out slowly in the same plane as the head until they snap. That way, the artery remnants are beneath the bone and under the skin where they can clot. One to four arteries may be seen spouting and can be pulled. Often doing the one main ventral artery is sufficient. A thermal cautery dehorner can be applied to the exposed bleeding area if needed to assist hemostasis. The opening into the sinus is most often left open, or a thin piece of gauze can be laid across it to help stem minor bleeding and cover the sinus opening to keep it clean, particularly to be considered if horn removal is necessitated in fly season.

Keystone

A large cutting instrument is the guillotine or Keystone-type dehorner, which has two opposing blades that cut the horn when brought together by two long handles (Figure 12-11). These are used on large heifers, cows, and smaller bulls. Room is needed to accommodate the handles. After the animal's head is secured, the head is pushed down and turned, so the back horn is topmost. The blades are set far apart and set firmly at the base of the now topmost horn. The handles are pulled sharply together to cut the horn. If the horns are so large that the operator cannot close the handles easily, separating the handles slightly and rotating the blades a bit before pulling the handles together again can help complete the cut. Ideally, the head can be turned and the other side properly cut in like manner; if there is no place to turn and secure the head, the second horn can be cut without turning with extra attention to handle maneuvering. Pulling the arteries achieves hemostasis if the cuts are done well. If the arteries cannot be pulled, a tourniquet around the base of the horns and across the poll will usually suffice. Baler twine, large rubber bands, canning jar rubbers, and cut pieces of inner tube have been used as tourniquet material. With twine, another piece of twine across the top of the poll drawing the circle tighter may be necessary. Caution the owner to remove the tourniquet in a few days, because it can keep drawing together and get hidden if ignored, creating a nonhealing wound until it is removed. This instrument is

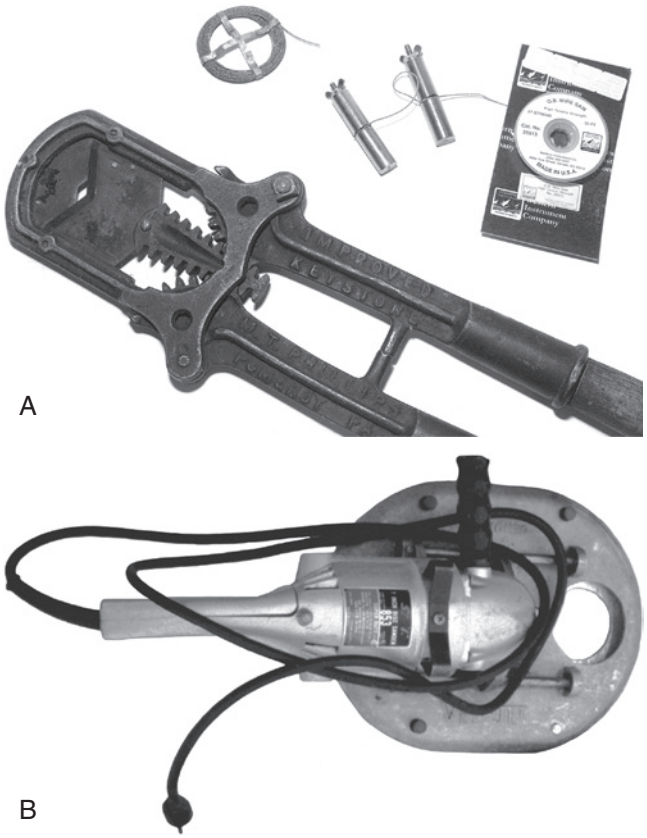


Figure 12-11 Instruments for dehorning mature cattle. *A*, From left to right: keystone, obstetric wire, and handles. *B*, electric guillotine.

properly less used because benefits of earlier dehorning to patient and operator are apparent.

Electrically Powered

Various electrically powered dehorning saws or cutters are available for use on large horns when electricity is available (see Figure 12-11). They cut quickly, but some types can be left open during cutting; therefore an ear can be accidentally removed as well. Caution is required to protect the operator and patient. Hemostasis and covering are the same as for other cutting methods.

Obstetric Wire and Others

Obstetric wire can be used when a cutting device will not work for really large horns occasionally found on cows and bulls and horn regrowth that curves into the head (see Figure 12-11). As with other techniques, it is essential to include a 1.0-cm ring of haired skin with the horn when one makes the cut. Anesthesia is recommended for cutting with an OB wire because the technique is relatively slow. Handheld saws with a stiff back can also cut horns. Because of the horn dust produced and the jaggedness of the cut from sawing, hemorrhage may be less, especially from capillaries and small arteries. Any horn dust produced can fall into the open sinus and be an irritant. Again, hemostasis is via pulling arteries as described previously. Occasionally, other cutting devices such as convex nippers or pruning shears can be used to remove horns.

Genetic and Other

Some beef breeds are now naturally polled, such as Angus and Polled Herefords, and occasional individuals of any

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breed, notably the Jersey dairy breed, are polled as the result of an autosomal dominant gene. Some cattle breeders have successfully selected for perpetuation of this trait, and the practice is attracting more attention. In fact, the Australian Model Code of Practice for the Welfare of Animals recommends breeding polled cattle where applicable. In the future, gene manipulation may offer an additional alternative to achieve hornless animals.

Although not in use yet except in extraordinary situations, cryosurgery and laser surgery may someday be added to the common ways of dehorning.

COSMETIC DEHORNING

Cosmetic dehorning allows primary closure of the skin over the defect created by removing the horn and is occasionally done to create a more predictably desirable-looking head. It is employed in situations in which the following conditions apply: 1) less scarring is desirable; 2) a short healing time is necessary; and/or 3) a cutting dehorning procedure is to be performed on mature subjects during fly season. It is easiest to attain apposition of the skin if this procedure is performed in animals younger than 2 years old. Disadvantages of this procedure include the following: 1) it takes more time and is more expensive than the aforementioned techniques; and 2) greater care must be given to sterile technique because the potential for drainage is eliminated. Clients whose cattle have shown potential or high live-market value often request this procedure. Generally, it involves cutting and reflecting skin around the horn base, removing the horn, undermining the skin, and suturing over the wound.

Preparation

Restraint for the procedure should be done as suggested previously, with a chute equipped with a head gate being the optimal alternative. To perform this operation, the veterinarian needs a sterile scalpel, hemostats, needle holder, #2 nonabsorbable suture, and obstetric wire. A cornual nerve block should be performed as described previously, along with a ring block around the horn and intravenous administration of a 0.05-mg/kg xylazine dose through the tail vein. No complications are anticipated with 20 mL of 2% lidocaine per horn.

The hair should be clipped in a wide area around the horns and across the poll. The area should receive a standard surgical preparation.

Technique

Elliptical incisions are made, leaving no more than a 1-cm margin around the base of the horn beginning 5 to 7 cm dorsal to and ending 5 to 7 cm ventral to the base of the horn. The incisions are made with the blade resting on the underlying bone. The skin is sharply dissected from the underlying tissues in the ventral incision, and the veterinarian must be careful not to transect the auricular muscles of the area (Figure 12-12). The obstetric wire is placed in the ventral incision against the frontal bone with the wire directed toward the poll and used to saw off the horn. It is essential the saw be seated properly at the very base of the horn. This should remove the germinal epithelium to prevent horn regrowth, adequately expose the cornual artery for pulling to provide hemostasis as described earlier, and allow apposition of the skin (Figure 12-13). The area is examined for loose bone chips and debris, and the site is lavaged with physiologic saline after adequate hemostasis has been achieved. The incised skin is undermined if necessary and brought into direct apposition by using #2 nonabsorbable sutures in a simple interrupted or mattress pattern. If there is a lot of tension on the wound, it may be helpful to put one tension-relieving suture in the middle of the wound. The sutures are removed in 2 to 3 weeks. The opposite horn is removed in like manner to achieve symmetry.

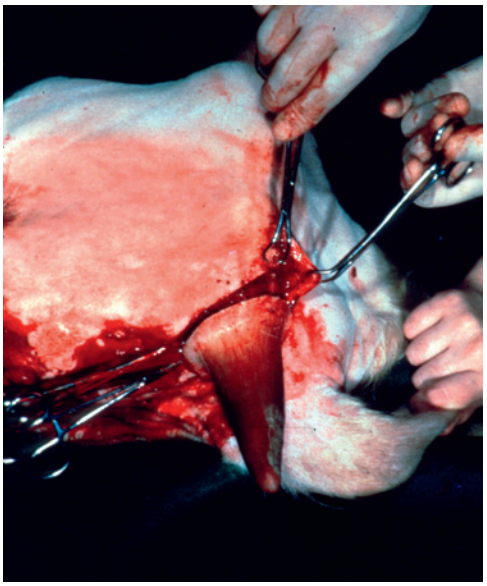


Figure 12-12 Skin dissected away from underlying tissues.

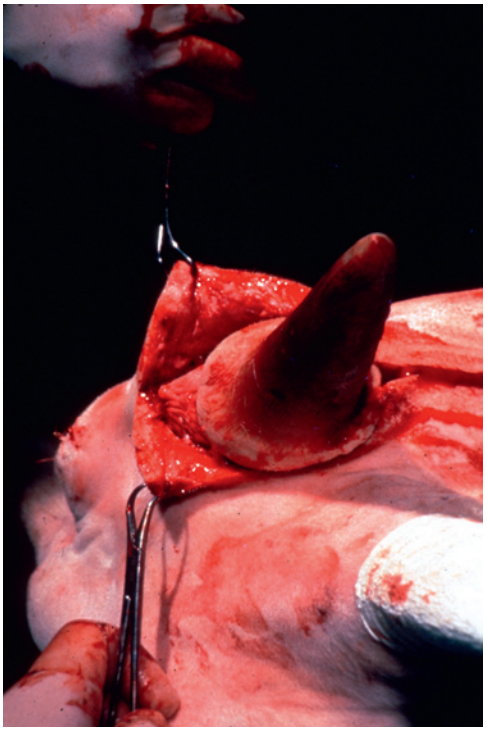


Figure 12-13 Exposure of area adjacent to horn.

AFTERCARE AND COMPLICATIONS

Postprocedural analgesia to mitigate stress on dehorned animals has long been sought and is a concern of animal welfare.

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NSAIDs (nonsteroidal antiinflammatory drugs) have provided a means to relieve the pain and possibly lessen the chance of reduced performance owed to the dehorning. A single dose of meloxicam at 1.0 mg/kg administered orally at the time of dehorning can last for approximately 48 hours and has found much favor by veterinarians and owners as well as, presumably, the dehorned patients. Ketoprofen given orally before dehorning and at 2 and 7 hours after dehorning showed reduced levels of behavioral responses to pain compared with the control group (Faulkner and Weary, 2000). Regarding the use of these drugs, please note the following paragraph:

> *"There are no approved pain drugs for use in cattle in the US. The AMDUCA allows extra label drug use (ELDU) provided a valid VCPR exists and the drug selection decision process is followed. Although flunixin melamine is an NSAID labeled for use in cattle and has been shown to have short acting analgesic effects, long acting NSAID analgesics, such as meloxicam, are more desirable to mitigate the pain associated with castration and dehorning. This extra label drug use is deemed appropriate under the Animal Medicinal Drug Use Clarification Act when proper meat withholding periods are observed. In the case of meloxicam, a meat withholding time of 21 days is recommended after a single dose."*

Hemorrhage is the most common possible complication. If a "bleeder" persists, the operator should check again for an artery to be pulled or ligated. A tourniquet can be applied. It has also been suggested that large quantities of sweet clover hay feed can have mold that interferes with hemostasis and should be investigated as a cause of uncontrolled bleeding. To give the clot a matrix on which to form, padding such as cotton can be pressed on the wound and left until it falls off. Blood stop powders, mainly astringents, can be applied to the bleeding areas as well. Other powders that have been used, mostly in the past and often in perceived desperation, include flour and corn starch. Dressings in the sinus should be avoided as they can be irritating and delay healing. In yesteryear, farmers applied cobwebs from the barn ceiling for the same purpose. With any form of dehorning, the seal that forms can be prematurely knocked off; occasionally exposing a bleeder that warrants attention. Cautery from a thermal-type dehorner can be used for hemostasis.

Infection is a serious complication, although it is rare with proper technique. Affected cattle are generally febrile, lethargic, and inappetent, and may have a malodorous discharge from the site. The resultant acute sinusitis needs to be drained by opening the dehorning site, flushing it copiously with a disinfectant, and tipping the head to drain it on a daily basis until it dries up and drainage ceases. Occasionally, systemic antibiotics may be needed. Sometimes sinusitis may become chronic, which is best treated by trephination and lavage, administration of topical and systemic antibiotics, and analgesics. If drainage persists, osteomyelitis and bone sequestrum may be the cause of a chronic condition. Surgical curettage of the affected area is then performed. These chronic sinus infections can be difficult, if not impossible, to clear up. For these reasons, the surgery should not be done in rainy, dusty conditions or during fly season. If dehorning occurs during fly season, appropriate fly control measures should be instituted, particularly in screwworm-endemic areas. Maggot infestation is handled as in sinusitis.

Another complication of dehorning, especially with large cutting instruments, is a fractured skull, which can generally be avoided by keeping guillotine blades sharp.

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INSERTION OF A NOSE RING

Robert O. Gilbert

Nose rings are commonly used to control bulls. They are inserted into the soft tissue of the nasal septum just cranial (rostral) to the cartilaginous septum. For insertion the bull should be tightly restrained, so head movement is restricted as much as possible. Infiltration of local analgesia is not practical, but sedatives or systemic analgesics may be administered. Most nose rings have a sharp point designed to be forced through the septum. However, the size and shape of the (hinged and open) ring and the rough nature of the pointed end make controlling and accurately placing the ring difficult. Instead, it is easier to use an appropriately sized trocar and cannula to pierce the septum at the desired site and then introduce the nose ring as the cannula is withdrawn. The ring is then snapped shut, screwed closed, and filed, if necessary, to ensure a completely smooth surface.

Although a nose ring is extremely useful in restraining bulls, it is often misused. The nose ring should not be used as the sole form of restraint. Ideally, a rope attached to a neck loop or halter serves as the primary form of restraint, with the nose ring rope used to get the bull's attention or provide additional restraint, if necessary. Constant tension on a nose ring eventually reduces the bull's sensitivity and may be counterproductive.

There is some debate about whether rigid poles or ropes are safer for handling bulls. Some feel there is a danger of a bull using a rigid pole as an instrument to injure the handler, whereas others feel that a rigid pole helps keep the bull at a safe distance from the handler. Ideally, ropes can be used and the handler kept safe by having appropriate facilities with specially designed walkways that allow separation of the handler and bull.

Occasionally, bulls may tear out their nose rings. This sometimes happens during handling; otherwise it may result from the ring being trapped on an immovable object. A nose laceration can be sutured to allow placement of a second ring. For this to be accomplished, the bull should be sedated and firmly restrained. A local anesthetic is infiltrated into the area of the laceration. As large an area as possible is freshened on both sides of the laceration, and the anatomy restored by multiple simple interrupted sutures of absorbable material, taking care to restore as much nasal septum as possible. A ring may be inserted once healing is complete, usually in about a month. Alternatively, it is possible to insert a ring in a vertical fashion through the dorsal part of the torn upper lip, but this is usually not as sturdy as a properly placed nose ring.

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CHAPTER 13

Surgery of the Bovine (Adult) Respiratory and Cardiovascular Systems

Norm G. Ducharme, André Desrochers, Pierre-Yves Mulon and Sylvain Nichols
(The editors and the current authors acknowledge the previous edition authors, Earl M. Gaughan and Judy Provo-Klimek)

DIAGNOSTICS

Norm G. Ducharme and André Desrochers

The need for diagnosis and surgical treatment of respiratory and cardiovascular disease in cattle is not common. However, several disorders are well documented and are most expediently addressed with surgical therapy. Although some of these disorders are congenital malformations, the majorities are acquired through trauma or are infectious in origin. Thorough physical examination can often determine an accurate diagnosis, which improves the success rate of the treatment. Several ancillary diagnostic exercises can assist physical examination findings to further direct specific treatment selection. This chapter focuses on surgical considerations in the treatment of cardiovascular and respiratory diseases, but other factors such as cost, genetic potential, and other business considerations should be included in the decision-making process.

PHYSICAL EXAMINATION

Clinical signs can often dictate the specific target of a physical examination. However, any thorough examination should evaluate the respiratory and cardiovascular systems. The focus and depth of the examination should be on both the morphology of the relevant anatomic structures and evidence of physiologic dysfunction of each of these systems.

When the animal is approached, indications of respiratory system dysfunction can be appreciated by noting respiratory characteristics such as rapid or shallow breaths, coughing, and open-mouth breathing, which can all be signs of impaired ventilation. Determination of respiratory rate is not as important as noting the pattern and ease of respiratory effort. Upper respiratory sounds can increase or be abnormal in cases of upper airway obstruction. Grunts can be heard at the end of a forceful expiration in cattle suffering from severe pneumonia, pain, or pneumothorax. In addition, other vital signs such as heart rate and body temperature are very important in assessing a patient. These can often help determine the likelihood of involvement of a septic process. Body condition and knowledge of the duration of the problem can help in determining potential success when considering surgical therapy.

The upper respiratory tract can be evaluated relatively readily via palpation, percussion, and auscultation. The nares of cattle should be moist and readily and regularly cleaned by the tongue; therefore the presence of even serous nasal discharge is abnormal. The openings of the nares do not flare or move as much as those of horses. Patency of the nares and nasopharynx can be readily accomplished by placing cupped hands in front of the nares and assessing the volume of air flow or, in cold climates, observing the condensed expired air. Inspiration is difficult to assess, but the relative volume of expired air can be readily determined. Symmetry of air flow may be the most important aspect of exhalation to be determined at the nares. The nature of any fluid at the nares should be examined. Exhaled air should be evaluated for odors that may be indicative of an infectious and/or necrotic process. Any abnormal sounds associated with inspiration or expiration should also be noted. Audible whistles, gurgles, or other abnormal sounds can be indicative of upper airway compromise.

Facial symmetry should be assessed, and any distortion may indicate an underlying disease disrupting upper airway anatomy. Percussion of the nasal passages and paranasal sinuses can be performed with fingers or with a plexometer. Placing a stethoscope over the percussed region may help determine the presence of abnormal tissue or fluid presence in otherwise air-filled spaces. The sounds can be augmented by opening the mouth during percussion.

The ventral aspect of the head should be visually examined and palpated. The intermandibular space should be examined for swelling and painful response to palpation. Congenital malformation, trauma associated with balling gun injury, or foreign body penetration may result in a perilaryngeal mass that can compromise the upper respiratory tract at the pharynx, larynx, and proximal trachea. These can be suspected by detection of proximal cervical swelling (see Figure 14-1). The cervical locations of palpable lymphatic tissues should be closely examined visually and by hand. The trachea should be auscultated with attention to airflow or abnormal sounds indicating the presence of fluid. The trachea and tracheal region should be palpated. Subcutaneous crepitation should be noted. Tracheal sensitivity to pressure and the ease of eliciting a cough should also be determined.

The thoracic cavity should be evaluated by observing the overall condition of the patient as well as the basic movements of the thoracic wall during respiratory efforts. A decline in body score and abnormal respiratory movements can indicate a primary disease process in the thorax. The dorsum is palpated for subcutaneous emphysema. Auscultation is important in evaluating the thorax. Careful attention and assessment of ventilation and lung sounds should be performed. This should include notation of the location or regionalization of abnormal findings. Abnormal lung sounds can indicate different pulmonary diseases, which may or may not need surgical therapy. Thoracic and cardiac surgical diseases are suspected by the absence of respiratory sounds or muffled normal sounds, which indicates a need for further diagnostic procedures. In conjunction with auscultation, percussion of the thoracic wall should be performed. A normal bovine thorax should have air-filled resonance throughout the thorax except for sites of closest cardiac association. Fingers or a plexometer used in a dorsal-to-ventral direction in the intercostal spaces can help detect loss of resonance associated with accumulated fluid or solid tissue

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in the pleural space. Notation of the interface between resonant and dull percussing regions can often indicate the relative level and severity of abnormal pleural fluids. This can also help when deciding if thoracocentesis will be of value.

Other physical manipulations can also assist when assessing the thorax of cattle. Hand pressure can be applied to the dorsal aspect of the spinous processes over the thorax or from the ventral aspect of the sternum. Observation while applying pressure can reveal a pain-avoidance response (grunt test), which can indicate an intrathoracic disorder that may require surgical treatment.

ENDOSCOPIC EXAMINATION

Endoscopy is a very useful tool for evaluating the upper respiratory tract. Endoscopy is certainly most familiar in equine practice, yet the same general techniques can be applied to cattle. Standing restraint is necessary and is likely best in a stanchion or substantial head catch. Although anatomy can be evaluated with any form of restraint, normal airway function of nares, nasopharynx, and larynx can only be assessed in a nonsedated animal. Therefore physical restraint alone is encouraged. Nose tongs can help gain control of the head. If these are used, care should be taken not to occlude passage of an endoscope through the nares into the nasal passages. It is advised to evaluate each nasal passage, which requires passing the endoscope through the left and right sides. Anatomic variation from the more familiar equine upper airway includes the following:

1. Pharynx: a caudodorsally tapering nasal septum in the caudal one third of the nasal passage (Figure 13-1), visualization of both ethmoid turbinates from the same viewing side, a pharyngeal septum (Figure 13-2), location of the nasopharyngeal openings of the auditory tubes dorsolateral to the pharyngeal septum (cattle do not have guttural pouches) (Figure 13-3).
2. Larynx: a triangular epiglottis with rounded tip and borders and very prominent corniculate processes of the arytenoid cartilages (Figure 13-4). Jersey cows have irregular, dark pigmentation of the mucosa of the pharyngeal and laryngeal structures (Figure 13-5). Finally, dorsal displacement of the soft palate is common after withdrawal of the endoscope from the trachea. Because of the ease of displacement of the soft palate, one should be careful in diagnosing dorsal displacement of the soft palate unless it is permanent or associated with dysphagia.

If sedation is deemed necessary to complete an endoscopic evaluation of an individual's upper airway, care should be exercised in choosing sedative agents. Xylazine can substantially alter the anatomic position of laryngeal structures and reduce response to stimuli. Therefore assessments of laryngeal function may be inaccurate. Acepromazine appears to result in much less interference with evaluation and may be preferable over xylazine if time and the animal's demeanor allow use of this agent.

Rarely and very cautiously in very particular cases, oral endoscopy can be used to evaluate pharyngeal laceration otherwise not visible through upper airways. The animal

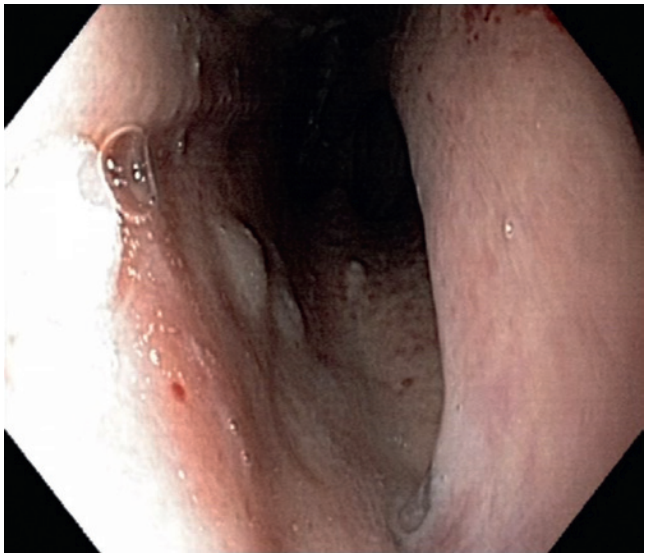


Figure 13-1 Endoscopic view of the nasopharynx; note the caudodorsally tapering nasal septum in the caudal third of the nasal passage.

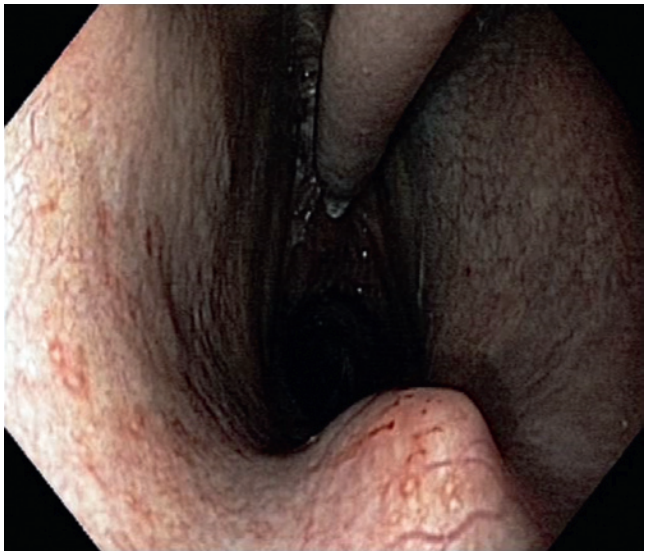


Figure 13-2 Endoscopic view of the nasopharynx: note the nasopharyngeal septum.

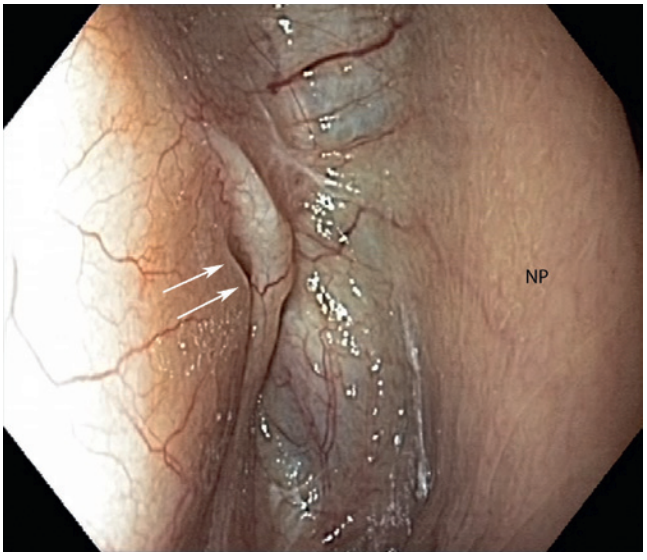


Figure 13-3 Endoscopic view of the nasopharynx: note the right nasopharyngeal opening of the auditory tubes (*arrows*) located dorsolateral to the nasopharyngeal (NP) septum.

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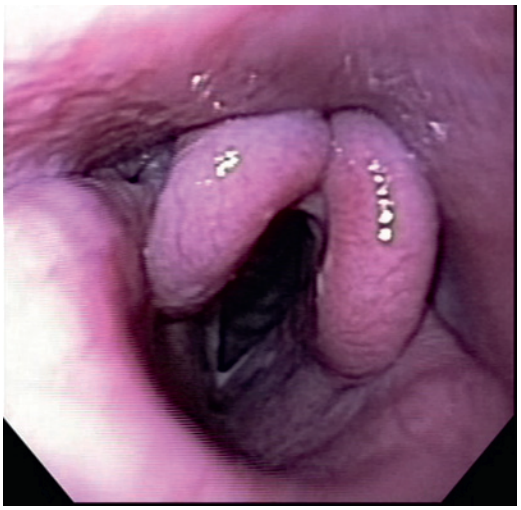


Figure 13-4 Endoscopic view of the larynx: note the very prominent rounded corniculate processes of the arytenoid cartilages and discrete vocal folds.

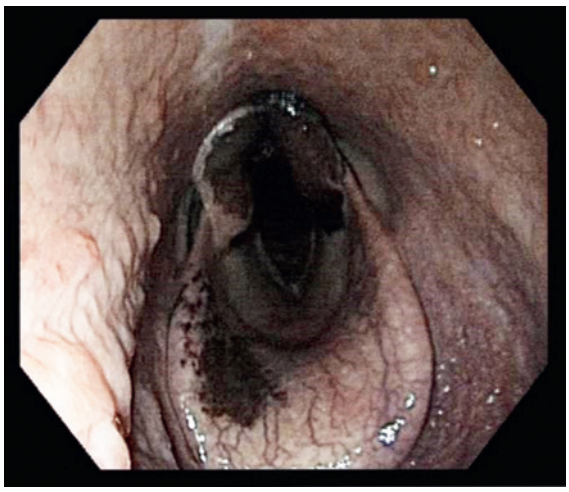


Figure 13-5 Endoscopic view of the nasopharynx and larynx in a Jersey cow; note the irregular, dark pigmentation of the mucosa of the laryngeal structures and the epiglottis with rounded borders.

must be under sedation, and a Frick speculum is used to protect the endoscope (Figure 13-6).

IMAGING EXAMINATION

Ultrasonography can be a very helpful tool in evaluating the airway for disease. It should be recalled that sound waves reflect from gas or air; therefore the aerated aspects of the respiratory tract cannot be satisfactorily imaged. However, a great deal of indirect information can be obtained with ultrasonography. Soft tissue facial distortion, peritracheal swelling, and pleural space fluid accumulation can be readily assessed. Ultrasonography is indicated anytime soft tissue or fluid-associated abnormalities are evaluated in and around the respiratory tract of cattle (Figure 13-7*A*).

Radiography can also be critical in imaging the respiratory tract of cattle. The upper airway is best imaged with lateral and dorsoventral radiographic projections. However, various

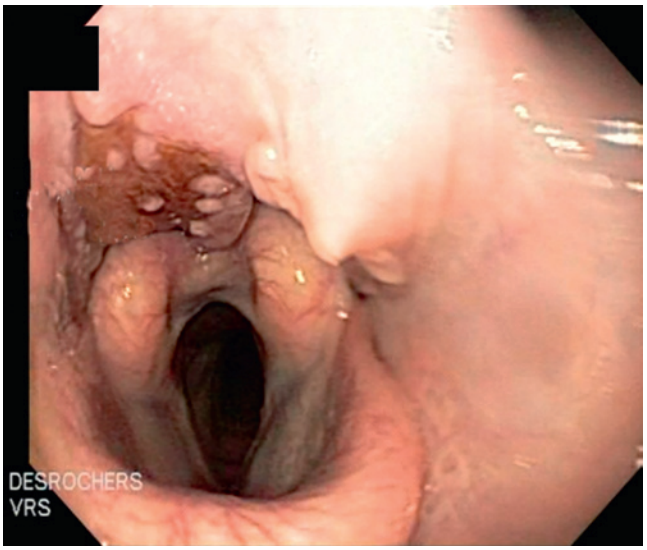


Figure 13-6 **Oropharyngeal endoscopy allows evaluation of an oropharyngeal laceration otherwise not visible through nasopharyngeal endoscopy.** The animal must be under sedation, and a Frick speculum is used to protect the endoscope.

oblique views can certainly assist in defining mass lesions and lesions associated with fluid accumulation. With the increasing availability of three-dimensional imaging, computed tomography and magnetic resonance imaging can assist the clinician in completing diagnoses in cattle. However, animal size and economic considerations will likely limit the practicality of these imaging modalities. The lower airway can also be imaged with radiographs (Figures 13-7*B*, 13-8, and 13-9); however, animal size often interferes with the ability to identify abnormalities. It should be assumed that radiographic detail will be lost as body size increases.

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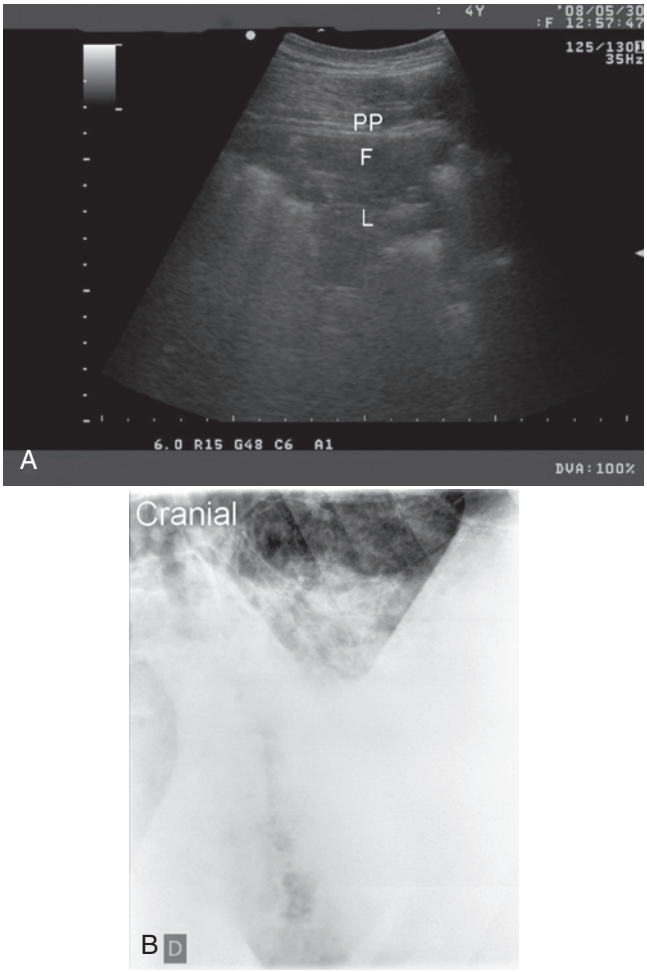


Figure 13-7 Medical images from an adult Jersey cow diagnosed with septic pleuropneumonia. *A*, Ultrasound images from the ventral thorax were obtained with a 3.5-mHz curvilinear probe. The heterogeneous hypoechoic area between the parietal pleura (PP) and the lungs (L) is compatible with fluid (F). *B*, Radiograph of the ventral thorax from the same animal. The heart silhouette and the caudal vena cava are not visible because of the fluid in the thorax.

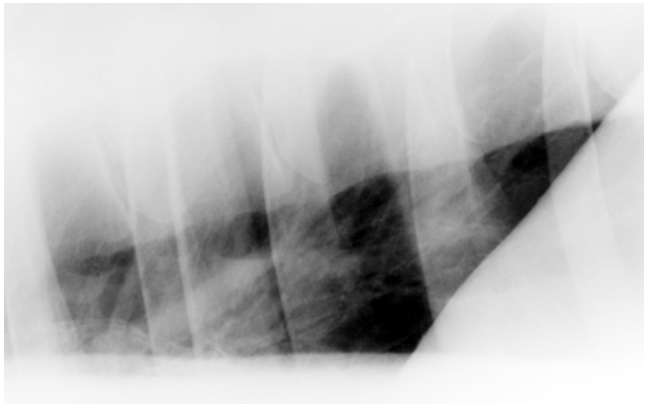


Figure 13-8 Pleural fluid accumulation in a cow with septic pleuritis. (Courtesy of Dr. A. Yeager, Cornell University.)

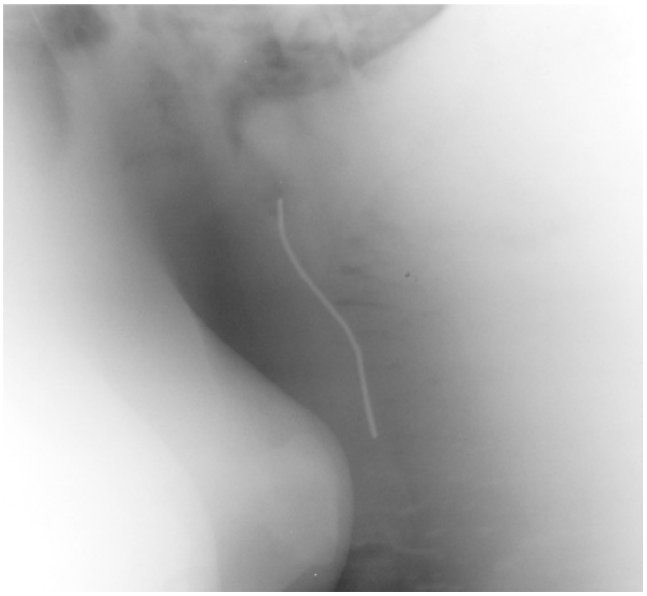


Figure 13-9 Radiograph of the caudal thorax and cranial abdomen in a mature cow with traumatic reticuloperitonitis and pericarditis. Note the metallic foreign body sticking out of the confines of the reticulum in the caudal thoracic area. (Courtesy of Dr. N. Dykes, Cornell University.)

NASAL OBSTRUCTION

Norm G. Ducharme and André Desrochers

Nasal obstruction in cattle, as in other animals, is typically marked by respiratory noise, which is readily localized to the upper airway. Unilateral obstruction can usually be detected with cupped hands near the nares to evaluate symmetry of expiration. Bilateral obstruction is accompanied by severe dyspnea and often with labored open-mouthed breathing. Disease entities most commonly associated with nasal obstruction include congenital malformation—such as conchal cyst (Figure 13-10) and choanal atresia—and acquired conditions, such as granulomas, polyps, and neoplasia (that is, adenocarcinoma, osteoma) (Figures 13-11 and 13-12).

Physical and endoscopic examinations in combination with radiography can usually delineate the presence of a discrete mass lesion (see Figures 13-10 and 13-13*A*). This is desirable when surgical treatment is considered, as a specific target helps in formulating a surgical plan. Some small and pedunculated nasal masses can be resected with transendoscopically guided long instruments, wire loop (with or without cautery), or laser. Small masses may also be amenable to traditional trephination approaches and therefore can be removed in standing cattle. It is possible to resect membranous choanal atresia using a laser (neodymium-doped yttrium aluminum garnet, holmium yttrium aluminum garnet, or diode) under video endoscopic guidance, but a well-vascularized membrane can hemorrhage and obstruct vision of the surgery site.

Nasal flap elevation is typically necessary to reach larger masses in the nasal passage or bony choanal atresia of affected animals. Often nasal masses come to veterinary attention after the size and potential invasiveness of the primary disease process indicates a need for general anesthesia and performance of a large facial flap procedure. Sinonasal cysts have been described in cattle as large nonneoplastic masses obstructing the nasal passage. Radiographic views of the head and nasal endoscopy confirm the diagnosis (see Figures 13-10 and 13-13*A*). Depending on the size, origin, and location of the cyst, it

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Figure 13-10 Lateral radiograph of a 7-month-old heifer calf with nasal conchae cysts. Note oblong opacity in the nasal cavity. (Courtesy of Dr. N. Dykes, Cornell University.)

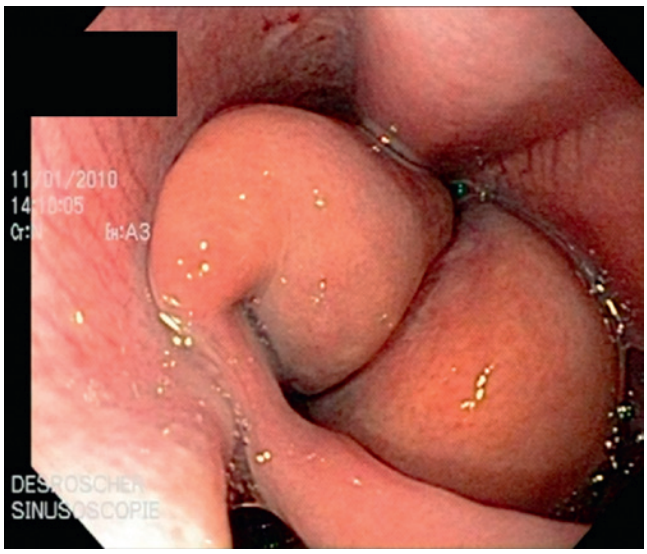


Figure 13-11 Endoscopic view of the nasal cavity from an adult Jersey cow diagnosed with nasal osteoma.

can be removed by an intranasal approach with a snare or maxillary bone flap. According to Schmid, the treated animals will return to their productive lives after surgical removal.

The typical preanesthetic preparations (including acceptable antibiotic and antiinflammatory therapies), induction, and maintenance of general anesthesia are recommended (see Chapter 5). Orotracheal intubation is essential to allow surgical manipulation within the nasal cavity. Lateral recumbency with the affected nasal side uppermost is usually a satisfactory position for unilateral disease. On rare occasions, sternal recumbency is desirable to reach bilateral lesions from a single incisional approach. A flap should be designed to allow exposure as complete as possible without potentially damaging vital structures. It should be noted that many, if

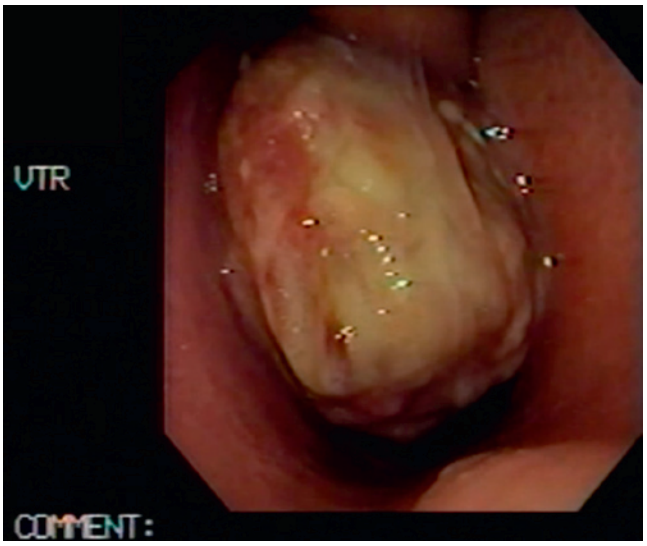
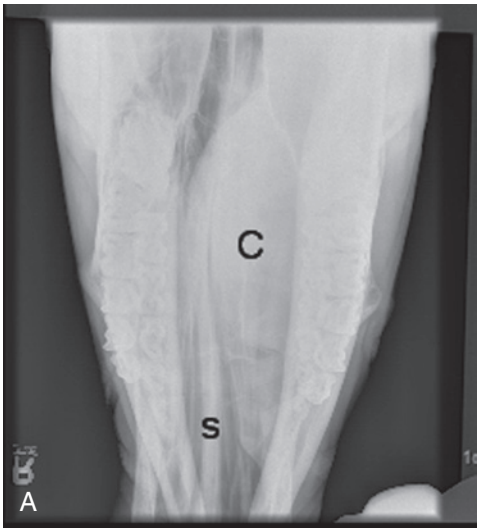


Figure 13-12 Endoscopic view of the nasal cavity from an adult Holstein cow with a granuloma.



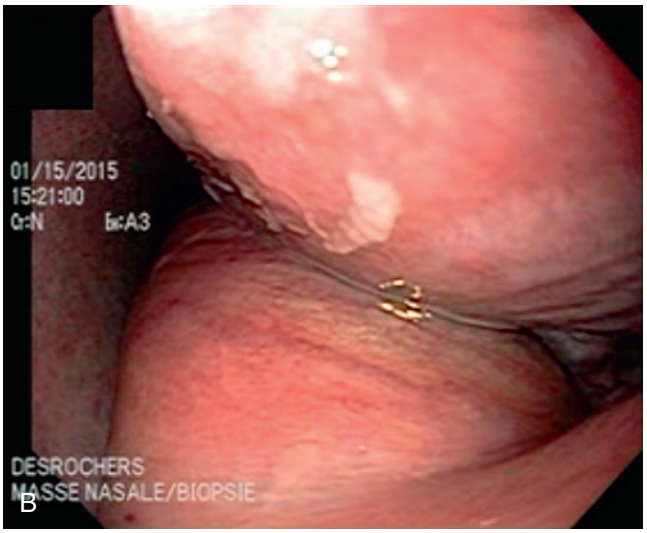


Figure 13-13 Adult Holstein cow diagnosed with a sinonasal cyst obstructing completely the left nasal cavity. *A*, Ventrodorsal radiographic views of the head showing a deviation of the nasal septum (S) from the cyst (C). *B*, The cyst is obstructing completely the nasal passage.

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not most, facial flaps will enter the paranasal sinuses. This is especially true in the caudal region of the nasal passages. The maxillary and frontal sinuses are often the first cavity entered in an approach to the nasal cavity.

A rectangular skin incision is made over the underlying bone and soft tissues that require elevation (Figure 13-14). Periosteum should be sharply incised, gently elevated, and moved from the line of incision into bone (not from the entire flap). An oscillating bone saw is ideal for this procedure (Figure 13-15); however, an osteotome and mallet can also be successful in producing a bone flap. The rostral, caudal, and axial aspects of the bone flap should be completely osteotomized. The dorsal and rostral aspects should be notched at the corners to allow the flap to be gently hinged away from the normal position (Figure 13-16). This generally produces good exposure to allow needed manipulations of diseased tissues in the nasal cavity (Figures 13-17 through 13-19). The nasal passages and paranasal sinuses are highly vascular regions, and extensive hemorrhage should be

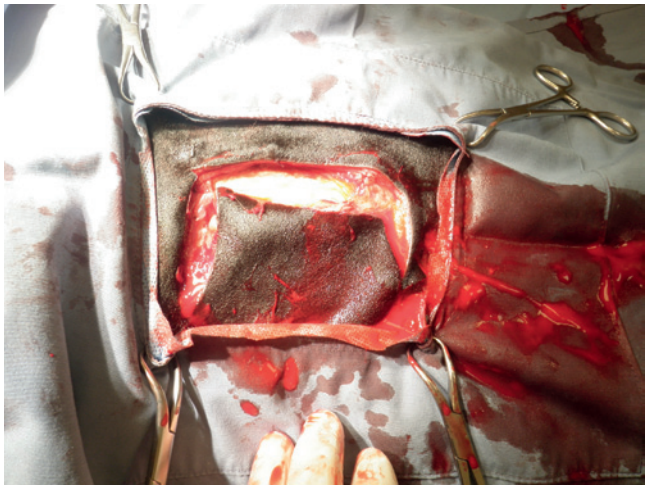


Figure 13-14 Same cow as Figure 13-13, showing a rectangular skin incision over the maxillary sinus.

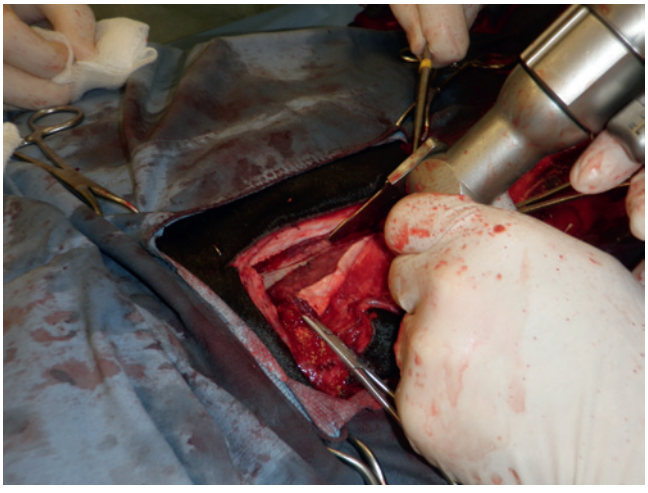


Figure 13-15 Same cow as Figure 13-13, showing an oscillating saw being used to cut the bone, gaining access to the maxillary and palatine paranasal sinus. The hinge of the bone flap is axial.

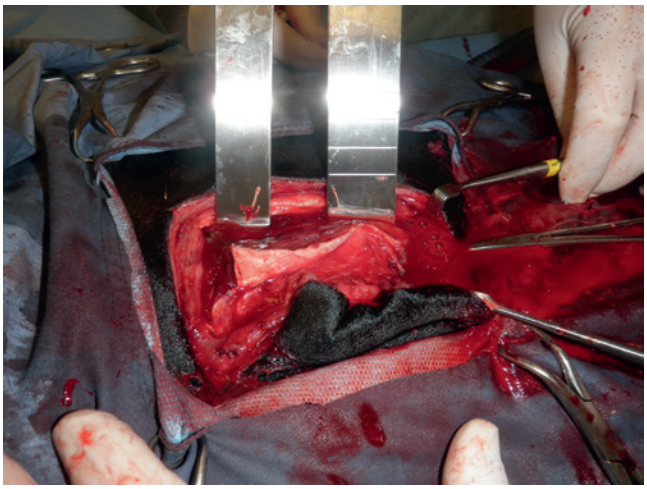


Figure 13-16 Same cow as Figure 13-13, showing that the bone flap is gently lifted with two wide osteotomes, taking care to avoid its fracture.

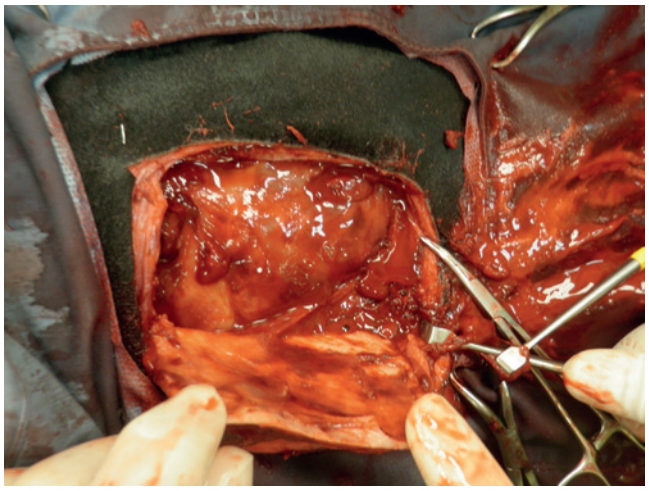


Figure 13-17 Same cow as Figure 13-13, showing that the cyst is occupying completely the cavity. The cyst is removed by digital dissection facilitated with sponge forceps.

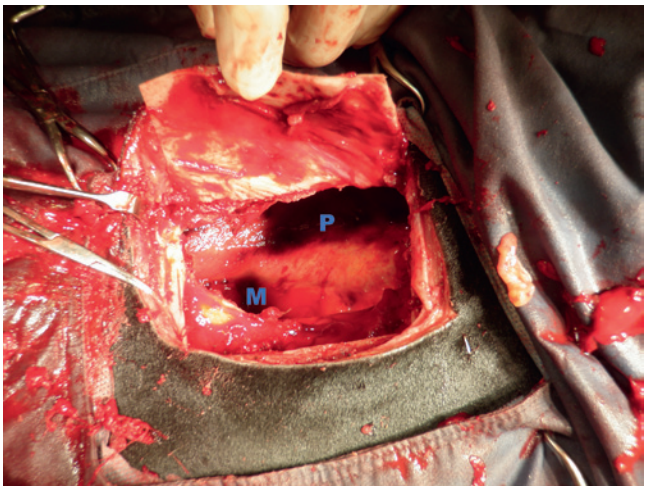


Figure 13-18 Same cow as Figure 13-13, showing that the cyst has been removed from the maxillary (M) and palatine sinus (P).

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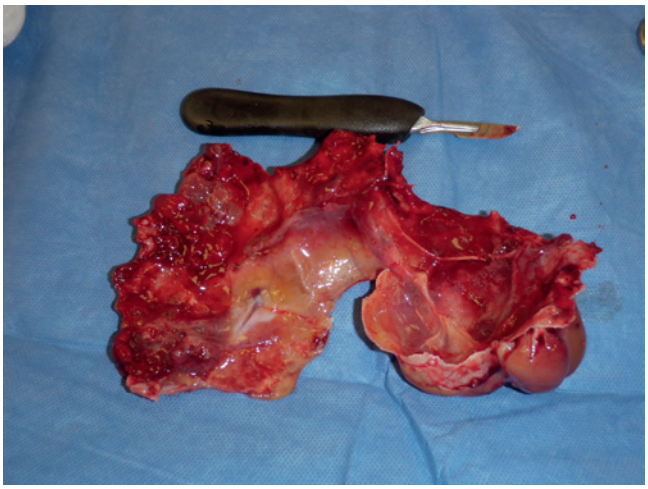


Figure 13-19 Same cow as Figure 13-13, showing the sinonasal cyst removed from the cavity.



Figure 13-20 Same cow as Figure 13-13, showing that the bone flap has been replaced and secured with stainless steel wire at each corner.

expected with aggressive manipulations. Hemostasis is difficult to obtain without direct packing of gauze into the affected airways. With unilateral surgical procedures, firm packing of the affected airway with continuous rolled gauze is very effective in controlling bleeding. In our experience, nasal bleeding is not as marked in cattle compared with that in horses. If bilateral disease is present such that both nasal passages are potentially obstructed by swelling or packing, a tracheostomy should be placed. The gauze packing can be exited from the nares and secured to the skin. Alternatively, the packing can be exited from the lateral aspect of the incision. This usually requires removal of a corner of bone with a rongeur forceps or osteotome. The bone flap can be repositioned and manually pushed back to its normal position. Periosteum, subcutaneous tissues, and skin are then closed. The facial bone of the flap can be wired to the parent bone, but this is rarely necessary if the overlying soft tissues can be successfully closed (Figure 13-20).

Gauze packing should be left in place for 24 to 72 hours. The gauze can usually be readily pulled from the airway without chemical restraint. Some form of confinement housing is probably best for several days after surgery. During this time, continued antibiotic and antiinflammatory therapy is usually indicated. Benign nasal polyps, foreign bodies, and infectious or allergic granulomas usually respond well to surgical removal and supportive medical management. Alternatively, some granulomatous masses can be treated or managed with repeated injections of formaldehyde (neutral buffered 10% formalin) (one should consult with one's regulatory veterinarian, as this may vary among countries). Nasal neoplasia is often very difficult to completely excise; therefore surgery is, at best, palliative, and recurrence is common.

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DISORDERS OF THE PARANASAL SINUSES

Pierre-Yves Mulon

OCCURRENCE AND ETIOLOGY

Disease of the paranasal sinuses is most commonly marked by discharge from the nares or a site of previous dehorning or fracture. The frontal or maxillary sinuses or both can be affected. The sinuses can be primarily affected—usually with infectious, congenital, or neoplastic disorders—or secondarily a disease process extension from a distant or near site. The most common cause of infectious sinusitis is extension of a septic complication after dehorning. Other causes of sinusitis are trauma, sinus cysts, and parasites. Sinus disease should be considered with unilateral or bilateral nasal discharge, facial distortion, and signs of abnormal head posturing, which possibly indicates pain. Other clinical signs may include foul breath odor, dullness upon sinus percussion, fever, anorexia, depression, weight loss, or decreased production.

Diagnosis of paranasal sinus disease is based upon physical-examination findings and imaging studies. On physical examination, bulging of the sinus and purulent exudates at the site of dehorning or nasal discharge are typical of sinusitis (Figure 13-21). Exhaustive evaluation of the sinus can only be obtained by tomodensitometry examination under general anesthesia. Most commonly, paranasal sinuses are evaluated using radiography. Lateral and dorsoventral radiographic projections will delineate abnormal soft tissue and fluid components within the airspace and walls of the sinuses (Figure 13-22*A* and *B*). Occasionally, oblique projections may be necessary to more fully understand the extent of the disease process. Finally endoscopy may help rule out other sources of nasal discharge. Final etiologic diagnosis depends on microbial culture, cytology, and/or histology of the abnormal tissues within the affected sinus. This may be obtained from sinus centesis and aspiration after a small trephine hole is

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Figure 13-21 Young bull with sinusitis. Note purulent drainage at the right nostril.

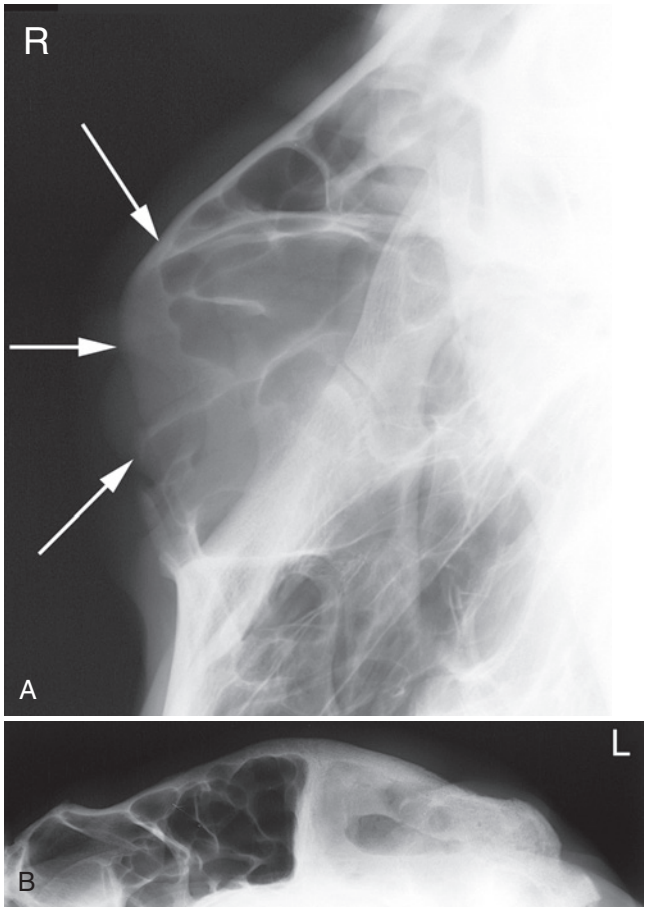


Figure 13-22 *A*, Right lateral radiograph of the frontal sinus in a 3-year-old Jersey cow. Note the fluid line in the left frontal sinus (*outlined by arrows*). *B*, Rostral to caudal radiograph view of the frontal sinuses. Note complete opacification of the left frontal sinus. (Courtesy of Dr. Anthony P. Pease, Cornell University.)

produced with a Steinmann pin (4 mm or 5/32 inch). In our experience, *Arcanobacterium pyogenes* is commonly isolated after dehorning, and *Pasteurella multocida* is often associated with sinusitis unrelated to dehorning.

Refractory or chronic infectious sinusitis is best treated by open drainage and lavage of the affected sinus. This is most directly performed with one or two trephine holes positioned to allow drainage. The site of trephination for each sinus is indicated in Figure 13-23. This can be done with physical restraint and local anesthesia. Generally, the site of drainage is localized in the middle of the bulging frontal or maxillary bone. The frontal sinus is the most commonly affected sinus, and one needs to effectively drain the postorbital diverticulum. The drainage site is 4 cm caudal to the caudal edge of the orbit just above the temporal fossa (Figure 13-23*A*). The rostral site of the frontal sinus can be drained by trephining 2.5 cm from the midline on a line passing through the orbit center (Figure 13-23*B*). The turbinate part of the frontal sinus can be drained by trephining just caudal to the nasal bone divergence point, again 2.5 cm from midline (Figure 13-23C). The main part of the frontal sinus can also be trephined if it bulges (Figure 13-23*D*). A ¾-inch (19 mm) trephine is recommended. Additional trephine holes may be required, depending on individual needs. The maxillary sinus can be opened with a trephine hole immediately dorsal and caudal to the facial tubercle. It may be necessary to place this hole more dorsally in younger cattle to avoid the maxillary teeth. After trephination, large-volume lavage with sterile fluid is often necessary to remove exudate and debris. Saline (0.9%), lactated Ringer's, or tap water with povidone-iodine solution can work well. Occasionally, debridement will be required to completely remove inspissated material and necrotic tissue. This can be performed though the trephine holes or a more aggressive sinus flap. The technique is the same as described for the various approaches to the nasal passages. Flaps should be elevated toward midline with sufficient exposure to accomplish the necessary excision or debridement. General anesthesia is usually required when large flaps are considered. Complete curettage and aggressive lavage are easier to perform via a sinus flap. Voluminous hemorrhage is more likely after creation of a flap and aggressive intrasinus manipulation. Therefore packing the sinus with gauze may be required before flap closure. Creating portals for lavage and drainage is recommended before closing the flap. Removing one or two corners of the facial bone flap allows easy access for subsequent lavage. This is essential to resolve septic disease processes in conjunction with systemic and local antibiotic therapy. Such a complication can be life threatening for the animal; having the material ready to perform an emergency tracheotomy as well as a blood transfusion is indicated to minimize the risks.

In cattle with dental disease as the primary cause of sinus involvement, dental extraction is required (see Chapter 9). Often oral extraction of the affected tooth can be successful. Because the tooth root is shorter in cattle and the disease process is usually chronic, oral extraction is easier than it is for horses. After extraction, drainage through the mouth with, or without, lavage usually resolves the problem. Alternatively, either a trephine hole over the affected tooth or a sinus flap can be effective in providing access for tooth repulsion. A general-purpose acrylic or special dental putty should be placed into the oral aspect of the dental alveolus to prevent oral contamination of the sinus. Plaster of Paris can be used for this purpose as well. The packing is an effective temporary barrier and is usually extruded (or removed) when sufficient granulation or fibrous tissue forms to occlude the mouth from the sinus. Treatment of the sinusitis with local lavage as described earlier is also required.

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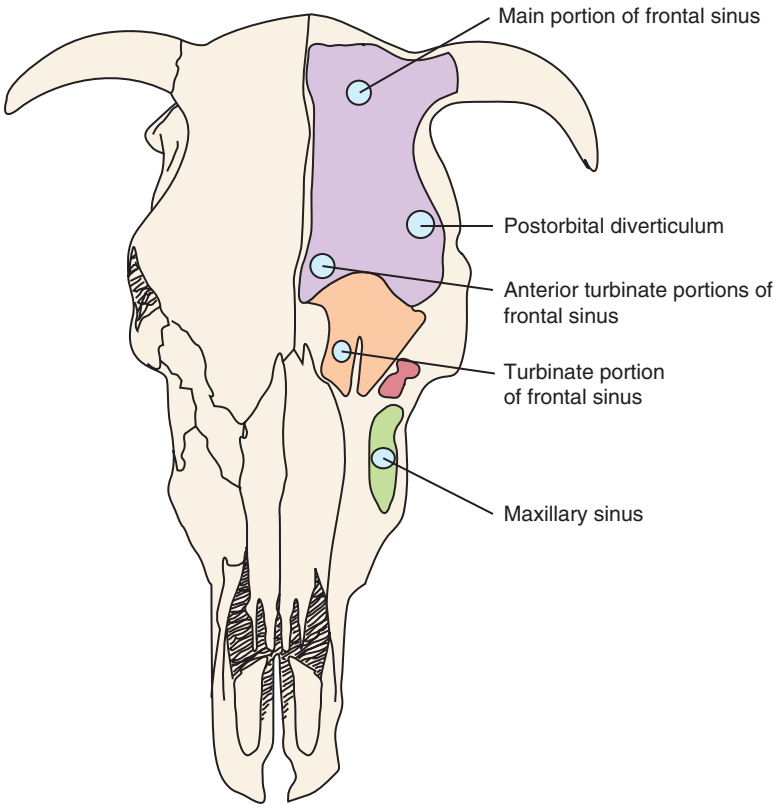


Figure 13-23 The circles indicate the site(s) of trephination for each sinus, and shaded areas are the frontal and maxillary sinuses.

Cattle with infectious sinusitis appear to respond well to surgical treatment if it is performed before general debilitation and development of deteriorating secondary clinical signs. If a neoplastic disorder causes the sinusitis, treatment (surgical debridement of an affected sinus) is palliative, but long-term prognosis is poor because complete excision is usually not possible.

Fracture extending into the sinus may occur after head trauma, especially at the base of the horn in intact animals. The affected horn is immobilized for 6 to 8 weeks using a contoured metal bar as a splint associated with a fiberglass cast from the tip of the affected horn to the tip of the intact horn.

Bone sequestration may develop over time following a head trauma. Complete sequestrectomy is needed. An S-shape surgical approach centered on the cloacum is performed, and a thorough curettage of the involucrum follows the removal of the sequestrum using powered instruments or curettes with constant lavage with sterile saline.

Sinonasal bone cysts are rarely diagnosed. Stridor is a common clinical sign, associated with dyspnea and nasal discharge. The most common location reported on a case report of 15 cases was the ventral nasal concha (8 of 15). Final diagnostic is best performed primarily by tomodensitometry and secondarily by radiography because the nasal passage may be occluded by the cyst for endoscopy. Cyst removal can be performed through the nostril or via a bone flap technique depending on their location.

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DISORDERS OF THE NASOPHARYNX

Sylvain Nichols

OCCURRENCE AND ETIOLOGY

Nasopharynx obstructions are caused by a direct trauma (balling gun injury or foreign body), by compression from a retropharyngeal mass (tumor, abscess), by a collapse from a neurologic disease affecting the glossopharyngeal nerve (listeriosis, otitis), or by edema from severe viral infection (infectious bovine rhinotracheitis). The clinical presentation is similar for all etiologies: variable degrees of mixed inspiratory and expiratory dyspnea. Frequently, a tracheotomy, to install a temporary tracheostomy tube, will be performed before further investigation (technique described in Disorders of the Extrathoracic Trachea). The diagnosis is obtained by oral palpation of the pharynx, endoscopy (Figure 13-24), and a combination of radiographic (Figure 13-25) and ultrasonographic evaluation. In case of pharyngeal collapse, evaluation of the cranial nerves and the tympanic bullae (ultrasonography, tomodensitometry, and/or radiography) are indicated.

In some cases, the animal will present dysphagia and ptyalism. It is important to realize that a large amount of fluids and electrolytes, especially bicarbonate and potassium, will be lost through the saliva. Fluid therapy and frequent

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Figure 13-24 Nasopharyngeal endoscopy of a 6-month-old Holstein heifer with a pharyngeal laceration following the administration of a magnet. The right arytenoid is compressed by the nasopharyngeal swelling. The laceration is now covered by healthy granulation tissue.



Figure 13-25 Standing lateral radiograph of an 8-month-old Holstein heifer presented for fever of unknown origin, distal limb edema, and inspiratory dyspnea. The radiograph was taken following the placement of a temporary tracheostomy tube. Severe narrowing of the nasopharynx is noted (*white arrows*).

monitoring of the electrolytes are necessary to correct the dehydration and to avoid acidosis and hypokalemic syndrome. Less frequently, ruminal bloat might be encountered. An emergency decompression, through a large-size needle/trochar or through a rumenostomy, might be necessary. If a rumen fistula is created, it can be used to feed the animal in the postoperative period.



Figure 13-26 Photograph of a 4-year-old Holstein cow with cellulitis of her left mandible and proximal neck area presumably from prior pharyngeal trauma.

Pharyngeal Trauma

Pharyngeal trauma creates halitosis. The laceration is explored manually to remove foreign materials that could be present. For the oral palpation, the cow is restrained in a standing chute with or without sedation. If sedation is used without a tracheostomy tube in place, it is recommended to decrease the dosage to avoid further pharyngeal collapse. An oral speculum or placement of the tongue in the diastema is used to keep the mouth open. Ideally, two persons hold the head straight for the manipulator.

If an abscess is noted during palpation, it can be lanced carefully within the pharynx with a blade protected in the manipulator's hand. Then a combination of antibiotics and nonsteroidal antiinflammatory drugs (NSAIDs) are given. The pharynx heals rapidly when ventral drainage of the abscess is established.

It is important to monitor the cervical area of cattle sustaining a pharyngeal trauma because it can rapidly get out of control and lead to cervical cellulitis (Figure 13-26). Proliferation of anaerobic bacteria is usually the cause of the rapid onset of this cellulitis. Creating multiple drainage points is indicated to prevent the infection from reaching the thoracic inlet and creating a septic mediastinitis. It is also recommended to sample fluids for bacteriologic culture (anaerobic and aerobic) to adjust the antibiotic therapy.

Pharyngotomy

If the abscess cannot be drained orally, it can be approached through a pharyngotomy incision. Ideally, this procedure is performed with the animal under general anesthesia, intubated through a tracheotomy. The cow is placed in dorsal recumbency and the pharyngeal/laryngeal area is prepped for surgery. The skin incision starts at the thyroid cartilage caudally and travels rostral, past the basihyoid bone, on the ventral midline. The oropharynx is approached by blunt dissection with a Metzenbaum scissor, between the paired sternohyoid and hyoepiglottic muscles, until the oral mucosa is encountered and sharply incised. If needed, the basihyoid bone can be split using an osteotome. The tissues are retracted using a self-retaining retractor. The abscess is located, incised, drained, and flushed. The airways are protected by making sure the cuff of the endotracheal tube is inflated and by putting the animal in a Trendelenburg

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position during the flush. The surgical site is partially closed. First, the oral mucosa is closed with a simple continuous pattern with 2-0 absorbable suture materials. The basihyoid bone, if split, is repaired with steel sutures. The sternohyoid muscles are sutured back together with a simple continuous pattern using 2-0 absorbable suture materials. The remainder of the incision is left to heal by second intention.

Other pharyngeal masses (tumors, cysts) can be approached from a pharyngotomy incision.

Retropharyngeal Mass

Most frequently, the obstruction is caused by a retropharyngeal abscess from an external trauma (Figure 13-27) or an infected lymph node. Less frequently, it may be caused by a hematoma, an infected or obstructed salivary gland, a brachial cyst, or a tumor.

The retropharyngeal area is evaluated carefully by palpation and with ultrasound. A biopsy or an aspiration is performed to determine the nature of the mass. If an abscess is diagnosed, ventral drainage is established, making sure to avoid important structures such as the parotid gland, the facial nerve, and the linguofacial vein. Rather than a sharp approach with a blade, a large chest trocar can be used, under ultrasonographic guidance, to decrease the risk of trauma to those structures. The cavity is then flushed and allowed to heal by second intention.

Salivary gland pathologies are described in Chapter 14.

Pharyngeal Collapse and Swelling

This condition is usually seen in younger animals. Internal and media otitis (see Chapter 19) could cause neurologic signs by affecting cranial nerves VII and VIII. However, in some cases, it can affect cranial nerve IX. With bilateral otitis and bilateral involvement of cranial nerve IX, pharyngeal collapse occurs and causes respiratory distress. A temporary tracheostomy tube is needed to alleviate the clinical signs associated with the obstruction. Adequate prolonged antibiotic therapy combined with NSAIDs should resolve the clinical signs.

Severe cases of viral infection (that is, infectious bovine rhinotracheitis) can create inflammation of the nasopharynx, leading to partial upper airway obstruction. As for the pharyngeal collapse, a temporary tracheostomy tube might be necessary to alleviate the obstruction while the immune system is responding to the viral infection. Steroidal anti-inflammatory drugs are indicated and work better than NSAIDs to decrease the inflammation.

Persistent Dorsal Displacement of the Soft Palate

Dorsal displacement of the soft palate is frequently encountered during endoscopic evaluation in cattle. It has no implication without clinical signs of upper airway obstruction such as roaring and exercise intolerance (noticed in breeding bulls). If persistently displaced, strap muscle resection has been successful in alleviating the clinical signs. The surgery can be done with the cow standing or in dorsal recumbency under local or general anesthesia. The middle third of the ventral neck area is prepared for surgery and infiltrated with 2% lidocaine. A 15-cm ventral midline skin incision is realized. The paired sternohyoideus and sternothyroideus muscles are exposed and isolated bluntly from the ventral trachea. Ten centimeters of each muscle are excised bilaterally. The subcutaneous tissue and the skin are closed separately. The clinical signs usually resolve within 24 hours after the surgery.

PALATOSCHISIS (CLEFT PALATE)

In cattle, cleft palates can be congenital or acquired. With the latter, a complete laceration of the palate may be created by inappropriate delivery of oral medication. Congenital cleft palate is the result of incomplete fusion of the palatal folds following descent of the tongue in the mouth in the early embryonic state. This condition could be inherited in Charolais and Hereford calves. It is associated with other skeletal malformations such as arthrogryposis. It can also be caused by ingestion of teratogenic substances such as piperidine alkaloids, which are present in various plants. It is believed that this substance decreases fetal movement (tongue and limb), leading to the formation of cleft palate and flexor tendon contracture.

In utero, the palate fuses from rostral to caudal. Therefore the soft palate is always involved if the hard palate is not fused. In cattle, both the hard and soft palates are usually involved. The defect is usually large, which complicates surgical correction (Figure 13-28).



Figure 13-27 Photograph of a 6-month-old Holstein heifer (same heifer as in Figure 13-24) with a neck and a retropharyngeal abscess secondary to a pharyngeal laceration.



Figure 13-28 Photograph of a 2-week-old Holstein calf with a large cleft involving both palates.

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Clinical signs include regurgitation of milk from the nose, aspiration pneumonia, and failure to thrive. The signs appear early in life. Therefore the diagnosis is obtained at a very young age. It is obtained by oral examination or by nasopharyngeal endoscopy. It is important to evaluate the calf for any other congenital anomalies and to evaluate the severity of the aspiration pneumonia. Chest radiographs and complete blood work analysis are indicated. Total proteins should be evaluated because those calves may have failure of passive transfer of colostral immunity.

Following a diagnosis of cleft palate, two options are given to the owner: euthanasia or surgical correction. Because of the frequent involvement of both palates, medical therapy alone won't allow the animal to grow and develop normally. With multiple congenital anomalies or with severe aspiration pneumonia, euthanasia should be the first option. If surgery is to be performed, the owner has to be informed of the high failure rate associated with the repair of a large cleft palate and the possible postoperative complications such as aspiration pneumonia, dysphagia, osteomyelitis, and cellulitis. Some cases will necessitate multiple surgeries to successfully close the defect, which involves a large investment from the owner. Before surgery, it is also important to discuss the possible hereditary nature of the disease and the risk of doing surgery for the genetic value of the animal. A large retrospective or prospective study about cleft-palate repair in cattle is lacking. Our clinical impression is that 30% of calves will have a positive outcome following surgical repair.

Because of the risk of aspiration pneumonia and the necessity of doing the surgery before the calf becomes a true ruminant, the procedure is not delayed as it might be in other species (horses). Multiple surgical approaches have been described: transoral, bilateral buccotomy, pharyngotomy, and mandibular symphysiotomy. The latter is the only approach that will allow correction of a cleft involving both the hard and soft palates. Therefore it is the technique most frequently used in cattle.

Preoperative Treatments and Surgical Preparation

Antibiotics are started on admission to treat aspiration pneumonia. If the surgery has to be delayed to properly treat the pneumonia, a temporary nasogastric tube is installed and used to feed the calf. NSAIDs are given before the surgery. During induction for general anesthesia, while the calf is still in a sternal position, the neck is shaved and cleaned to perform a tracheotomy (the technique is described in Disorders of the Extrathoracic Trachea). An endotracheal tube is used rather than a traditional tracheostomy tube. During intubation, it is important not to pass the tracheal bifurcation to avoid unilateral pulmonary intubation.

The calf is placed in dorsal recumbency. The head is secured in a perfectly dorsal position with the help of sand bags. The mandibles are prepared for surgery.

Surgical Technique

A ventral midline skin incision is performed from the basihyoid bone to the tip of the lower lips. To decrease morbidity, the lips can be spared by doing a transverse skin incision at the level of its attachment on the mandible. The lips can then be pushed dorsally in the oral cavity. Saving the lips will decrease the exposure to the soft palate in young calf.

The mandibular symphysis is then split with a No. 21 blade or an osteotome in older calves. A plane of dissection is created 1.5 cm from one ramus of the mandible. First, the tendon of insertion of the geniohyoid muscle is incised 1 cm from its attachment on the mandible. Then the genioglossus muscle and the soft tissue, including the mandibular salivary gland and the hypoglossal nerve, are bluntly separated with a Metzenbaum scissor. Finally, the oral mucosa is incised. The tongue is retracted caudally with a large malleable retractor, and both mandibular rami are gently distracted to gain access to the soft and hard palates (Figure 13-29*A*). A Finochietto rib spreader can be used to maintain the mandibles distracted.

The correction starts with the soft palate. First the tension on the palate is evaluated. If the margins of the defect cannot be apposed without tension, a sliding mucosal flap will have to be created. If the margins can be apposed without excessive tension, they are incised to allow the creation of a nasal and oral mucosal flap (Figure 13-29*B* to *F*). The incision is performed with a No. 12 Bard-Parker blade. Having stay sutures at the caudal end of the soft palate helps to keep tension during dissection. Each layer created is closed independently using 2-0 multifilament absorbable suture materials. First the nasal mucosa is closed with a simple continuous or a continuous Lembert pattern. Then the muscular layer and the oral mucosa are closed with an interrupted or continuous horizontal mattress pattern. Finally, the everted oral mucosa is closed with a simple continuous pattern, making sure to bury the knots. This precaution will avoid the calf's playing with the knots with its tongue.

To correct the hard-palate defect, two mucoperiosteal flaps are created (Figure 13-29*G* to *J*). First the hard palate is incised longitudinally to the maxillary bone, making sure to avoid the palatine artery, from the soft palate to a point 1.5 cm caudal to the maxillary pad. Then the hard palate is incised axially from the soft palate to the rostral edge of the defect using a No. 12 Bard-Parker blade. With a blunt periosteal elevator, the flap is detached carefully from the palatine bone, making sure not to lacerate the palatine artery. The flaps created are slid axially and sutured together with interrupted horizontal mattress sutures using 2-0 multifilament absorbable suture material. Finally, the abaxial portions of the flaps are sutured to the nasal mucosa using a simple continuous pattern with 2-0 multifilament absorbable suture material. The exposed bone will heal by second intention.

The surgery site is closed in four layers after repair of the mandibular symphysiotomy. Cerclage wires passed around the incisors and through mandibular holes are usually sufficient to reduce the symphysiotomy. If more stability is required, transcortical bone screws placed in lag fashion can be used. Then the oral mucosa is closed with a simple continuous pattern. The genioglossus muscle is sutured back together with a simple continuous pattern. The tendon of insertion of the geniohyoid muscle is reattached with a simple interrupted pattern. Finally, the skin is closed with an interrupted pattern. A passive drainage system (Penrose) is placed in the subcutaneous layer to avoid formation of a seroma.

Postoperative Treatments

The antibiotics are continued for 5 days postoperatively or until the aspiration pneumonia has resolved. NSAIDs can be given the following day. If more analgesia is needed, butorphanol can be given. Nursing dairy calves have to drink from a bucket rather than from a bottle. In beef calves, a nasogastric tube should be used for the first week postoperatively. The surgery site is evaluated carefully 7 to 14 days after the surgery. Dehiscence occurs, usually in that time period. The skin sutures are removed 14 days after the surgery.

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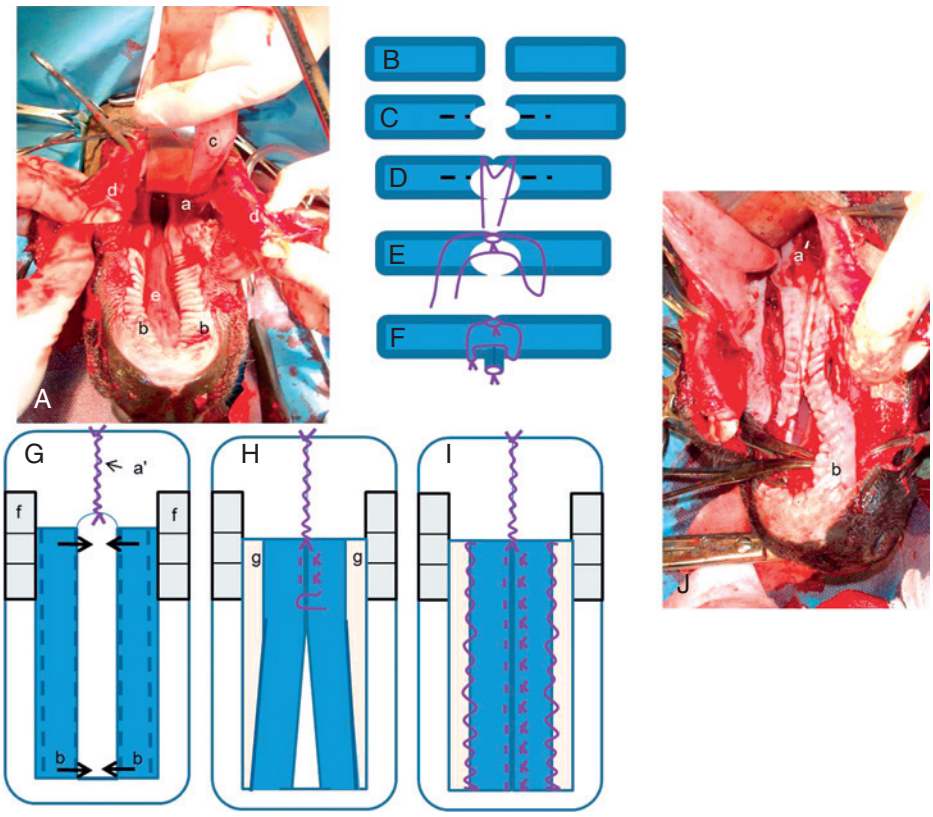


Figure 13-29 Repair of a cleft involving the hard and soft palates in a 2-week-old Holstein calf. *A*, Exposure after a mandibular symphysiotomy. *B*, Diagram of the soft palate's defect. *C*, Diagram of the incision of the edge of the defect in the soft palate. *D*, Diagram of the suture pattern (continuous Lembert) used to repair the nasal mucosa of the soft palate. *E*, Diagram of the suture pattern (vertical mattress) used to repair the muscular layer of the soft palate. *F*, Diagram of the suture pattern (simple continuous) used to repair the oral mucosa of the soft palate. *G*, Diagram of the incision to be performed on the hard palate to create the flaps. *H*, Diagram of the suture pattern (horizontal mattress) to suture the flaps. *I*, Diagram of the final repair showing the suture pattern (simple continuous) to suture the abaxial part of the flaps to the nasal mucosa. *J*, Ongoing repair of the hard palate. *a*, soft palate; *a'*, repaired soft palate; *b*, hard palate; *c*, tongue; *d*, mandibles; *e*, nasal septum; *f*, premolars; *g*, palatine bone.

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DISORDERS OF THE LARYNX

Sylvain Nichols

OCCURRENCE AND ETIOLOGY

Larynx pathologies are frequently a complication of oral necrobacillosis in calves. They occur more frequently in

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Figure 13-30 9 year old brown swiss cow with left arytenoid chondritis with abscessation. Note drainage on lateral aspect of the left arytenoid cartilage.

double-muscled breeds. The clinical signs include variable degrees of dyspnea (inspiratory), halitosis, and abnormal lung sounds (secondary to bronchopneumonia). The diagnosis is obtained by a combination of endoscopy (Figure 13-30), radiography, and/or ultrasonography. Medical therapy (antibiotics and antiinflammatory drugs) can resolve the infection. In severe cases, a tracheotomy combined with a temporary tracheostomy tube is necessary to alleviate the clinical signs while treating the infection. On some occasions, the disease can cause chondritis of the arytenoid cartilages, arytenoidal abscess and/or granulomas, and vocal cord necrosis causing permanent obstruction of the rima glottidis. In those situations, without surgery the clinical signs do not resolve, and the calves are not able to perform adequately.

Three surgical options have been described: tracheolaryngostomy, permanent tracheostomy, and arytenoidectomy through a laryngotomy incision. The tracheolaryngostomy is ideal in calves destined to be slaughtered. According to Gasthuys et al., the long-term success rate is 58%. The permanent tracheostomy can be successful in the long term. Its disadvantage compared with the tracheolaryngostomy is that the larynx cannot be accessed from the surgery site. The arytenoidectomy through a laryngotomy incision had a success rate similar to that of tracheolaryngostomy in a short case series. This latter technique may have a better cosmetic outcome, but the necessity to keep the tracheostomy tube for an extended period of time after the surgery increases the morbidity and the hospitalization time.

In this section, a tracheolaryngostomy combined with an arytenoidectomy will be described. The permanent tracheostomy is described in the section Disorders of the Extrathoracic Trachea.

PREOPERATIVE TREATMENTS AND SURGICAL PREPARATION

The calf is appropriately fasted, and if antibiotics were not already given, they are started before the surgery. A β-lactam is indicated to cover *Fusobacterium necrophorum* and *Truepurella pyogenes*, bacteria frequently involved in the pathology. NSAIDs are also given. The procedure can be done under sedation and local block or under general anesthesia. Ideally, a tracheostomy tube is placed before the surgery. However, it can be done without it. In this situation, efficiency is important to avoid respiratory collapse of the calf.

Surgical Technique

The calf is placed in dorsal recumbency and the ventral neck and throat area are prepared for surgery. An oval or fusiform skin incision is realized on ventral midline (Figure 13-31*A*), centered over the cricoid cartilage and the first two tracheal rings. The skin is incised in an angle to facilitate closure. The paired sternohyoideus and sternothyroideus muscles are split by a combination of sharp and blunt dissection. In heavily muscled calves, those muscles have to be partially excised to decrease tension during creation of the stoma. The cricoid cartilage and the first two tracheal rings are incised on the midline. To improve the access to the arytenoids, the thyroid cartilage can be split (Figure 13-32). In young calves, it can be done with a No. 21 blade. In an older animal, a hammer and a chisel are needed. The cartilages and mucosa are retracted with a self-retaining retractor (Weitlaner). The arytenoids and the vocal cords are evaluated. Abscesses are lanced, necrotic vocal cords are excised, and enlarged and deformed arytenoids are removed.

Arytenoidectomy

Two types of arytenoidectomies have been described: subtotal (saving the corniculate and muscular process) and partial (saving only the muscular process). In cattle, because of rumination, it is not recommended to remove both arytenoids. It is not clear, at this moment, if subtotal is better than partial arytenoidectomy. Both techniques have been used with good long-term outcomes. The decision in regard to which surgical technique is to be used is made in surgery.

With the partial arytenoidectomy, the corniculate process is first excised using a long curved Mayo scissor (this step is not performed with the subtotal approach). Then the ventral and caudal mucosa surrounding the cartilage is incised with a No. 15 blade. The body of the arytenoid is freed from the thyroid cartilage by lateral blunt dissection. The dorsal mucosa and the muscular process are cut with a curved Mayo scissor allowing excision of the body of the arytenoid. The muscular process is left in place. Redundant mucosa is excised, and the defect is left to heal by second intention. The thyroid cartilage is reattached with simple interrupted suture using United States Pharmacopeia (USP) 2-0 polydioxanone. It is important to avoid placing the suture through the laryngeal mucosa.

Finally, the tracheolaryngostomy is realized (Figure 13-31*B*). First a wedge of the cricoid and tracheal cartilages on each side of the midline incision is removed. Ideally the mucosa underneath the cartilage is saved. The cartilages are attached to the skin with horizontal mattress sutures using USP 0 polypropylene suture material. Then, the mucosa is attached to the skin with simple interrupted sutures using USP 2-0 polypropylene (Figure 13-31C). The cranial and caudal parts of the skin incision are closed.

Postoperative Treatments and Complications

The tracheostomy tube, if present, is kept for 2 to 3 days postoperatively. The antibiotics are given for 5 to 7 days after the surgery. The surgery site is monitored closely for signs of infection or dehiscence. The skin sutures are removed 14 days after the procedure. Over time, the stoma will reduce in size and may eventually close (3-4 months).

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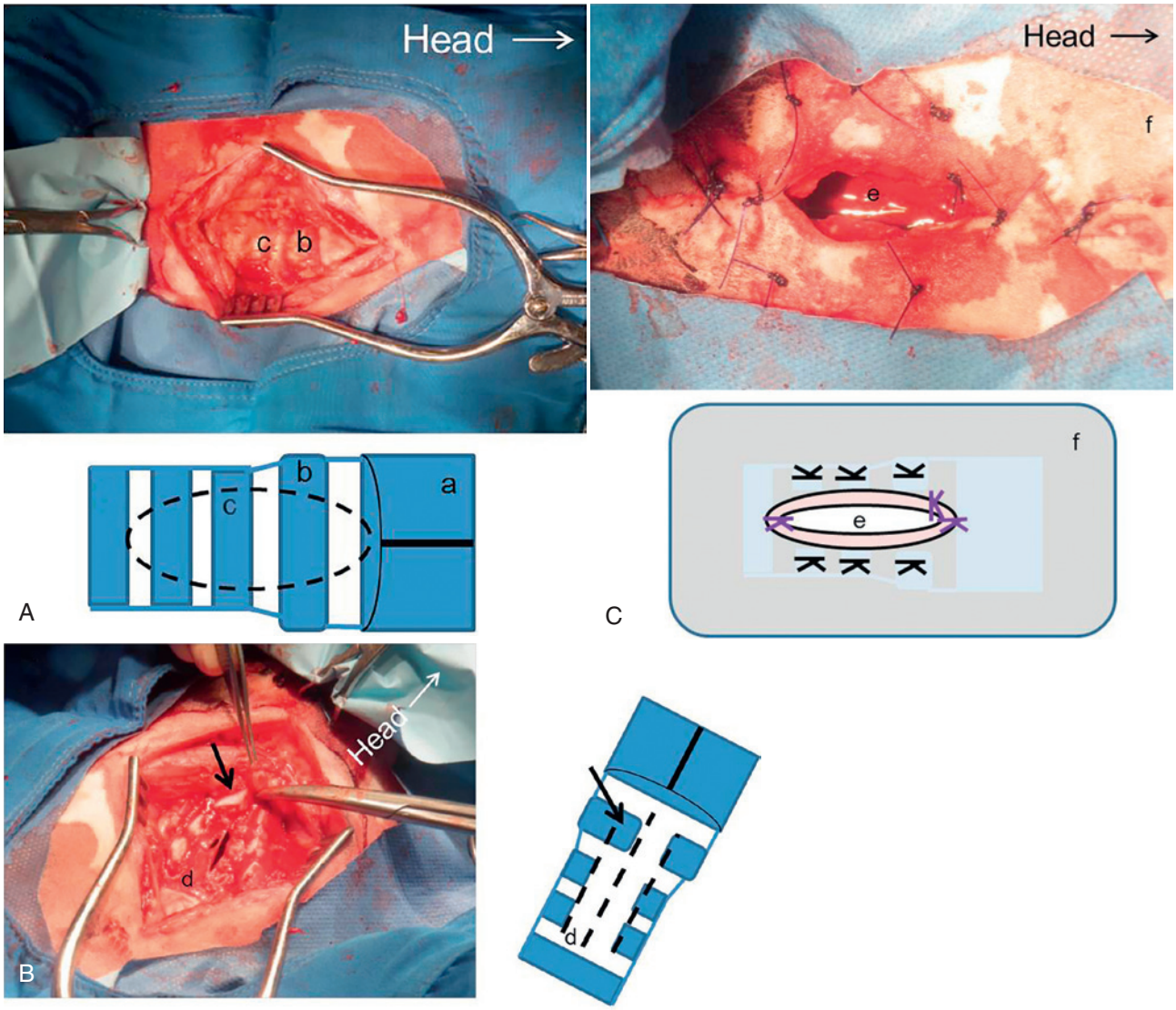


Figure 13-31 *A*, Photograph of a 1-month old Charolais calf diagnosed with bilateral arytenoidal chondritis undergoing a tracheolaryngostomy surgery. The diagram shows the location and shape of the skin incision over the trachea and larynx. *a*, thyroid cartilage; *b*, cricoid cartilage; *c*, tracheal ring. *B*, Photograph of a 1-month-old Charolais calf diagnosed with bilateral arytenoidal chondritis undergoing a tracheolaryngostomy surgery. A wedge of the tracheal rings and the cricoid cartilage are removed, saving the underlying mucosa. *d*, tracheal mucosa. *C*, Photograph of a 1-month-old Charolais calf diagnosed with bilateral arytenoidal chondritis undergoing a tracheolaryngostomy surgery. The tracheal ring and the cricoid cartilage have been secured to the skin with horizontal mattress sutures (outside suture). The cranial and caudal aspects of the skin and the tracheal mucosa are beginning to be secured to the skin with interrupted sutures. *e*, tracheal lumen; *f*, skin.

Having performed an arytenoidectomy might allow the animal to breathe freely even with a stricture of the tracheolaryngostomy.

Early complications include dehiscence of the surgery site leading to acute upper airway reobstruction, ruminal bloat, and bronchopneumonia. Long-term complications include stricture of the surgery site leading to upper airway obstruction and chronic bronchopneumonia.

Other Surgical Approaches to Laryngeal Obstruction

Pathologies involving the vocal cords can be treated by transendoscopic laser surgery. Granulomas can be removed by an oral approach using various instruments such as a chain écraseur. Subepiglottic cysts can be treated through a laryngotomy or pharyngotomy incision (the surgical technique is described in the Disorders of the Nasopharynx section). For the laryngotomy, the approach is similar to what has been described for the tracheolaryngostomy with the exception that only the cricothyroid membrane and the thyroid cartilage are incised. After removal of the cyst, the thyroid cartilage is sutured back together, and the skin incision is left to heal by second intention.

Fourth branchial arch defects are also seen occasionally in cattle. They cause an airway obstruction because of the

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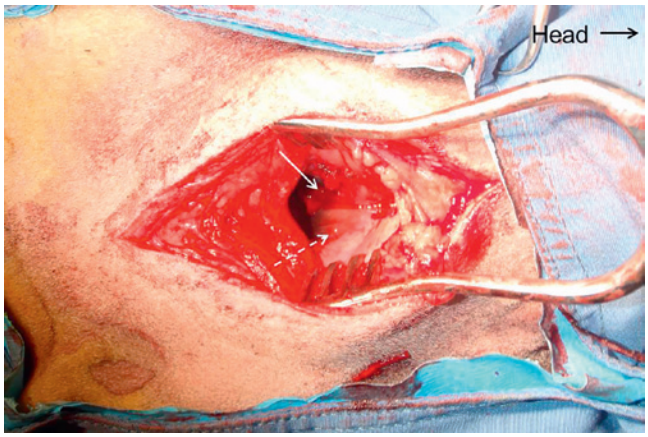


Figure 13-32 Photograph of a 1-month-old Jersey calf undergoing a partial arytenoidectomy. The cricothyroid membrane and the thyroid cartilage have been incised to expose the arytenoids. *White arrow*, excised right arytenoid; *white dotted arrow*, cyst located on the caudal aspect of the left arytenoid.

medial position of the affected arytenoid by deformed thyroid cartilage or laryngeal cyst (Figure 13-33*A*). After incision of the thyroid cartilage (Figure 13-33*B*), laryngeal cysts (Figure 13-33C) or deformed cartilage is removed. Alternatively, a partial arytenoidectomy can be done.

Laryngeal Obstruction in Adult Cattle

Laryngeal obstructions in adult cattle are uncommon. Very few cases have been reported. Lymphoma, associated with the bovine leukosis virus, has often been found infiltrating the larynx, causing a primary or a secondary obstruction (from cranial nerve involvement). Treatment is usually unrewarding.

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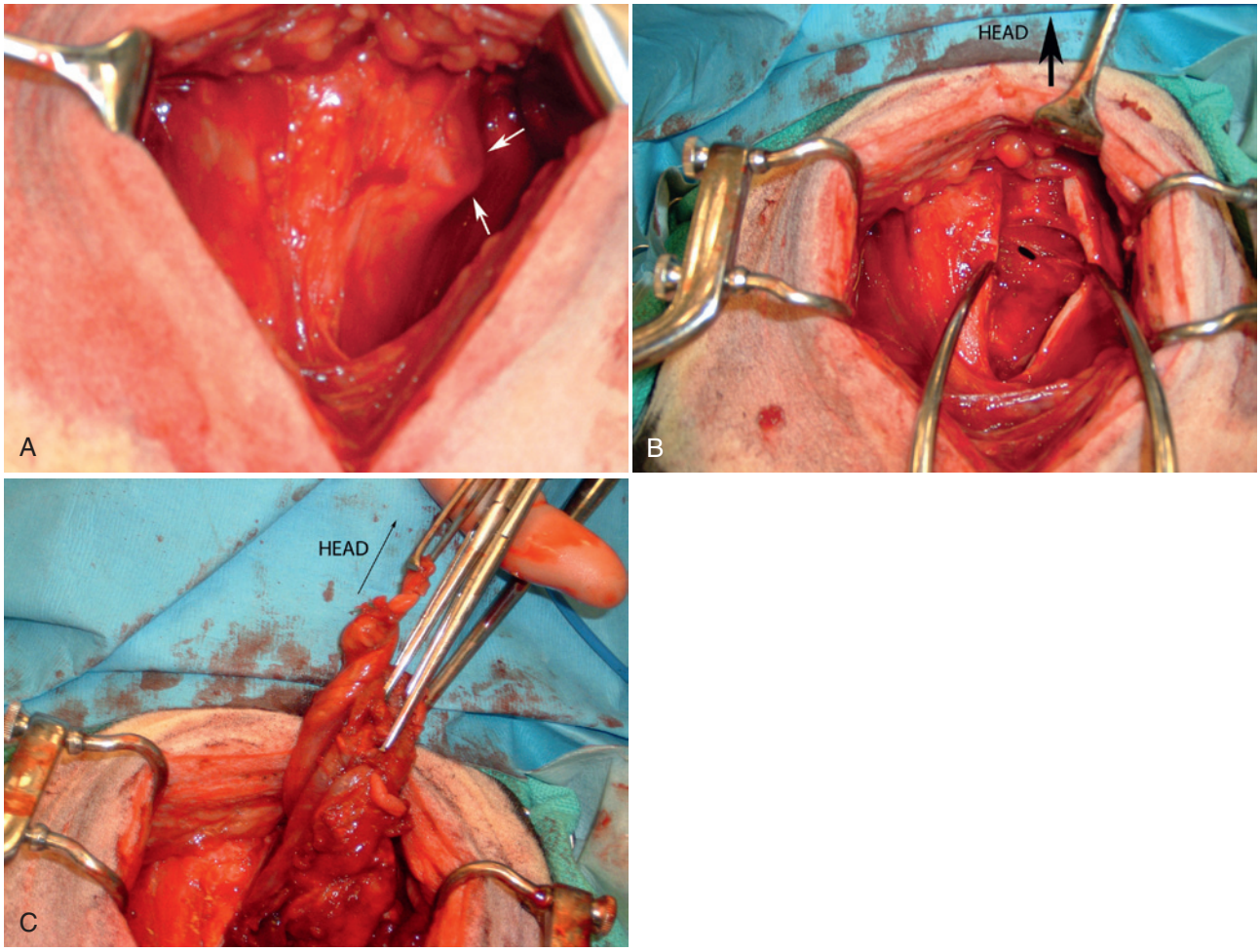


Figure 13-33 Fourth branchial arch defect. *A*, Note lateral bulge of the right thyroid lamina (*arrows*) caused by a laryngeal cyst between thyroid and arytenoid cartilages. *B*, After incision of thyroid cartilage. C, Removal of the laryngeal cyst, which was medializing the body of the right arytenoid. (Courtesy of Dr. Norm G. Ducharme, Cornell University.)

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DISORDERS OF THE EXTRATHORACIC TRACHEA

Sylvain Nichols

Pathologies involving the extrathoracic trachea are uncommon. Tracheal collapse, stenosis, and compression are the most frequent conditions encountered. However, even if the pathologies are uncommon, the trachea is a frequent site for surgery to relieve upper airway obstruction through a temporary or permanent tracheostomy.

TRACHEOTOMY AND TEMPORARY TRACHEOSTOMY TUBE

This procedure is performed in an emergency to relieve a dyspneic animal from an upper airway obstruction or to allow transtracheal intubation to free the airway from a cumbersome endotracheal tube during an upper airway surgery.

The procedure is realized with the cow standing or in dorsal recumbency. In calves it is easier to perform the procedure in dorsal recumbency. The ventral part of the neck is shaved, cleaned, and anesthetized. A line block using 10 to 20 mL of 2% lidocaine is performed on ventral midline at the junction of the cranial and middle third of the neck. At this location, the trachea is more superficial. The preoperative preparation is done with the head in normal anatomic position. At the time of surgery the head is stretched up in the air, or if the procedure is to be performed in dorsal recumbency, the calf is flipped on its back before the alcohol and chlorhexidine wipes. It is important to realize that those positions (head stretch or dorsal recumbency) may aggravate the respiratory distress of the animal. Therefore it is crucial to be efficient to avoid respiratory collapse. Emergency drugs should be readily available during the procedure.

With one hand, the trachea is mobilized while making a 10-cm ventral midline skin incision at the junction of the cranial and middle third of the neck. The paired sternohyoideus and sternothyroideus muscles are split on midline using a combination of sharp and blunt dissection. Care should be taken to remain on the midline to avoid splitting the muscle fibers rather than separating the paired muscle. The trachea is exposed (Figure 13-34), and the annular ligament, between two tracheal rings, is sharply incised. The incision is extended, making sure not to cut more than 50% of the diameter of the trachea. At this point, a hemostatic forceps is introduced in the trachea. The jaw is opened and the animal is allowed to breathe.

The biggest tube fitting through the tracheotomy incision should be used. In calves, half the width of the rings surrounding the incised ligament can be excised with a curved Mayo scissor (Figure 13-35). It will ease the insertion of the tracheostomy tube. A stylet, a forceps, or a finger is used to guide the tube within the trachea. With the tube in place, the skin incision is partially closed using cruciate with nonabsorbable suture material.

If the animal is not already on antibiotics, they are started and given for 3 to 5 days. NSAIDs are also indicated. If the

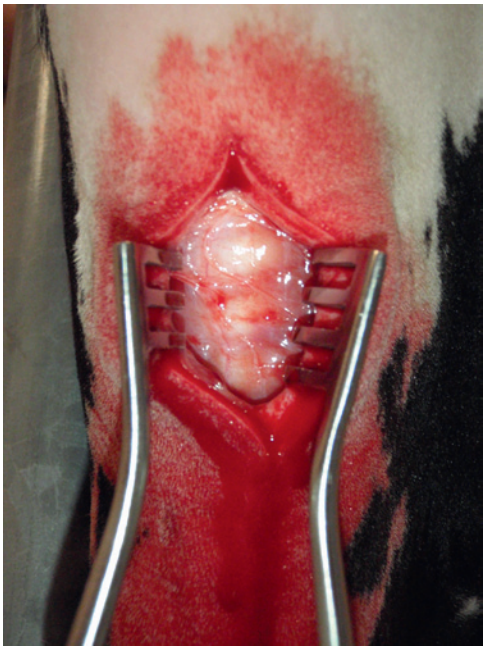


Figure 13-34 Exposed trachea of a 1-month-old calf presented with severe dyspnea. The incision is located at the junction of the cranial and middle third of the neck. The paired sternohyoideus and sternothyroideus muscles have been split and retracted with a Weitlaner retractor.



Figure 13-35 Trachea of a 1-month-old calf with its annular ligament incised and half of the width of the proximal tracheal cartilage removed. Removing a semilunar portion of a tracheal cartilage will facilitate placement of the temporary tracheostomy tube without predisposing to tracheal collapse.

tracheostomy tube has a cuff, it is not inflated, to allow the animal to breathe around the tube in case of obstruction. The tube and the surgery site are cleaned twice daily or as often as necessary to allow easy breathing.

Complications associated with this procedure are cellulitis, tracheitis, bronchopneumonia, asphyxia, and death. It is important to monitor the surgery site for excessive swelling and foul discharge. A dyspneic animal has to have its tube removed to allow breathing through the tracheotomy site.

PERMANENT TRACHEOSTOMY

Tracheolaryngostomy is usually preferred over permanent tracheostomy in cattle. However, this procedure can be successfully performed and may allow long-term survival. Therefore it deserves its description in this section. Ideally, the animal should not have a tracheostomy tube in place when attempting this procedure.

The preoperative treatments and preparation are similar to the tracheotomy procedure described earlier. The surgery can be performed standing in adults or in dorsal recumbency in calves (sedation and local anesthesia or general anesthesia).

A fusiform skin incision is realized on the midline at the junction of the proximal and middle third of the neck. The skin is removed, and the paired sternohyoideus and sternothyroideus muscle are split. In beef cattle, part of those muscles can be excised to decrease tension on the stomy. Three to four tracheal rings are selected. Their cartilages are incised on the midline and on each side of the midline, to allow removal of approximately one third of the circumference of each ring (Figure 13-36*A*). The incision does not implicate the tracheal mucosa. The cartilage is then carefully detached from the mucosa using a combination of sharp and blunt dissection. When the pieces of cartilage are all removed, the remaining mucosa is incised in a double Y pattern (Figure 13-36*B*). Finally, the mucosa is sutured to the skin with an interrupted pattern using nonabsorbable monofilament suture material (Figure 13-36C).

The antibiotics and NSAIDs are repeated for 5 and 2 days, respectively. The surgery site is cleaned daily, and the stitches are removed 14 days postoperatively.

In the early postoperative period, complete or partial dehiscence of the surgery site is the most likely complication. A temporary tracheostomy tube will be used before surgical revision is possible. In the long term (more than 5 years), tracheal collapse at the surgery site has been reported.

TRACHEAL COLLAPSE

Tracheal collapse is usually an acquired condition in calves. It is the result of external compression from an exuberant callus following rib fractures at calving. In the latter case, the clinical signs appear several weeks after birth and cause inspiratory dyspnea, coughing, and poor growth. The diagnosis is confirmed by endoscopy and by lateral radiographs centered at the thoracic inlet (Figure 13-37).

Implementation of an extratracheal prosthesis with or without unilateral resection of the ribs is the only technique described in cattle. The success rate is around 30%.

The prosthesis is fabricated from a 35- or 60-cm^3 syringe barrel (Figure 13-38). Rings of different length (cut in their middles) or a spiral-shaped prosthesis is made. Holes are predrilled to allow attachment of the prosthesis to the tracheal rings. Edges are smoothed to avoid traumatizing the soft tissues.

The calf is appropriately fastened, and preoperative antibiotics and NSAIDs are given. Under general anesthesia the calf is placed in dorsal recumbency, and the neck area is elevated with rolled towels. The surgical site is prepared from the larynx to the midsternebral area. A ventral midline incision is performed from the proximal tracheal rings to the manubrium. The paired muscles (sternohyoideus and sternothyroideus) are split to expose the trachea. The trachea is

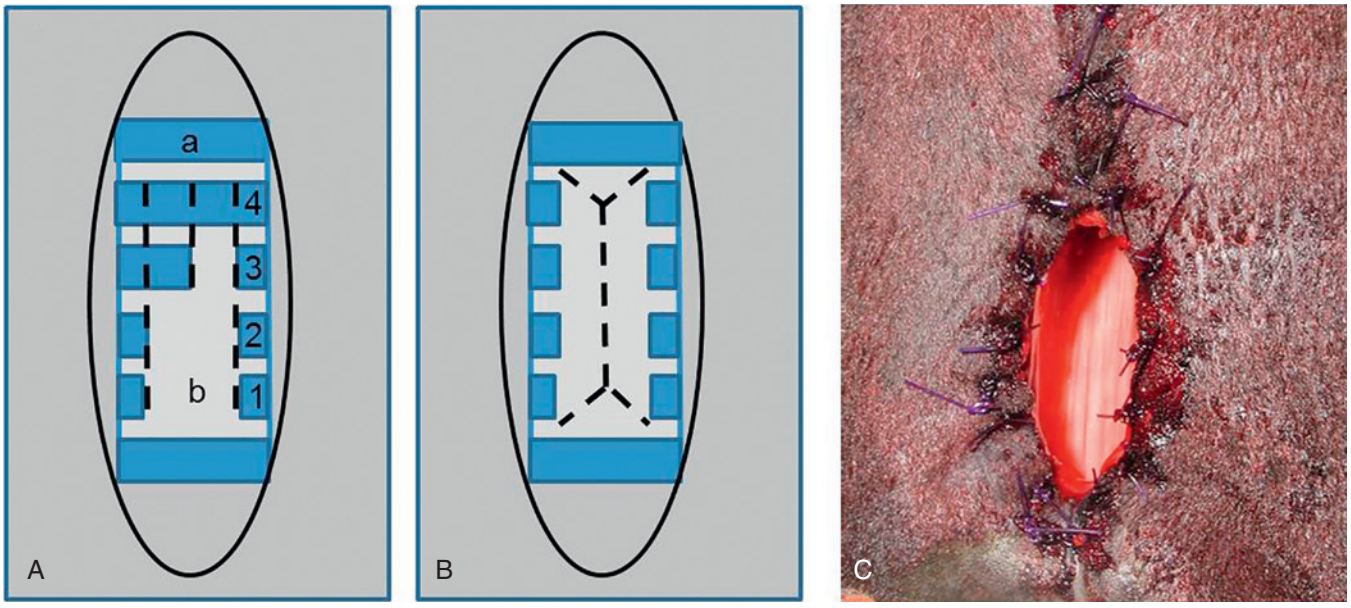


Figure 13-36 Permanent tracheostomy. *A*, Diagram of the skin (*black line*) and cartilage incision (*dotted black line*). One third of the first and second rings has been removed. One sixth of the third ring has been removed. Only the cartilage of the fourth ring has been incised. *B*, All the cartilage has been removed and the mucosa has been incised with a double Y pattern. C, The mucosa has been sutured to the skin using a simple interrupted pattern with nonabsorbable suture material. *a*, tracheal ring; *b*, tracheal mucosa.



Figure 13-37 Lateral radiograph of a 1-month-old calf with distal tracheal collapse following healing of multiple rib fractures. *Black arrow,* site of the collapse. (Courtesy of Dr. André Desrochers, Université de Montréal.)

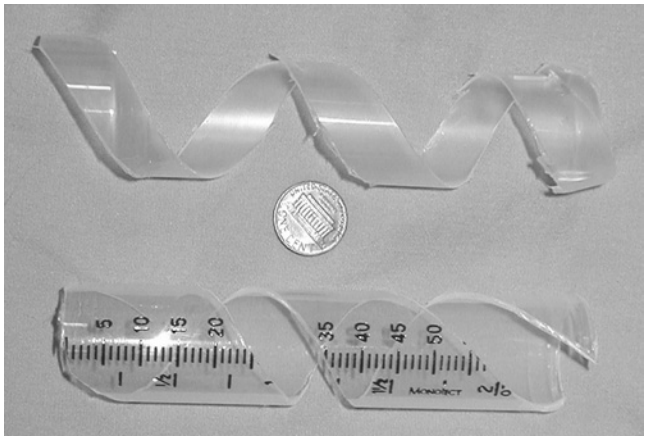


Figure 13-38 The prostheses can be made from 60-mL polypropylene syringe barrels or cases as follows: with a pruning shear, a spiral cut is made along the length of syringe case or barrel. A second spiral is made 1 cm parallel to the first cut. The section created is removed (*top*) leaving the prosthesis (*bottom*). The rough edges are sanded for a smooth finish. The desired length should approximate the length of 2 to 4 tracheal rings.

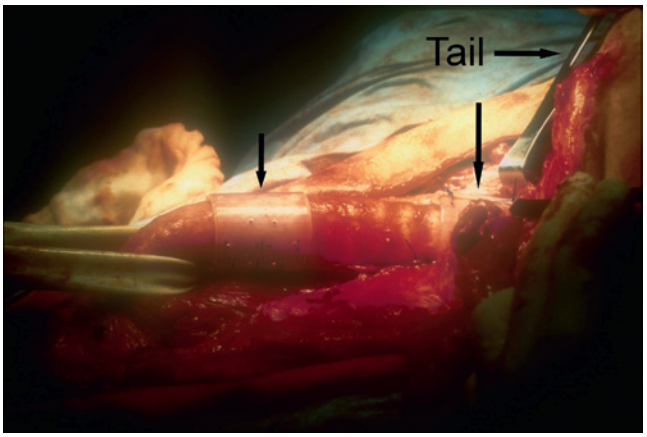


Figure 13-39 The trachea has been mobilized with a Penrose drain (*a*). One prosthesis has been sutured to the collapsed trachea (*black arrow*). The other prosthesis is slid in position (*black dotted arrow*). (Courtesy of Dr. André Desrochers, Université de Montréal.)

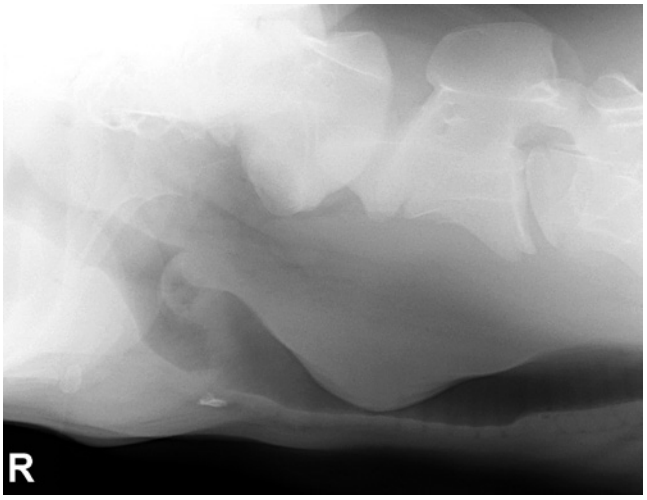


Figure 13-40 Right lateral proximal cervical radiographs showing soft tissue opacity confluent with the dorsal tracheal wall in a calf. This mass was an abscess. Note partial compression of the proximal trachea. The abscess was drained through endoscopy and the calf recovered. (Courtesy of Dr. Anthony Pease, Cornell University.)

mobilized on 360° by blunt dissection of the neurovascular bundles. The thymus is retracted, and if necessary, the incision is continued over the first rib to allow resection of the bony obstruction. The prosthesis is positioned and sutured to the trachea (Figure 13-39). Polypropylene suture materials should be used. If prosthetic rings are used, multiple rings should be used to allow ingrowth of the trachea between the rings. The length of each ring should not be more than the length of two to four tracheal rings.

The surgery site is closed in layers (muscle and skin independently). Antibiotics are given for 5 days or more if bronchopneumonia was diagnosed before the surgery. Ideally, the prosthesis is removed or changed 3 to 4 months after the surgery to avoid obstruction caused by the growth of the trachea within the stiff prosthesis.

TRACHEAL STENOSIS

Tracheal stenosis is seen in feedlot cattle. The clinical signs are similar to the one present with tracheal collapse. However, the obstruction is caused by edema and hemorrhage beneath the tracheal mucosa (similarly to what is seen with hemorrhagic bowel syndrome). The etiology is uncertain, but it is thought that it could be infectious in nature because antibiotics combined with steroidal antiinflammatory drugs can successfully treat this condition.

EXTRATRACHEAL COMPRESSION

Extratracheal compression may result from cervical cellulitis, a localized abscess (Figure 13-40), or a tumor/hematoma involving the thymus (Figure 13-41). Medical therapy alone



Figure 13-41 A 1-year-old Holstein heifer with a thymus hematoma causing moderate respiratory distress and ruminal tympany.

or combined with surgical drainage may be necessary to relieve tracheal compression. The need for surgery is dictated by the severity and/or the nature of the obstruction (abscess). It is important to realize that a mass compressing the trachea will most likely compress the esophagus and cause ruminal tympany. This clinical sign has to be addressed and taken into consideration in the elaboration of a treatment plan.

INTRATRACHEAL OBSTRUCTION

Granuloma from an external trauma or from a previous tracheal surgery can partially obstruct the airway. If the obstruction is small and pedunculated, it can be removed endoscopically. Larger masses, in the cervical trachea, can be removed by tracheal resection and anastomosis. As a rule of thumb, no more than five rings should be removed.

Tracheal Resection and Anastomosis

The trachea is isolated as previously described and the affected section is excised. The anastomosis is realized by using simple interrupted sutures with polydioxanone suture material. Special care should be taken to keep the sutures outside the tracheal lumen. Overextension of the neck should be avoided at all costs after this procedure. Partial dehiscence of the surgery site could still be compatible with good productivity in nonathletic cattle.

RECOMMENDED READINGS

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DISORDERS OF THE LUNGS AND PLEURAL CAVITY

Norm G. Ducharme and André Desrochers

OCCURRENCE AND ETIOLOGY

Although cattle frequently experience pulmonary disease, surgical treatment of the lungs and pleural disease is not commonly indicated. However, cattle have a propensity to develop pleuritis and pulmonary abscesses (Figure 13-42) secondary to penetration of foreign objects from the reticulum. In addition, pleuritis may result from an extension of pneumonia, abscesses in the lungs or liver, or other penetrating trauma. Pulmonary abscesses may also be present in association with thrombosis of the caudal vena cava, which is associated with a very poor prognosis. The latter is best diagnosed with a combination of radiographic evaluation (increased density in the caudal diaphragm at the level of the caudal vena cava, Figure 13-42) and ultrasound detection of the round to oval vena cava in cross-section (instead of its normal triangular shape).

Pneumothorax can result from penetrating trauma or pulmonary disease. The typically complete mediastinum of cattle usually prevents life-threatening consequences of pneumothorax; however, correction of the pneumothorax is desirable to prevent further complications in the pulmonary tissues or pleural space (that is, atelectasis and consolidation of pulmonary parenchyma). Wounds can be primarily closed if deeper tissue complications are not likely, or these wounds can be managed by second-intention wound healing. A one-way valve allows evacuation of pleural/air from the pleural space and assists normal healing by allowing lung reinflation. If the purpose of a chest drain is to evacuate air, it should be placed dorsally in the caudal thoracic cavity. Fluid is best drained from a more cranial and ventral portal. A teat cannula should be introduced through the thoracic wall from a skin incision placed 1 to 2 cm caudal to the intended thoracic insertion site at the caudal aspect of the rib intercostal space. This will avoid intercostal neurovascular structures immediately caudal to each rib.

Intrathoracic bronchogenic cysts are a rare abnormality reported to lead to dyspnea, ruminal tympany, and general poor condition. This developmental abnormality is a result of extra budding of the respiratory diverticula during the embryonic stage leading to supranumerary bronchi, which are cystic when connection to the bronchial tree is absent. These large cysts interfere with ventilation and esophageal function. A large cavitary structure identified by thoracic radiography or computed tomography must be differentiated from a thoracic abscess. Systemic absence of an infectious process and needle aspiration of the mass are useful to obtain a diagnosis. Surgical excision through a thoracotomy is curative.

Finally, thoracostomy is indicated as a diagnostic procedure such as characterization (location, degree of adhesion) of thoracic abscesses. Thoracotomy is required in large intrathoracic abscesses or extensive loculated fibrinous pleuritis.

Management

More aggressive approaches to the pleural space are indicated for advanced pleuritis (more fluids and fibrin are

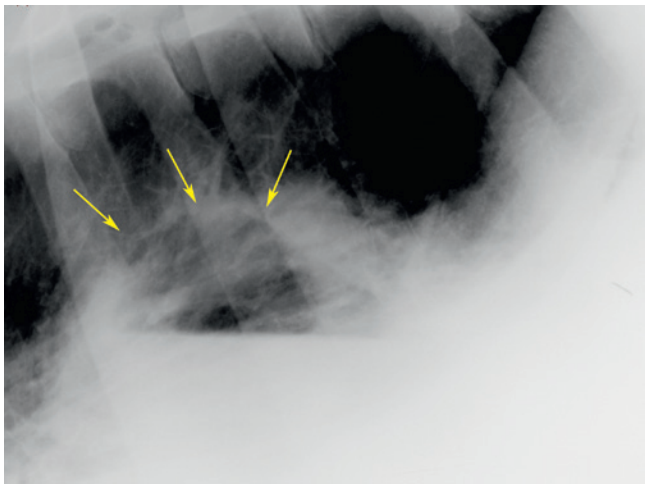


Figure 13-42 Lateral radiographs of the thorax of a 4-year-old cow. In the caudodorsal lung, there is a large 14-cm cavitary mass (*yellow arrows*) with a gas/fluid interface and an ill-defined soft tissue rim.

present) or septic diseases that require lavage therapy of the pleural cavity. Large-bore chest tubes (26-32 French) can be placed in the pleural cavity with the affected animal standing by using local anesthesia at the tube placement site. Ultrasonographic guidance is suggested to avoid trauma to major intrathoracic structures. The fifth and sixth intercostal spaces at the costochondral junction approximately level with the elbow are the most successful sites for tube placement. After skin incision, a chest tube with trocar can be pushed into the pleural space. Fluid will usually be apparent after the typical "pop" of pleural penetration and trocar removal. A one-way valve, condom, or multiway stopcock is then placed on the drain to allow one-way air or fluid evacuation. A single tube can be used for drainage and lavage. More than one tube may be used with difficult or refractory cases but often indicates a poor prognosis.

ANESTHETIC CONSIDERATIONS FOR LATERAL THORACOTOMY

Lateral thoracoscopy and thoracotomy surgical approaches can be performed in standing or recumbent cattle. Standing thoracic procedures (such as standing thoracoscopy [see Chapter 6] and thoracotomy) result in unilateral pneumothorax that remains unilateral because cattle typically have an intact mediastinum that allows unventilated procedures. Despite the decreased ventilation associated with unilateral pneumothorax, standing thoracic procedures are still preferable because lateral recumbency results in poor ventilation of the down (usually normal) side. The mortality rate from general anesthesia is high if the disease process affects a significant portion of the up-side lung.

The patient is placed in stocks without sedation because sedated cattle tend to lie down and sedation impairs ventilation. Local anesthetic is applied to the intercostal nerves of the rib to be resected (at least 20-cm length for proper exposure), and two to three ribs cranial and caudal to the intended surgical site, or at two adjacent ribs if an intercostal approach is planned. Local linear infiltration of an anesthetic agent should also be performed at the intended surgical site. Preparation should be made for emergency ventilation in case the animal shows signs of distress. Typical preparation includes 100% oxygen available for nasal insufflation, an endotracheal tube for emergency intubation, preparation of the midcervical area for an emergency tracheostomy, availability of positive pressure ventilation, an impervious material to seal the thoracotomy site, and gas suction to reverse a pneumothorax.

The greater control and analgesia offered by general anesthesia is recommended only when extensive pleural debridement near the mediastinum is required, and therefore the likelihood of creating potentially fatal bilateral pneumothorax is increased. An individual animal's ability to tolerate general anesthesia is best determined by thorough physical examination, complete blood count, and blood gas analysis. If general anesthesia is selected, placing the animal in sternal recumbency to optimize ventilation is best. Positive-pressure ventilation is a requirement.

SURGICAL CONSIDERATIONS

One must first consider the location of the lesion when deciding on the approach. Whenever possible, thoracic lesions need to be localized by a combination of ultrasound and thoracic radiographs. Lesions located in the cranial aspects of the thorax are very difficult to access surgically because the most cranial thoracotomy can only be done at the level of the fifth rib. The caudal lung lobes can be reached through a partial rib resection or intercostal approach from the seventh to ninth ribs. The size of the lesion and purpose of the surgery determine the surgical procedure: thoracotomy through an intercostal space allows limited manipulations but is sufficient for simple drainage, lavage, limited manual debridement of the pleural space, and marsupialization of an abscess adhered to the parietal pleura if postoperative access to the thorax is not required after surgery.

The animal is restrained in a chute where aseptic site preparation and infiltration of local anesthetic has been performed. If an intercostal thoracotomy is chosen, the skin incision should be centered over the lesion in a proximal to distal direction. The targeted intercostal space should be incised at the cranial aspect of a rib in an effort to avoid the intercostal neurovascular structures that reside immediately caudal to each rib. If a rib resection technique is used, the incision should be started 20 cm dorsal to the costochondral junction centered over the middle of the longitudinal aspect of the rib. The incision can be elongated dorsally to the desired working length. Care must be taken not to extend the incision ventral to the costochondral junction to prevent inadvertent transection of the cranial epigastric vessels. The incision is extended through subcutaneous tissue and then the latissimus dorsi muscle dorsally and the intercostal muscles deep in and ventral to the latissimus dorsi muscle (Figure 13-43). The incision is extended to the periosteum, which is sharply incised. The periosteum is elevated by using a periosteal elevator. At the most proximal extent of the incision, a Gigli wire is passed subperiosteally around the rib (Figure 13-44): this is facilitated using a long-handled, right-angle hemostat. After transecting the proximal aspect, the rib is removed by dislocating it distally at the costochondral junction insertion (Figure 13-45). Alternatively, an oscillating bone saw, osteotome and mallet, or large rongeur can be used to remove part of a rib. The axial rib periosteum is incised along with the parietal pleura to reach the thoracic cavity. If a thoracotomy was made over the fifth or sixth rib, ensure that the pericardium is not adhered to the pleura and opened inadvertently. Handheld or self-retaining retractors can then be used to increase the observable area of the affected hemithorax. Partial lung lobectomy can be effective in removing solitary abscesses and other types of confined masses. Unfortunately,

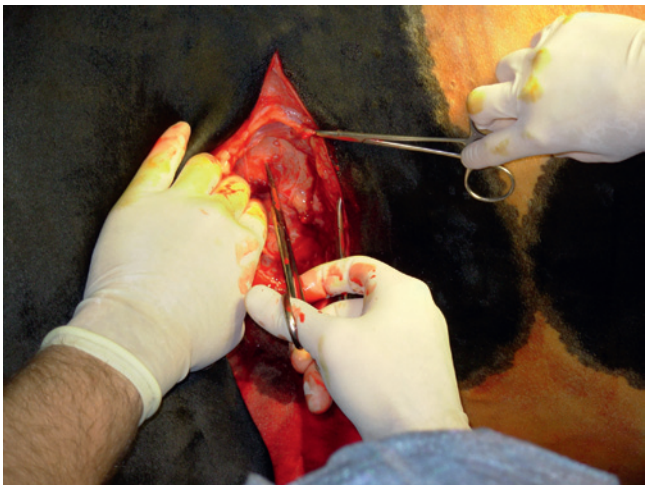


Figure 13-43 The animal is standing in a chute while the surgeon is extending the skin incision through the latissimus dorsi.

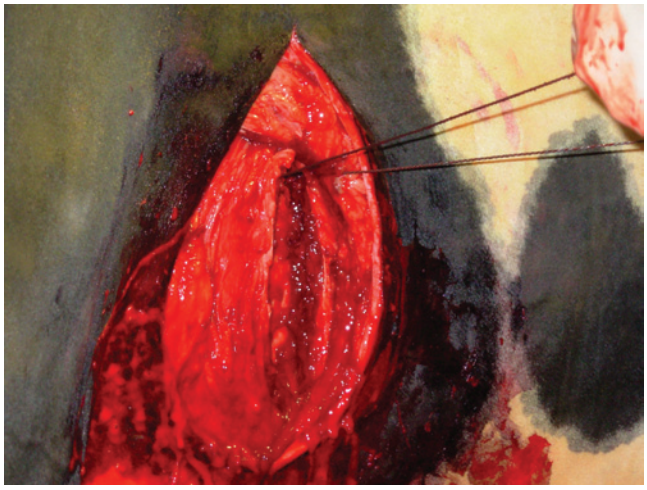


Figure 13-44 A Gigli wire was threaded around the proximal aspect of the dissected rib.

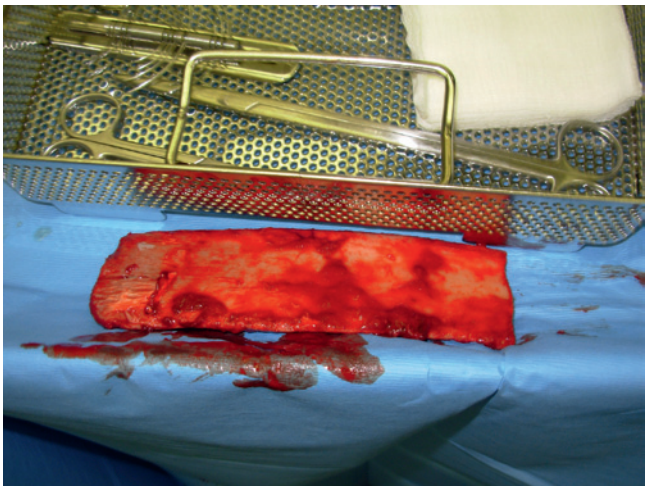


Figure 13-45 Resected rib with its costochondral attachment visible on the left side. Note how wide a bovine rib is.

most neoplastic diseases do not present with readily resectable masses. The affected lung should be elevated to define the interface between normal and abnormal tissue. Stapling instruments[1] can be used to place overlapping staple lines at the resection site to effectively seal the remaining lung tissue. This can also be hand sutured with overlapping mattress sutures to prevent air loss. Depending on location, larger diameter airways may require suture closure independent of pulmonary parenchymal closure.

Before closure, an intercostal block should be performed. Five milliliters of a long-acting local anesthetic (bupivacaine hydrochloride 0.5%) is administered at the caudal aspect of the dorsal remnant of the resected rib as well as two ribs cranial and caudal. Local anesthesia can be performed percutaneously by external palpation or by placing a hand in the thorax and identifying the caudal aspect of the targeted ribs. In the latter case the injection is facilitated with the use of a 19-gauge needle and flexible tubing connected to a syringe with local anesthesia.

Some animals exhibit substantial postoperative pain if the pleural cavity is left open after surgery, which allows air to rush in and out of the pleural cavity. Therefore, if possible, the incision should be partially closed with drainage and lavage enhanced by using drains. However, in all cases with an intact pleural cavity where an abscess is marsupialized, the incision should be left open as the parietal pleura is sutured to the skin. If a nonseptic process was present, or if the abscess is marsupialized at another site (see the following), then the thoracic wall is closed by apposing the parietal pleura, periosteum, and intercostal muscles in one layer using No. 2 absorbable sutures, such as polyglactin 910 or poliglecaprone, in a simple continuous pattern. Suction through a teat cannula or needle in the pleural space is used to reinflate the collapsed lung. If general anesthesia was used, positive-pressure ventilation during closure will express most of the air from the pleural space and facilitate this procedure. The subcutaneous tissue and skin can be routinely closed. The placement of a drain and Heimlich valve in the dorsal aspect of the thorax is optional but in the authors' experience increases the animal's comfort by decreasing the postoperative pneumothorax.

In cattle with large, caudally located pulmonary abscesses in which partial lung lobe resection is considered impossible, marsupializing the abscess capsule to the skin may be possible. A similar intercostal or rib resection approach can be employed. Most lung abscesses adjacent to the thoracic wall are adhered to the pleural cavity, allowing for safe marsupialization. If not, the fibrous wall of the abscess should be initially secured to the thoracic wall and skin with monofilament absorbable sutures size 1 or 2 USP. The sutures should effectively seal the abscess from the pleural cavity and leave access for a drainage incision in the abscess wall. The abscess capsule should then be incised to produce an exit portal for the accumulated purulent exudate and debris or foreign material. The abscess cavity can then be lavaged if necessary and the surgical wound left to heal by second intention.

Lung biopsy is rarely desired; however, percutaneous techniques can be frustrating as appropriate diagnostic tissue samples may be difficult to obtain. Surgical biopsy can be successfully performed under direct observation by using a thoracoscopy (see Chapter 6) or thoracotomy. Thoracoscopy is less invasive and requires little knowledge of the lesion site. On the other hand, a thoracotomy for a lung biopsy is far more invasive and requires an accurate anatomic diagnosis to locate abnormal tissues.

[1]TA 90, US Surgical, Tyco Health Care, Norwalk, CT.

Thoracoscopy can be performed with a laparoscope or a sterilized flexible endoscope. The detailed use of the laparoscope is described in Chapter 6. If the laparoscopic equipment is not available, a diagnostic evaluation can be done with a sterilized flexible endoscope. The procedure is also performed with the animal standing with the affected hemithorax prepared for aseptic surgery. Local infiltration of the anesthetic is done over the junction between the dorsal third of the ninth or tenth intercostal space. A 1-cm skin incision is made slightly caudal to the intended intercostal space entry. A 6-cm^3 syringe barrel is used to manufacture a thoracoscopic port. The tip of the syringe barrel is cut and beveled to serve as a trocar. The sterilized syringe case is then inserted into the intercostal space and used as an entry site for the flexible endoscope. This also gives some rigidity that helps direct the endoscope toward the cranial or caudal aspect of the thoracic cavity. Because of farm animals' tendency to create fibrous adhesions, observation of the chest area may be limited in cases with extensive adhesions, in which case ultrasonographic examination would be preferable.

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DIAPHRAGMATIC HERNIA

André Desrochers

Diaphragmatic hernia is a rather rare condition in cattle. The diaphragm is a musculotendinous cupola-shaped structure separating the thorax from the abdomen. The diaphragm is made of a centered tendinous portion and a peripheral muscular portion in three parts: sternal, costal, and lumbar. Dorsally, the costal part attaches to the 12th rib and its ventral portion attaches to the ribs and eighth costal cartilage. There are three openings through the diaphragm: the esophageal hiatus, the aortic hiatus, and the foramen vena cava.

Diaphragmatic hernia can be of three origins: congenital, traumatic, and hiatal. Water buffaloes seem to be more susceptible than cattle. The most common type of hernia described in the literature is related to the reticulum. The exact origin of this type of hernia is unknown, but many affected animals showed concomitant signs of reticuloperitonitis. A congenital weakness in water buffaloes is also suspected. Pericardioperitoneal congenital diaphragmatic hernia has been described in a few animals. In two different case reports, the animals were presented at 6 weeks of age. It is usually a necropsy finding and some of these calves have concomitant congenital abnormalities such as ventricular or atrial septal defect. Finally, traumatic hernia has been reported in newborn calves following dystocia or adult cattle during pregnancy.

The clinical signs will vary depending on the cause and the organs of the herniation. In general, neonates or young calves will have acute signs of respiratory distress with abdominal respiratory effort, will be tachycardic, and will be weak. Thoracic auscultation might reveal absence of respiratory sounds, muffled heart, or gastrointestinal borborygmus. Adult cattle with a herniated reticulum will show vague digestive symptoms from tympanism to rumen atomy similar to reticuloperitonitis.

Radiographic images of the thorax will confirm the diagnosis. It is preferable to avoid the ventrodorsal view on distressed animals unless oxygen or intubation can be done rapidly. A lateral radiographic view is usually diagnostic (Figure 13-46). If the reticulum is herniated, its soft tissue opacity will be superimposed on the heart silhouette. Radiopaque foreign bodies can also be observed in the reticulum within the thoracic cavity. Thoracic ultrasound examination was compared with radiographic examination for the diagnosis of diaphragmatic reticulum hernia in cattle. The reticular motility was observed at the fourth intercostal space confirming the hernia.

Exploratory laparotomy for diagnostic purposes must be done with extreme caution unless the reticulum is the herniated organ because it can lead to pneumothorax. The sudden loss of abdominal negative pressure will cause immediate lung collapse if there is a communication with the thoracic cavity.

Treatment is surgical and must be performed under general anesthesia with mechanical respiratory ventilation. Hypoxemia, dehydration, hypovolemia, and hypoglycemia must be addressed first and the patient stabilized before



Figure 13-46 Left lateral radiographic images of a newborn calf presented for severe dyspnea. Intestines are in the thoracic cavity. The lungs are collapsed dorsally.

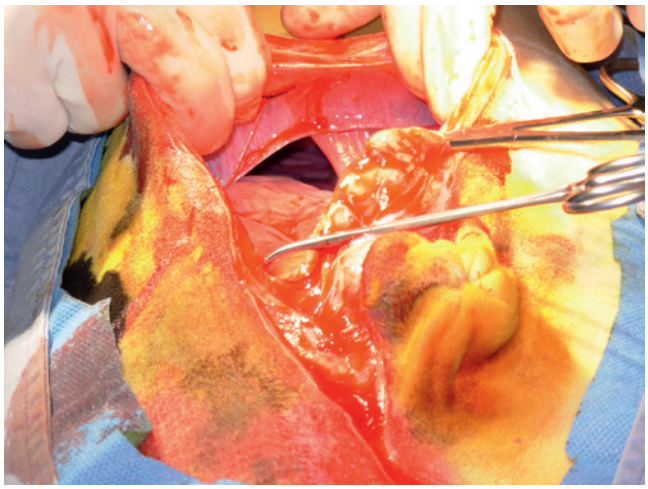


Figure 13-47 Viscera are herniated through a diaphragmatic tear.

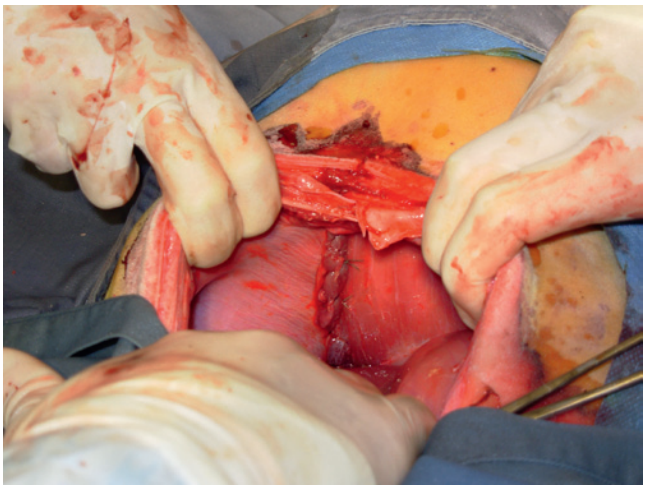


Figure 13-48 The diaphragmatic tear has been sutured with two layers: continuous and horizontal mattress.

surgical intervention. Depending on the cause, the age of the animal, and the herniated structure, the surgical approach will differ. In calves, the ventral approach is preferred, giving access to most of the diaphragm (Figure 13-47). Surgical preparation must include the ventral thorax. The ventral midline incision is from the xyphoid process to the cranial aspect of the umbilicus. The Balfour self-retractor allows adequate assessment of the hernia, the herniated organs, and the thoracic cavity. It also helps the surgeon to access and suture the defect. The herniated organs are carefully pulled from the thoracic cavity back into the abdomen. Depending of the duration of the disease, adhesions, and size of the hernia, the organs might be congested and must be manipulated with extreme care. If traumatic, the tear can extend from ventral to dorsal, making suturing quite challenging. Before suturing the defect, a fenestrated chest tube can be placed to keep a negative pressure postoperatively. Depending on the size of the defect, partial exteriorization of abdominal organs might be necessary to access the dorsal portion of the tear. The organs are kept moist with sterile saline-soaked towels. The diaphragmatic defect is sutured with polydioxanone or polyglactin 910 in a one- or two-layer simple continuous suture or interrupted mattress depending on the tension on the diaphragm (Figure 13-48). Once the thoracic cavity is closed, the negative pressure is reestablished using a butterfly needle through the diaphragm attached to a 60-cm^3 syringe or other type of suction. If the defect cannot be sutured because of excessive tension, then a polypropylene mesh is used.

In adult cows with diaphragmatic reticular hernia, the surgical treatment is in two phases: left-flank rumenotomy and cranioventral laparotomy. With the animal standing, the hernia is confirmed through a left-flank laparotomy. A rumenotomy is performed, taking care to remove foreign bodies from the reticulum but without dislodging it from the thoracic cavity. After routine surgical closure of the rumen and the abdomen, the animal is feed restricted to keep the rumen small for the second surgery, which is planned in 2 to 3 days. The surgery is performed under general anesthesia with the animal in dorsal recumbency. The ventrocranial abdomen is accessed through a 30-cm crescent-shaped incision starting from the xyphoid process. The herniated reticulum is carefully freed from the adhesions and the diaphragmatic hernia sutured as previously described. The acquired pneumothorax is eliminated by inflating the lungs while the surgeon ties the last knot of the suture on the diaphragm.

Postoperatively, the animal is monitored for vital signs, respiratory pattern, and dehydration. If a chest tube and a Heimlich valve are in place, it must be carefully fixed to the thorax, and regular assessment should be made of the draining pleural fluids. It is left in place for no more than 2 days. Postoperative antibiotics and analgesia are given according to surgical findings or comorbidities. The prognosis is always guarded, but animals that survive the first week postoperatively seem to do well long term.

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DISORDERS OF THE PERICARDIUM

André Desrochers and Norm G. Ducharme

Traumatic reticulopericarditis is the most common reason for surgical treatment involving the pericardium. Clinical signs are related to signs of congestive heart failure with distended jugular, brisket edema, tachypnea, and tachycardia with muffled heart sounds. The diagnosis is confirmed by thoracic radiography and thoracic ultrasound (Figure 13-49*A* to C). Lateral thoracotomy is most commonly used

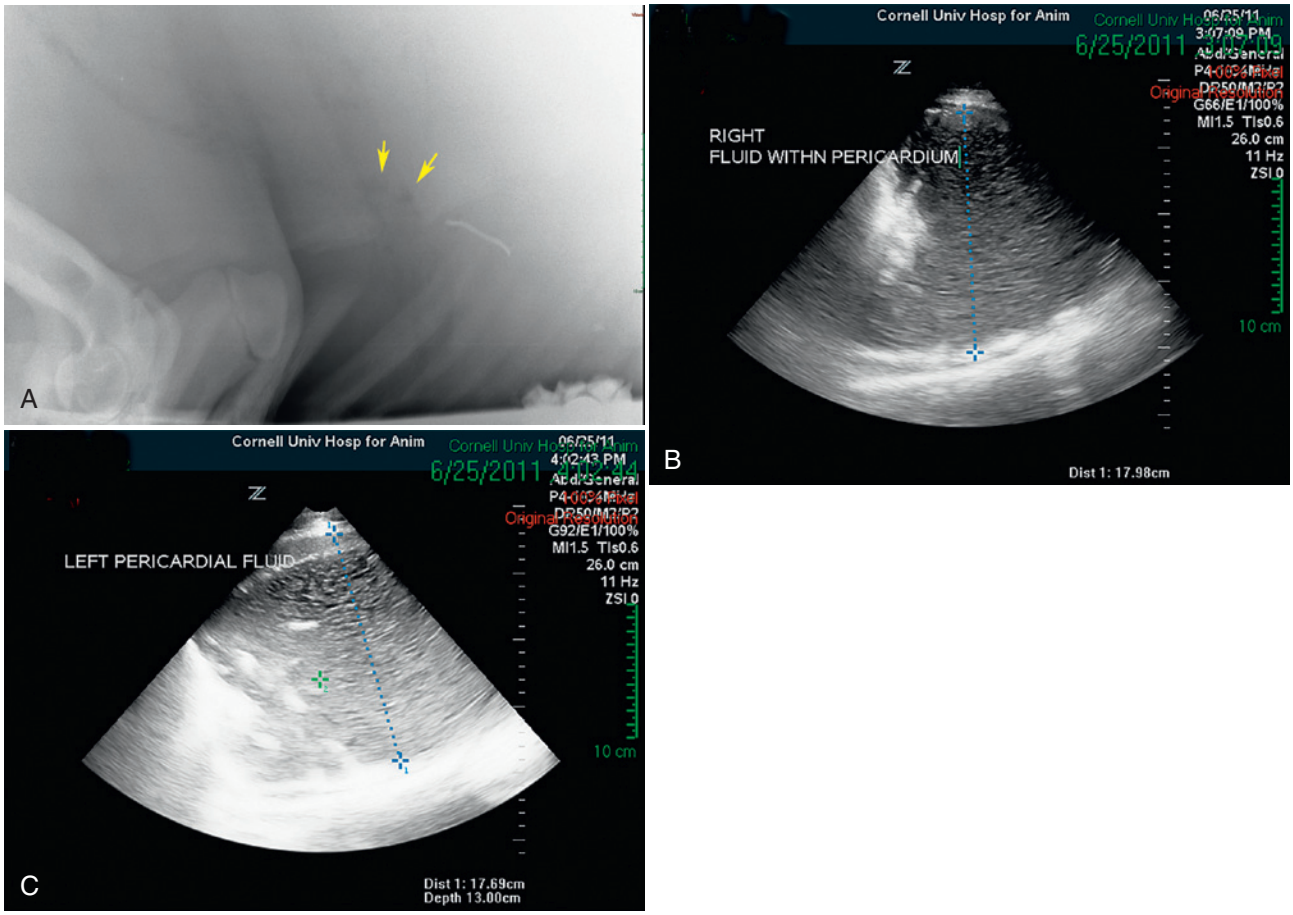


Figure 13-49 Radiographs. *A*, Radiographs of a 14-month-old Holstein-Friesian with traumatic reticuloperitonitis; at the junction of the caudoventral thorax and cranioventral abdomen is an approximately 3 to 4 cm curvilinear metal wire with multiple coalescing gas opacities (*yellow arrows*). *B* Thoracic ultrasound showing distended pericardium with fluid containing fibrin on right and (C) left side.

in a clinical situation for drainage and debridement of the pericardium, foreign body removal, and rare surgical manipulation of major vessels such as patent ductus arteriosus ligation. Median sternotomy gives better access to all cardiac chambers and large vessels in experimental surgery in a training center or research instrumentation involving those structures. Postoperative care and recovery including pain management are similar between the two approaches.

LATERAL THORACOTOMY

Thoracotomy can be done with affected cattle standing or by using general anesthesia in sternal or inclined recumbency. In the authors' experience, general anesthesia in lateral recumbency in cattle with pericarditis is associated with a high mortality rate. A reticular foreign body may enter the thorax from either the left or right side (see Figures 13-7 and 13-49*A*); therefore an accurate diagnosis is essential for choosing the correct surgical success. Medical imaging such as lateral radiographic views of the thorax and ultrasound examination will help the surgeon to take the most appropriate approach.

The most typical approach to the pericardium is to enter the thorax at the left fifth or sixth ribs or intercostal spaces or at the sixth or seventh ribs by the lateral thoracotomy approach described in the section pertaining to diseases of the lungs and pleural cavity (see disorders of the lungs and pleural cavity in this chapter). The length of the skin incision for a pericardectomy should be at least 20 cm to provide good exposure. Upon entering the chest, the pericardium is often adhered to the regional pleura if the disease is advanced. Therefore incising into the pleural cavity must be carefully performed although cattle have separate pleura from the pericardium when no adhesions are present (Figure 13-50). Presurgical ultrasound examination may provide the necessary forewarning of this possibility. Before draining the pericardium, the surgeon should look for a fibrous tract that enters the pericardium caudally. Septic pericarditis is most commonly the result of foreign body penetration from the reticulum. If preoperative radiographs indicate a foreign body present in the chest, early identification of this tract is critical for successful removal of the foreign body and a successful procedure. Pericardial drainage will be unsuccessful if the foreign body is left in the thorax. The key is identifying the fibrous tract encircling the foreign body early to prevent its cranial or caudal displacement. The fibrous tract is clamped with a large Ochsner clamp to immobilize the foreign body as soon as the tract is identified. The surgeon then incises the fibrous tract with large scissors until the center is identified. The foreign body is then grasped and

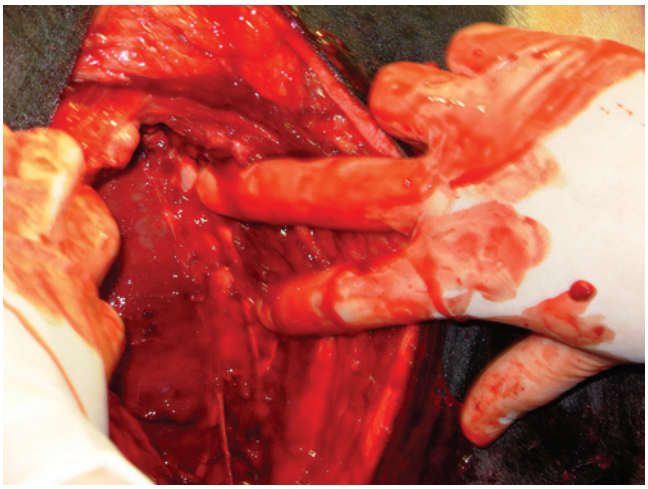


Figure 13-50 After resection of the rib, the periosteum is seen intact covering the pericardium.

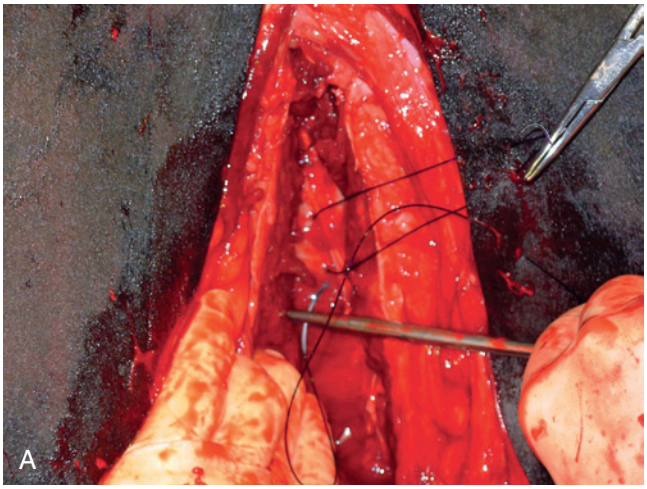




Figure 13-51 *A*, A monofilament United States Pharmacopeia 2 is used to marsupialize the pericardium to the skin. *B*, Marsupialization is terminated.

removed. Idiopathic septic pericarditis is rare but possible. The affected animal will have no foreign body on radiographic views or ultrasound examination of the reticulum and the thorax and no cranioventral peritonitis. Case management is similar without the effort of retrieving the foreign body. Thereafter in both cases, the pericardium is sutured to the skin at the incision edge. This can be accomplished with large (#2 or #3), monofilament, absorbable, or nonabsorbable sutures in an interrupted or continuous pattern (Figure 13-51*A* and *B*). The pericardium is often quite fibrotic and capable of holding suture tension; however, sepsis can render it friable and frustrating to suture. The pericardium is then incised and drained manually (Figure 13-52). Depending on the duration of septic pericarditis, there can be thick caseous purulent exudates that must be manually removed from the pericardium (Figure 13-53). After drainage, lavage with warm isotonic fluid is used as needed. Because of the postoperative pain and delayed healing, it is best to reinflate the lungs and use a drain to manage the pleural space as described in the previous section. The pericardial cavity may be left open to drain or be partially closed and managed with drains if this allows appropriate lavage and adequate drainage (Figure 13-54). Extensive chronic pericarditis will often require marsupialization of the pericardium for postoperative drainage. Drains can be placed in the pericardial sac for targeted lavage with warm saline.

STERNAL THORACOTOMY (MEDIAN STERNOTOMY)

This approach, used in calves up to 80 kg in weight, required general anesthesia with inhaled anesthetics and positive-pressure ventilation. After aseptic preparation a midline skin incision is made over the sternum. The incision is extended through the subcutaneous tissue using electrocautery. A sternal saw is used to transect the sternal vertebrae starting on the left or right of the manubrium (manubrium sparing median sternotomy) extending rostrally to the first intercostal space. Cautery is used to provide hemostasis at the incision line. A Finochetto retractor is used to give access to the thoracic cavity. The pericardium is incised with curved Metzenbaum scissors, taking care to elevate the pericardium before incising to avoid contact with the myocardium. Local anesthesia can be used to irrigate the myocardium to prevent inadvertent cardiac arrhythmia. The edge of the pericardium is then sutured to the edge incision to prevent fluid accumulation in the pleural cavity. The sternum is then reapposed with eight surgical wires. The deep muscular layers and subcutaneous tissue are closed with 0 monofilament in a simple continuous pattern, and the skin is closed routinely.

IDIOPATHIC HEMORRHAGIC PERICARDIAL EFFUSION

Recently described in adult cows, it is not considered a surgical condition. However, surgeons must know this condition and include it in their differential. The origin is unknown, but it is hypothesized to be a precursor to epicardial

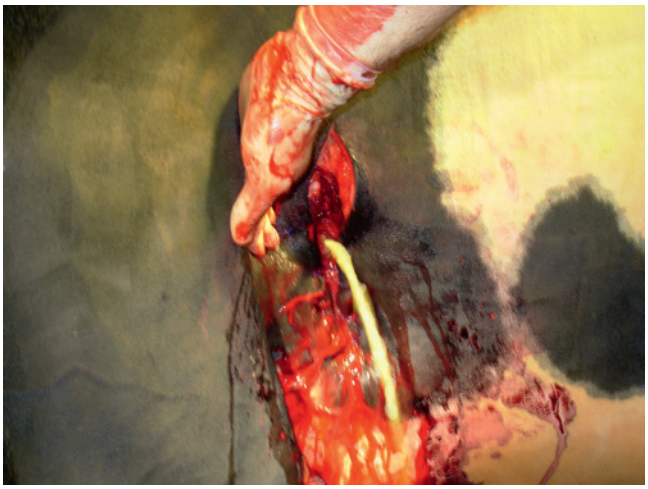


Figure 13-52 The liquid pus is slowly drained from the infected pericardial sac to avoid shock.

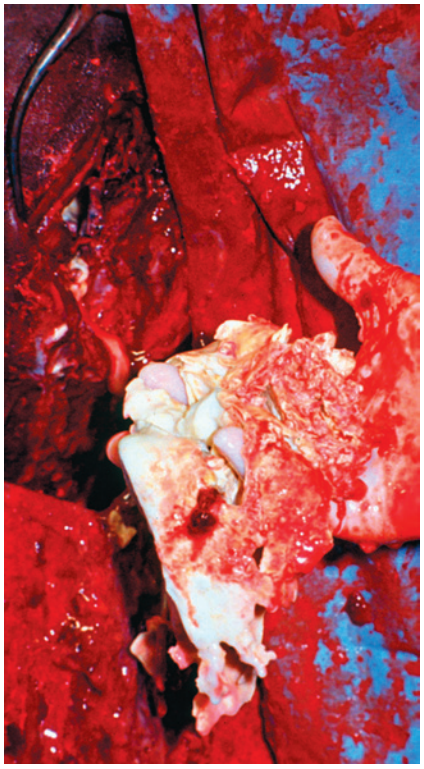


Figure 13-53 Thick caseous purulent exudates being removed from around the pericardium.

lymphosarcoma or of bacterial origin. Affected animals are presented for congestive heart failure with distended jugular, brisket edema, tachypnea, and tachycardia with muffled heart sounds (Figure 13-55*A*). Cardiac ultrasound confirms the presence of anechoic fluid in the pericardial sac. Although volume is difficult to objectively quantify, it is usually significant. The heart has a flaccid contractility like a leaf in the wind with diminished ventricular chambers (Figure 13-56). A rounded distended caudal vena cava is usually seen on liver

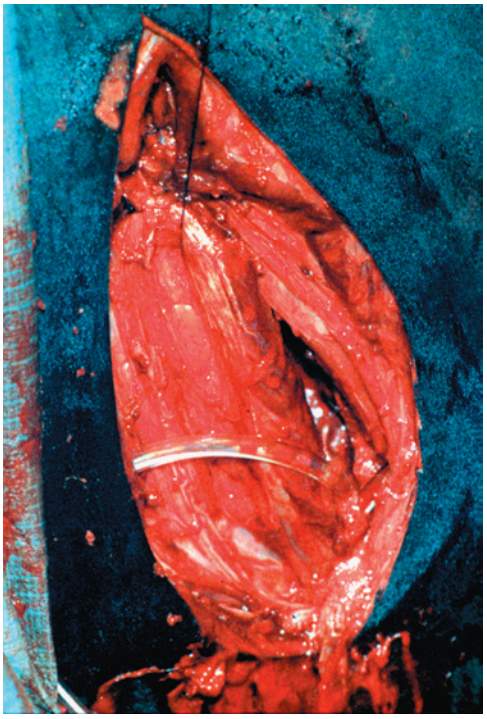


Figure 13-54 The incision is being partially closed, and drains are placed in the pleural space and pericardium for postoperative lavage and drainage.

ultrasound. A pericardiocentesis confirms the diagnosis of cardiac tamponade (Figure 13-57). The liquid is hemorrhagic and usually with an abnormally high percentage of small lymphocytes. The pericardial sac must be drained either with suction or with a chest tube. Fifteen liters of hemorrhagic fluid can be removed. Post drainage, the animal must have regular ultrasounds to monitor for recurrence. Affected animals can survive more than a year, but recurrence must be expected (see Figure 13-55*B*).

POSTOPERATIVE MANAGEMENT

Postoperatively, continued access and good hygiene practice with repetitive lavage is necessary if the resulting wound is left open. Chest bandages to cover the wound or local bandages secured with loops of suture can work well (Figure 13-58). NSAIDs and butorphanol administered intravenously are used to control pain in the first postoperative week (see Chapter 5 for farm animal anesthesia and pain management). Broad-spectrum antibiotics are used perioperatively for 5 to 7 days. Central venous blood pressure is an efficient way to monitor the benefit of the procedure on animals with clinical signs of congestive heart failure (distended jugular, brisket edema). The prognosis is guarded and one common condition is a secondary constrictive pericarditis (Figure 13-59).

If a foreign body is returned into the reticulum during the manipulation, a rumenotomy to remove the foreign body may be necessary at the same restraint or anesthetic episode. It may be preferable to delay a rumenotomy and place a magnet in the reticulum until the initial surgical morbidity of the thoracotomy has resolved.



Figure 13-55 *A*, Adult Holstein cow with brisket edema from cardiac tamponade. *B*, Same animal but 3 days after pericardial drainage.

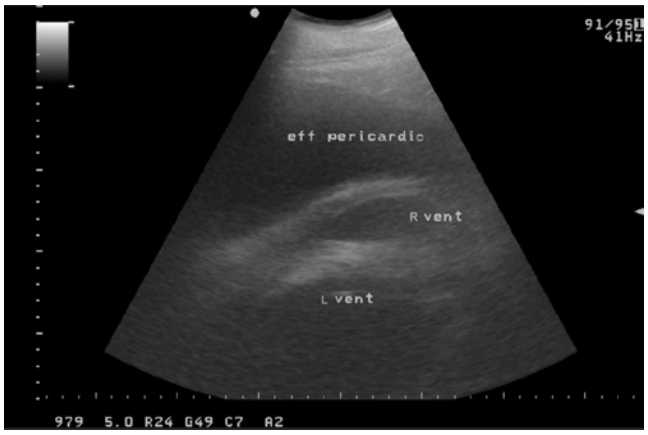


Figure 13-56 Cardiac ultrasound from the right side showing a large amount of anechoic fluid in the pericardial sac. The cardiac silhouette is abnormal with small ventricles. eff pericardio, pericardial effusion; L vent, left ventricle; R vent, right ventricle.



Figure 13-57 A needle or cannula can beinserted into the pericardial sac from the left or right ventral sixth intercostal space. Pericardial fluid was be drained and cultured. (Courtesy of Dr. Tom Divers, Cornell University)



Figure 13-58 Stay sutures are surrounding the marsupialization site, allowing the surgeon to secure a stent for protection.

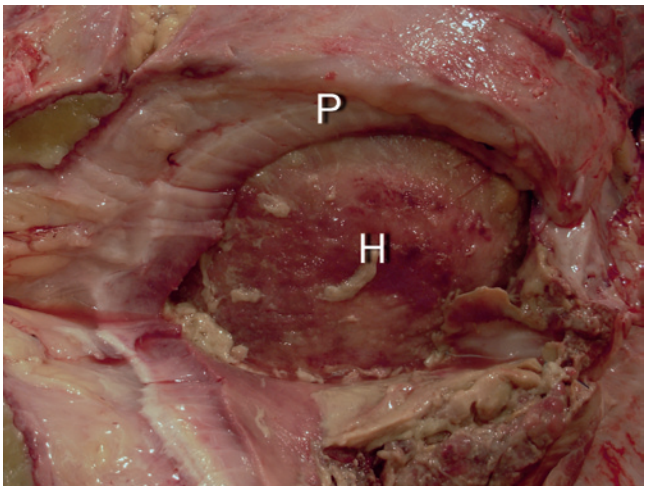


Figure 13-59 Cadaver specimen of a cow that underwent marsupialization but eventually suffered from constrictive pericarditis. The heart (H) is surrounded by a thick fibrous pericardium (P).

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DISEASES OF THE VASCULAR SYSTEM: THROMBOPHLEBITIS AND PATENT DUCTUS ARTERIOSUS

Norm G. Ducharme

OCCURRENCE AND ETIOLOGY

Diseases of the cardiovascular system amenable to surgical treatment are not common in cattle. Other vascular diseases are described under the caudal vena cava thrombosis earlier in this chapter, and Chapter 16 (mammary vein laceration/hematoma).

Long-term catheterization or problematic jugular injections can result in thrombosis and septic thrombophlebitis of the cervical jugular veins of cattle. The physicochemical properties of the catheter used for venous access contribute to the prevalence of this problem because polytetrafluoroethylene is more thrombogenic than polyvinyl chloride catheters in cattle. In addition, polytetrafluoroethylene catheters are more prone to getting kinked and leakage at the kink than polyvinyl chloride catheters after 4 days of implantation. Furthermore the damage caused by the catheter can predispose the animal to injury to the endothelium of the vein and thus can induce thrombophlebitis. Other factors influencing the occurrence of jugular thrombophlebitis included duration of implantation, frequency of being flushed with heparinized saline, and age of heparinized solution. Other factors such as health status of the cow (septicemia, endotoxemia, etc.) also play a role in the occurrence of thrombophlebitis. Clinical signs associated with these disorders include warm, firm, "corded" distention of an affected jugular vein, venous distention of the affected side of the head, fever, and possible cardiac abnormalities. Local and systemic antibiotic and antiinflammatory therapy is indicated but may not resolve advanced aggressive thrombophlebitis. Ultrasonography can be very beneficial in defining the extent of a lesion (Figure 13-60). When present at the time of catheter placement, thrombi are usually at the distal end of the catheter or in the first venous valve distal to the catheter. Surgical treatment should be considered if a septic process fistulates through the skin or the thrombotic process advances toward the thoracic inlet. The surgical goal is resection of the abnormal infected section of the jugular vein. This preferably is performed with the patient under general anesthesia. The affected region of the jugular vein should be aseptically prepared. An incision should be made in the skin through the entire length of the targeted aspect of the jugular vein. The vein can be bluntly elevated and isolated from surrounding tissues. The interface between thrombotic and normal vein should be identified. Vascular forceps or circumferential ligatures can be applied across the normal aspects of the vein at the cranial and caudal ends to isolate the diseased aspect of the jugular vein. The vein should then be transected with only normal venous tissue left. The remaining ends of the jugular vein can be oversewn or left with ligatures in place. The incision should be left open to heal by second intention. Close attention to wound hygiene is important until normal granulation tissue covers the wound. Quite satisfactory and cosmetic results can be achieved if the vascular disorder is confined to the cervical jugular vein.

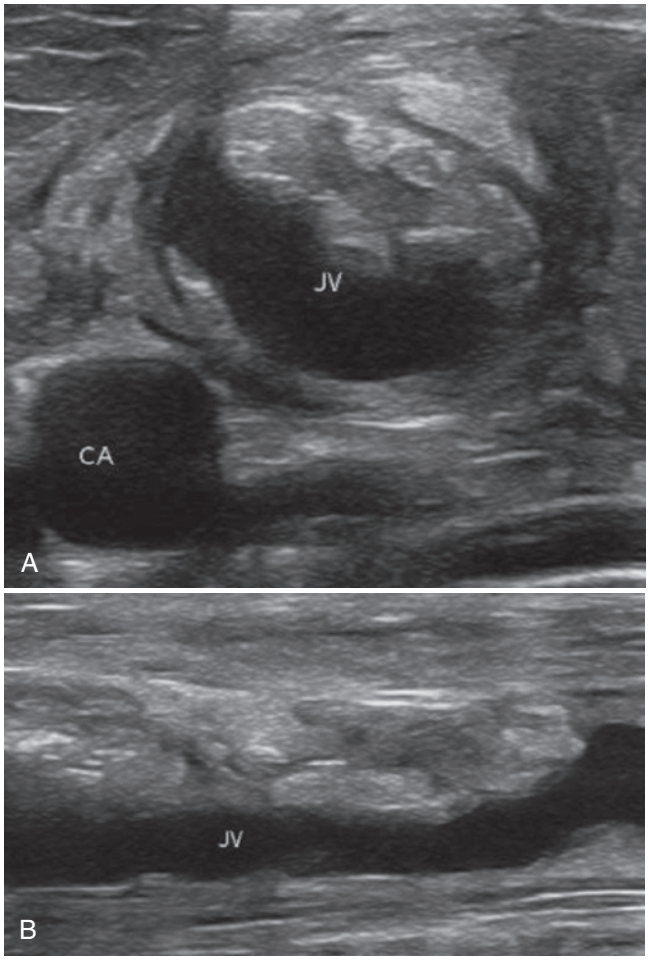


Figure 13-60 *A*, Cross section and, *B*, longitudinal cross-section of a thrombosis within the jugular vein (JV). (Courtesy of Dr. Rolfe Radcliffe, Cornell University). CA, carotid artery.

PATENT DUCTUS ARTERIOSUS

Patent ductus arteriosus (PDA) is a rare congenital malformation in calves. This disease results from the ductus arteriosus (which allows blood to flow from the pulmonary

artery to the descending aorta in a fetus, bypassing the nonfunctional lungs) failing to close. In most cases, the ductus arteriosus closes within 10 days of birth and has little to no clinical significance. If it persists, the calf will have an elevated heart rate as a response to decreased cardiac output. In calves with PDA the differential blood pressure forces blood from the aorta to reenter the pulmonary circulation through the pulmonary artery. This results in left ventricular hypertrophy, and possibly failure, as the heart attempts to increase cardiac output to systemic circulation. If the pulmonary pressure is elevated, the differential blood pressure forces poorly oxygenated blood into systemic circulation through the aorta. Calves are presented for decreased stamina, growth, exercise intolerance, and elevated heart rate. Cardiac enlargement is associated with increased troponin I above 0.035 ng/mL. The diagnosis is suspected by auscultating a holosystolic murmur and confirmed by angiography or echocardiography outlining the PDA. Prostaglandin inhibitor has been used successfully in humans to resolve PDA. No data are available for cattle; empirically two intravenous treatments of flunixin (1 mg/kg intravenously) once per day would be used at our clinic.

We have only treated one calf surgically where a PDA was ligated with umbilical tape through a fifth rib left thoracotomy. Ligation assisted by thoracoscopy would be less invasive; however, the use of intraarterial occlusion devices is now available and should be considered first if the ductus arteriosus fails to close after administering prostaglandin inhibitor. The biocompatible devices used for intraarterial occlusion of the PDA allow early platelet aggregation. They have been performed in calves and require individuals trained in interventional imaging or cardiology.

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CHAPTER 14

Surgery of the Bovine Digestive System

Norm G. Ducharme, André Desrochers, Susan L. Fubini, Anthony P. Pease, Linda A. Mizer, Wade Walker, Ava M. Trent, Jean-Philippe Roy, Marjolaine Rousseau, Rolfe M. Radcliffe and Adrian Steiner
(The editors wish to acknowledge and thank prior author Dr. J. Brett Woodie)

SURGICAL DISEASES OF THE ORAL CAVITY

Norm G. Ducharme

Many surgical diseases can interfere with an animal's ability to prehend and transfer food material to the esophagus. The cause of dysphagia can be a congenital abnormality or diseases acquired through pain, mechanical obstruction, and/or neurologic deficits (motor or sensory). Of course, pain itself can prevent an animal from eating or drinking (e.g., severe oral inflammations, mandibular fracture, glossitis, foreign-body penetration, temporohyoid arthropathy, etc.). Mechanical causes of dysphagia include a foreign body, anatomic defects such as cleft palate, or peripharyngeal masses such as neoplasia and abscess. Although this chapter focuses on surgical diseases, when evaluating an animal with dysphagia, one should consider a variety of centrally mediated neuromuscular disorders such as epizootic hemorrhagic disease virus, listeriosis, and rabies. Peripheral neurologic diseases such as neuropathy of the lingual, glossopharyngeal, vagal, and hypoglossal nerves should also be considered. Probably the most common cause of muscular disorders associated with dysphagia is white-muscle disease. The following sections propose a diagnostic and therapeutic approach to surgical diseases of the oral cavity.

ANATOMIC CONSIDERATIONS

The lips of cattle play an important role in prehension of food and, of course, suckling, but their shape varies significantly. They are relatively immobile and insensitive, which presumably contributes to the indiscriminate eating habits of cattle. The relatively immobile lips and rostral position of the commissure limit the extent the mouth can open and therefore interfere with a thorough oral examination. On the other hand, small ruminant lips are much more mobile and serve to prehend much better than cattle.

The mouth of cattle is long and narrow, with the hard palate being narrowest rostral to the cheek teeth. The wide gap between the incisors and cheek teeth (diastema provides a hand grip for restraining the head and opening the mouth. Paired dental pads replace the upper incisors seen in most other species. Unlike that of small ruminants, the tongue is most important for prehension in cattle: the tongue grasps forage and drags it into the mouth where the ventral incisors' pressure against the dental pads cuts it. The tongue's importance in prehension explains why tongue amputation after laceration causes greater morbidity in cattle than in horses or small ruminants. Small-ruminant lips have replaced the tongue's function as a prehension organ. The dental formula of farm animals is fully described in Chapter 9.

The large quantity of salivary glands in ruminants (Figure 14-1) and swine (Figure 14-2) contributes to large amounts of saliva being produced, estimated to be as much as 100 L per day in adult cattle. Physiologically, the saliva is needed to assist shredding and swallowing given the fibrous and dry diet of most ruminants. Saliva is also needed to stabilize rumen pH through its bicarbonate and phosphate buffers. The left and right parotid glands are located ventral to the ear, extend along the caudal border of the mandible, and drain into the mouth by a single large duct (i.e., the parotid or Stenson's duct). The parotid duct continues rostrally along the ventral border of the mandible following the rostral aspect of the masseter muscle and finally opening in the caudal aspect of the mouth at the level of the second-to-last cheek tooth. The left and right mandibular glands are more medial than the parotid glands but also more ventral, and they are centered on the angle of the jaw (mandible). Each gland drains into the mouth by its own single duct. These mandibular ducts extend rostrally submucosally and open on their respective sublingual caruncles on either side of the frenulum of the tongue. The left and right sublingual salivary glands contain two parts: a monostomatic and a polystomatic. The polystomatic glands lie on either side of the tongue on the floor of the mouth and drain to many stomas beside the frenulum. The left and right monostomatic glands are located rostral to their respective ipsilateral polystomatic gland and drain into the mouth through a single duct alongside—or joining—the mandibular duct. Many other small salivary glands exist in various locations of the oral cavity.

DIAGNOSIS AND TREATMENT (DENTAL DISEASES ARE COVERED IN CHAPTER 9)

Lacerations

Oral lacerations in cattle are associated with the same indiscriminate eating habits that result in traumatic reticulopericarditis. Lacerations are more common in calves because of their oral prehension and suckling habits on objects in their environment such as barbed wire, needles, and thorns. The lacerations may involve the lips, buccal membranes, and the tongue. Animals usually present with excess salivation, which may be mixed with blood, decreased appetite, and various degrees of dysphagia, depending on the severity of the laceration. The animal's tongue often protrudes past its lips.

The diagnosis is based on physical examination. First, the head is grasped with one hand on the maxilla at the level of the interdental space. The rostral aspect of the mouth can then be inspected and palpated using the other hand. Most lacerations heal without surgical intervention by using daily mouth lavage and systemic antibiotics and by feeding a soft diet.

Severe tongue lacerations sometimes require a partial glossectomy. Because of the tongue's crucial role in prehension of food, as much of the tongue as possible should be preserved. In preparation for surgery the animal is anesthetized and placed in lateral recumbency. A tourniquet (made of rolled gauze) is applied proximal to the intended

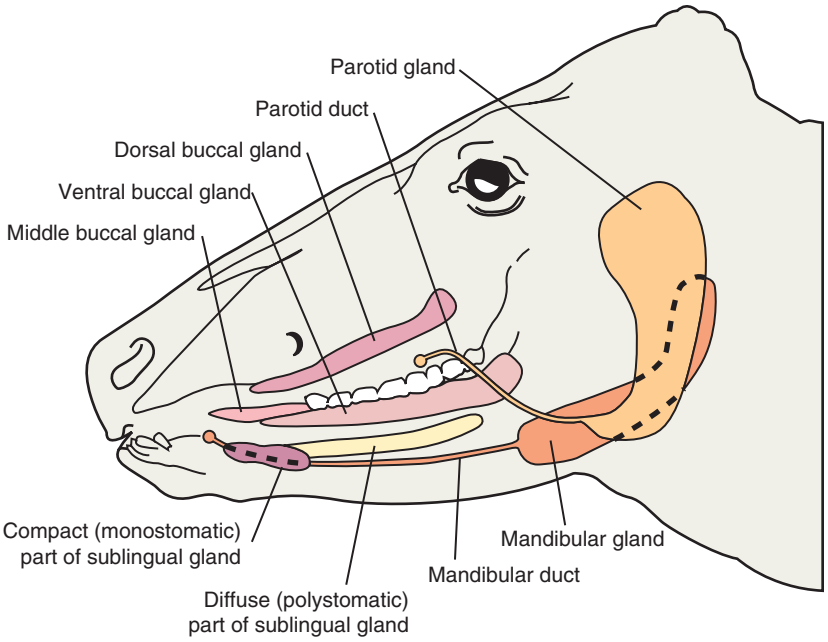


Figure 14-1 Schema summarizing the distribution of salivary glands in ruminants.

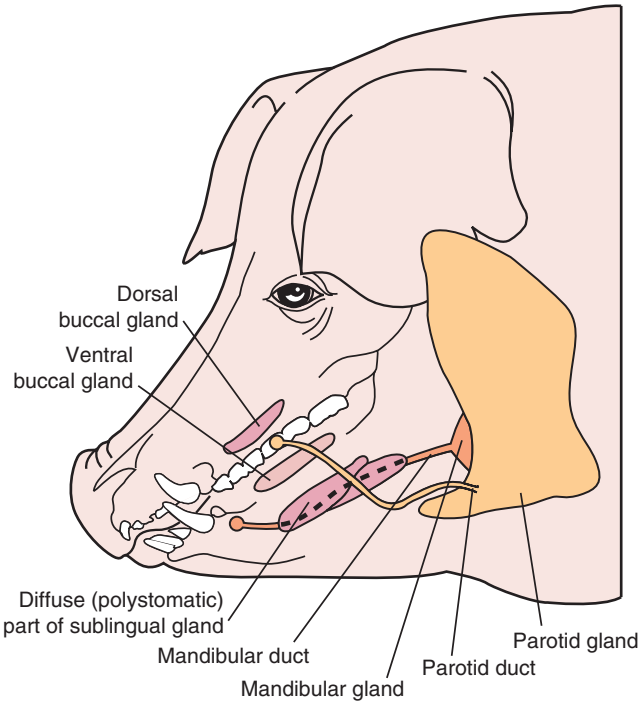


Figure 14-2 Schema that summarizes the distribution of salivary glands in swine.

transection site. The tongue is transected so that the dorsal and ventral aspects protrude beyond the center (Figure 14-3*A*). The ventral and dorsal aspects are sutured together with an interrupted horizontal mattress pattern with No. 1 or No. 2 absorbable sutures (Figure 14-3*B* and *C*). The animal should receive systemic antibiotics postoperatively and should be fed a soft diet (not pasture) for best results.

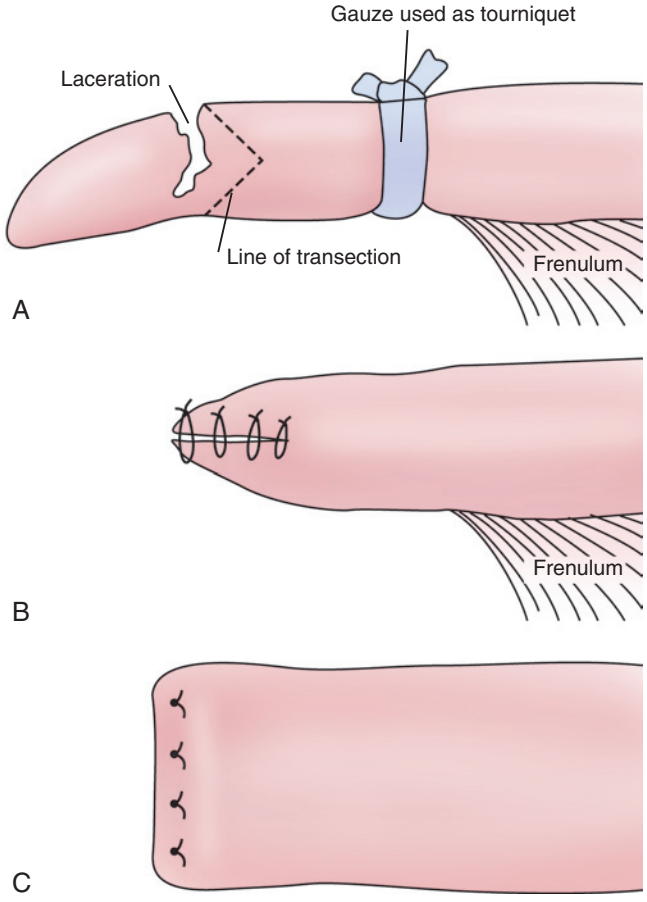


Figure 14-3 The tongue is transected so its dorsal and ventral aspects protrude beyond its center. *A*, Lateral view of the tongue, showing laceration and intended transection line. *B*, Lateral view of the tongue, which shows the position of the horizontal mattress suture. C, Dorsal view, which shows the position of the horizontal mattress suture.

Soft-palate lacerations present with nasal regurgitation of water and feed material and tracheal aspiration of this material. For further details on diagnosing and treating cleft-palate lacerations, please see the cleft-palate section in the chapter on disorders of the nasopharynx (Chapter 13).

Buccal fistulae result from lacerations or other traumatic incidents and result in loss of saliva and feed material as well as cosmetic defects. While the animal is ruminating, the cud may be dropped during mastication. The diagnosis is obvious; one needs to inspect the lesion to determine the optimal time of repair. Surgery should be done on fresh lacerations or after any inflammation and infection in the local musculature have been resolved. The fistula edges are debrided while the animal is under sedation following infiltration of a local anesthetic or under general anesthesia. The defect is closed in three layers. The muscles (usually buccinator) are reapposed with absorbable suture material (No. 1 or 2) in a simple interrupted pattern. The oral mucosa is closed with a simple continuous pattern using No. 00 absorbable sutures. Finally, the skin is reapposed with a simple interrupted suture (No. 1). Postoperatively, systemic antibiotics are indicated along with a soft gruel or liquid diet, preferably for 10 to 14 days.

Oropharyngeal trauma and subsequent retropharyngeal cellulitis and dysphagia can occur after improper administration of medication with a balling gun. Animals are presented because they become anorectic and have an associated decrease in milk production (when relevant). On examination, they have varying degrees of cervical swelling and associated signs of infection—elevated temperature, leukocytosis, and hyperfibrinogenesis. The cervical swelling may interfere with respiration (see Disorders of the Nasopharynx, Chapter 13); the animal will extend its head and neck while trying to straighten its upper airway (Figure 14-4). A foul-smelling odor indicative of necrotic tissue may originate from the mouth. Endoscopic, or open-mouthed, examination of the nasopharynx and oropharynx will reveal the laceration and/or abscess (Figure 14-5). The cervical area is swollen, and crepitus can sometimes be palpated if the area is not too severely distended. Ultrasonographic evaluation will reveal pockets of fluids in the subcutaneous tissue of the proximal cervical area. Radiographic evaluation will reveal air and fluids in the cervical area (Figure 14-6). These animals may aspirate feed and saliva and develop signs of lower airway disease. Therefore the lower airway should be evaluated for signs of mediastinitis (Figure 14-7) and aspiration pneumonia.



Figure 14-4 Adult Holstein-Friesian cow with perilaryngeal abscess caused by pharyngeal trauma. Note the extended head and swollen shaved perilaryngeal area.

The treatment principle is to limit the extension of the cellulitis with appropriate parenteral antimicrobials and surgical drainage. If cellulitis is not controlled, it will proceed alongside the trachea and may result in septic mediastinitis (see Figure 14-17). Therefore if there is significant accumulation of fluid and feed material in the cervical area, the accumulated fluid is surgically drained under general anesthesia. See Disorders of the Nasopharynx (Chapter 13) for a description of this procedure.

Cross-Suckling

Cross-suckling (i.e. a heifer sucking on the teats of another heifer) results in teat cistern fibrosis, which may have a serious effect on milking. This behavior usually resolves with increasing age. If it does not or is considered excessive, treatment is indicated to prevent teat injuries. The most common treatment is the placement of a nasal ring with a burr (called a *crown weaning ring*, Figure 14-8), nasal flap, or individual housing. If these more conservative treatments are not successful, a partial glossectomy can be considered (Figure 14-9). In tropical climates, dairy production with restricted suckling, defined as calf suckling on the dam for 30 minutes at the end of milking, reduces cross-suckling.

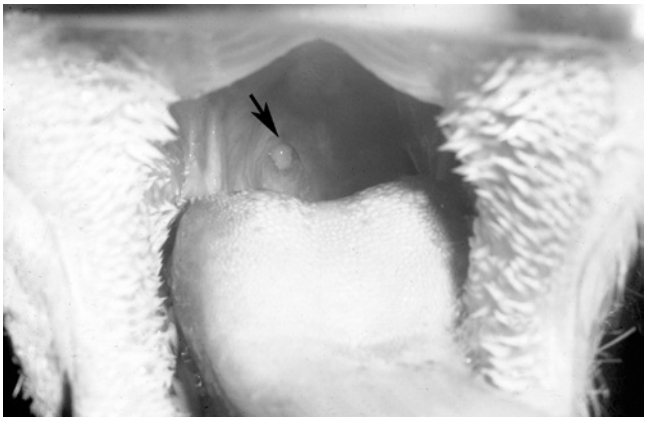


Figure 14-5 Oral examination of a calf, which reveals abscessation (*arrow*) of the oropharynx.

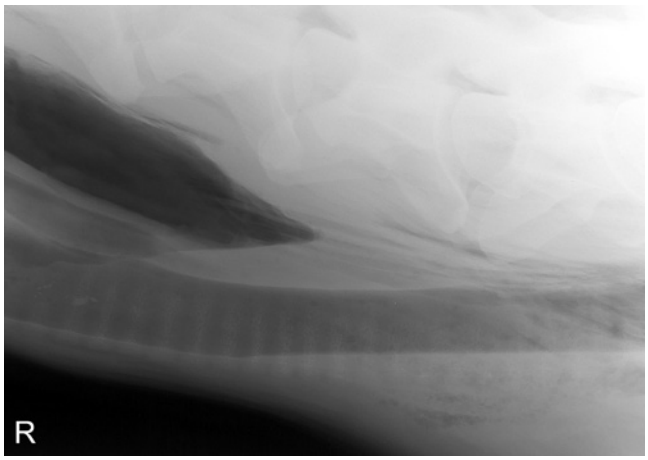


Figure 14-6 Right-lateral mid-cervical radiographs in a mature cow that is suffering from nasopharyngeal perforation associated with balling-gun injury. Note fluid line, a large gas pocket, and linear gas pattern as air dissects between cervical fascias. (Courtesy Dr. Anthony P. Pease.)

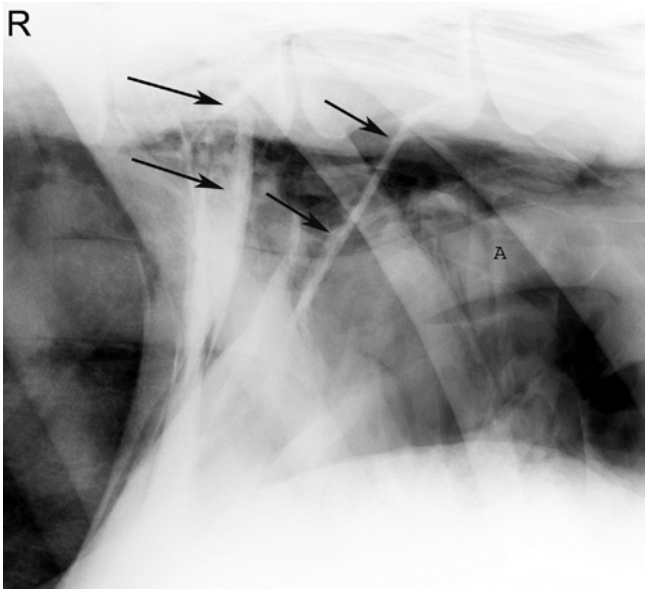


Figure 14-7 Right thoracic radiograph of a mature cow with pneumomediastinum and pneumoretroperitoneum. Thoracic cavity, left; abdominal cavity, right. *A*, aorta; arrow identifies each crura of the diaphragm. (Courtesy Dr. Anthony P. Pease.)



Figure 14-8 Crown weaning ring used to prevent cross suckling. (Courtesy of Dr. Lorin Warnick.)

Partial Glossectomy

Two surgical techniques have been created to perform a partial glossectomy to prevent self-suckling in animals. The techniques are performed with sedation and local infiltration of lidocaine or general anesthesia. Both techniques alter the tongue's contour to prevent the animal from forming a U-shaped tongue for suckling. For the ventral glossectomy technique, an elliptical incision is made that is approximately 5 cm at its widest part and starts rostral to the frenulum attachment on the tongue and extends rostrally 2.5 cm caudal to the tip of the tongue (see Figure 14-9*A*). Each side of the ellipse is incised at an angle toward the midline to facilitate closing the defect, as shown in Figure 14-3*B*. The lateral glossectomy technique removes half of the tip of the tongue (see Figure 14-9*B*). Again, the incision is extended at an angle to facilitate closing the tongue, similar to what is shown in Figure 14-3*B* except in a different plane.

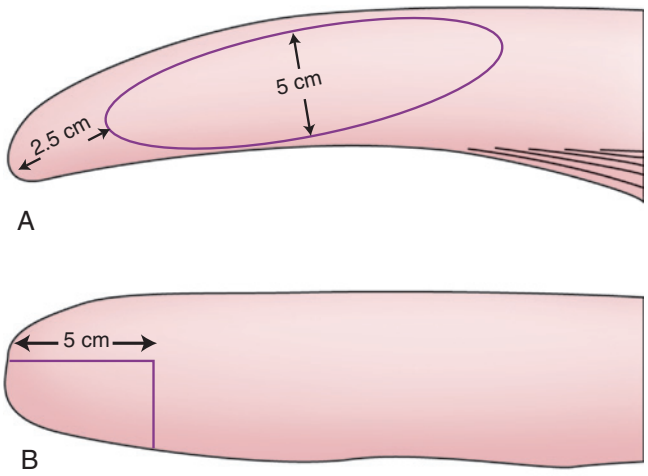


Figure 14-9 *A*, Ventral glossectomy; note elliptical excision of a section of the tongue. *B*, Lateral glossectomy: note unilateral excision of the first two inches of the tongue.

Oropharyngeal Membrane

Similar to choanal atresia, a persistent membrane can obstruct the oropharynx, thus preventing any milk, saliva, or other liquid from reaching the esophagus. This rare congenital anomaly prevents an animal from ingesting any nutrients. Newborns present with this history and a progressive loss of condition. Treatment has not been reported in large animals but presumably would consist of membrane resection, as described in humans.

SALIVARY GLANDS

Diseases of the salivary glands can be divided into two categories: congenital and acquired. Congenital abnormalities of the salivary glands are associated with agenesis or atresia of the parotid duct, resulting in a fluid-filled swelling proximal to the obstruction site.

Acquired diseases are usually secondary to lacerations or other trauma to the parotid gland that ruptures the salivary gland/or duct. Sometimes a rumen cud obstructs the parotid duct and results in back pressure in the duct, which leads to rupture. The ruptured duct may accumulate saliva in the subcutaneous tissue (salivary cyst or mucocele [mucous cyst or retention cyst of the salivary gland]) or form a fistula if it was ruptured by a laceration. Secondary ascending infections of the glands may also result from any ruptured salivary gland or duct.

Diagnosis of these various diseases is made by physical examination and salivary diagnostic imaging, such as ultrasound examination or sialogram. Palpating a soft fluctuant swelling within the confines of a parotid duct (Figure 14-10) strongly suggests an obstructed duct with a secondary distention of the duct. An example of a normal sialogram is shown in Figure 14-11.

Generally, salivary gland duct obstruction is unilateral. Therefore treatment mainly focuses on correcting a cosmetic defect, because the effect on digestive activity from unilateral loss of saliva is inconsequential. First, the duct's opening in the mouth should be examined to ensure that it is not



Figure 14-10 A soft fluctuant swelling can be palpated within the confines of a salivary duct in this young goat. (Courtesy of Dr. Mary Smith.)

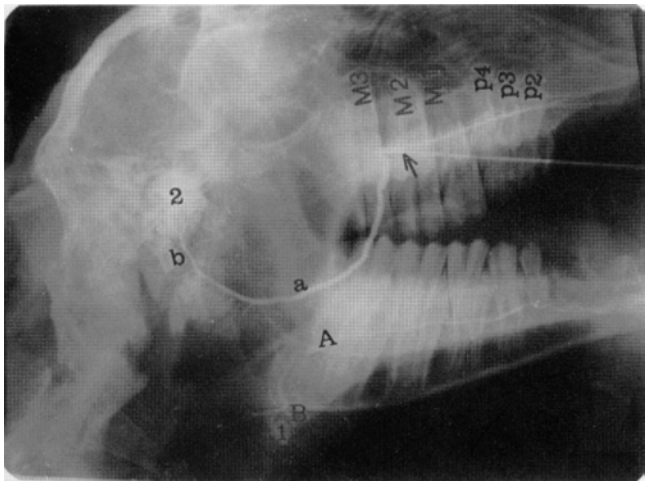


Figure 14-11 Normal parotid (2) and mandibular (1) sialography in a ewe. Main parotid duct (a), their smaller branches (b), and the parotid duct opening (*arrow*), main mandibular duct (A), and their smaller branches (B), premolar 2 (P2), premolar 3 (P3), premolar 4 (P4), molar 1 (M1), molar 2 (M2), and molar 3 (M3). (Reproduced with permission from Deghani et al, *Res Vet Sci* 68: 3-7, 2000.)

obstructed. One can cannulate the duct to estimate the length of the obstructing membrane. A sialography study can also be performed at the same time if ultrasound examination combined with physical examination is not conclusive. Aspiration of the duct may confirm the diagnosis if saliva is present.

Many surgical options are available for treating an obstructed duct or salivary gland fistula. Congenital salivary duct obstruction can be left untreated and simply be monitored. The salivary function loss in a unilateral case is insignificant and results mainly in a cosmetic defect.

The duct proximal to the obstruction can be marsupialized to the oral cavity. This is technically difficult because the duct's unobstructed section is always more caudal than the anatomic opening. The marsupialization is done as follows. A longitudinal incision is made in the oral cavity at

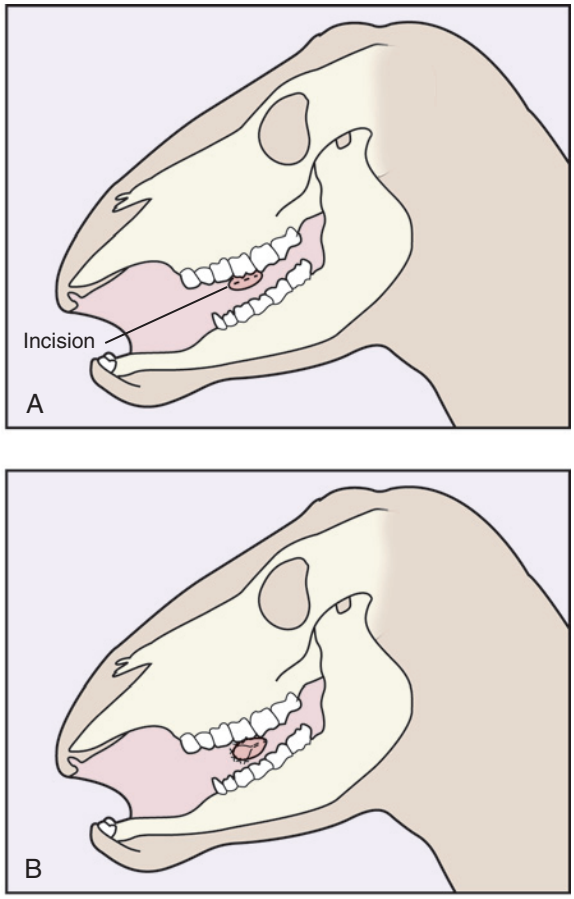


Figure 14-12 *A*, A longitudinal incision is made in the oral cavity at the level of the distended duct. *B*, The mucosa edge of the duct is sutured to the buccal mucosa in a simple interrupted pattern.

the level of the distended duct (Figure 14-12*A*). The incision is extended to the axial wall of the parotid duct in the same plane. Saliva will leak out into the incision. The incision is enlarged so the stoma created is 1 to 1.5 cm. The oral mucosa is sutured to the parotid duct mucosa with a simple interrupted pattern of absorbable monofilament suture material of appropriate size (2-0 or 3-0) (Figure 14-12*B*). A size 5 to size 8 French polyethylene catheter should be passed through the newly formed stoma and sutured to the buccal mucosa to prevent unwanted closure. The catheter is removed 7 to 10 days later.

The gland may be injected with a caustic agent to destroy all secreting cells until the fistula resolves and heals. Use of 10 to 15 mL of Lugol's iodine or up to 35 mL of 10% buffered formalin (note: check with a local regulatory veterinarian and follow the Food Animal Residue Avoidance Databank [FARAD] or other country's appropriate meat and milk withdrawal) injected through a catheter placed into the duct for this procedure has been reported. The duct must be held closed for a few minutes to achieve diffusion of the caustic agent throughout the gland. Posttreatment glandular and periglandular swelling may require an antiinflammatory agent such as acetylsalicylic acid or flunixin meglumine.

Excising the parotid gland is the last surgical option. This procedure is done under general anesthesia with meticulous care in the dissection because of the proximity of the salivary gland to important neurovascular bundles.

The surgeon should weigh each procedure's advantages and disadvantages. Creating a new stoma is the preferred physiologic approach; the morbidity is restricted to recurrence of the condition because the created stoma may close or stricture. Destroying the gland by injecting caustic material causes temporary discomfort and requires analgesia but usually resolves the problem; the resulting loss of gland function appears to be inconsequential. Gland excision is the most complicated approach and requires careful dissection to avoid facial and vagal nerve damage.

Acquired salivary diseases such as fistula and lacerations offer many surgical options: simple duct ligation, destruction of the gland, resection of the gland, or primary repair of the defect. Under appropriate anesthesia (sedation plus local infiltration or general anesthesia), the duct is surgically isolated and ligated with a nonabsorbable suture material. Failure of the ligature as a result of pressure buildup and ascending gland infection is a complication associated with this procedure. Resection of the gland is even more complicated in these cases because of the associated fibrosis and inflammation caused by the laceration. Gland destruction is the simplest form of treatment. As previously described, this treatment is associated with some discomfort, but no long-term complications have been reported.

Primary repair of the lacerated duct is physiologically the best approach but is associated with a greater risk of morbidity from causes such as failed repair and ascending infection. Under appropriate anesthesia, the lacerated duct is isolated. A size 5 to size 8 French polyethylene catheter is passed through the defect into the mouth. A portion of the catheter is passed retrograde proximal to the laceration, thus bridging the defect. The laceration in the duct is sutured over the stent with absorbable monofilament suture (3-0 or 4-0) in a simple continuous pattern. The end of the stent that exits into the oral cavity is sutured to the buccal mucosa.

RECOMMENDED READINGS

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MANDIBULAR FRACTURES, OSTEOMYELITIS, AND NEOPLASIA

Norm G. Ducharme and André Desrochers

MANDIBULAR FRACTURES

Mandibular fractures and, very rarely, maxilla and incisive bone fractures are seen occasionally in ruminants. These traumatic injuries lead to difficulty or inability to eat, dripping of saliva, and prolapsed tongue. The diagnosis is made by clinical examination, although radiographic examination will confirm the diagnosis and the extent of the fracture. One should attempt to evaluate tooth integrity in any oral fracture. For a fracture that involves an alveolus with an intact tooth, medically speaking, the tooth should be stabilized (wire, acrylic splints, acrylic caps, etc.) in place rather than being removed (see Chapter 9). If the tooth is stabilized, the periodontal ligament will heal at the same time as the alveolar fracture; the tooth will be preserved in many cases. However, the region of the fracture should be monitored radiographically because delayed effect on the tooth may occur up to 1 year after injury. A tooth root abscess remains a possible complication, and this should be assessed at the time of reevaluation. However, a tooth with a fractured root should be removed. Therefore because of financial considerations, tooth removal may be elected instead of stabilization.

In calves, common fractures involve the rostral aspect of one (Figure 14-13) or both mandibles (Figure 14-14) or along the mandibular symphysis. Mandibular fractures in young calves are secondary often to obstetric manipulation where a snare or chain is used to correct a malposition like a retained head. These calves will sustain a fracture at the rostral aspect of both mandibles in the interdental space,



Figure 14-13 Calf with a fracture of the rostral mandible, involving three incisors.

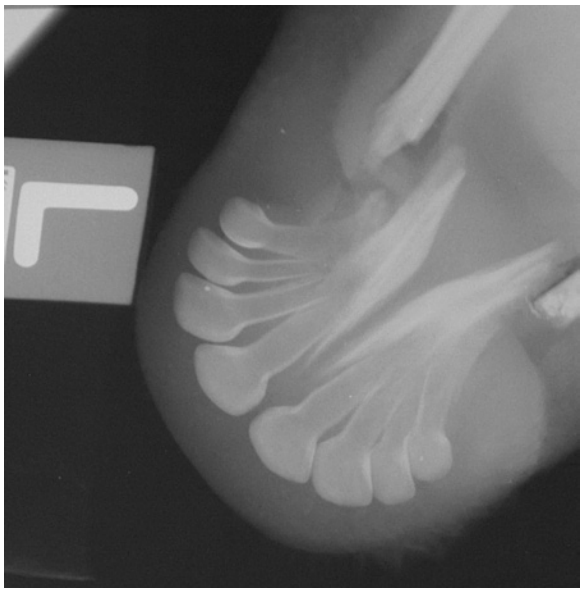


Figure 14-14 Intraoral radiographic view of the mandible; a newborn calf with rostral fracture of the mandible secondary to obstetric manipulation.

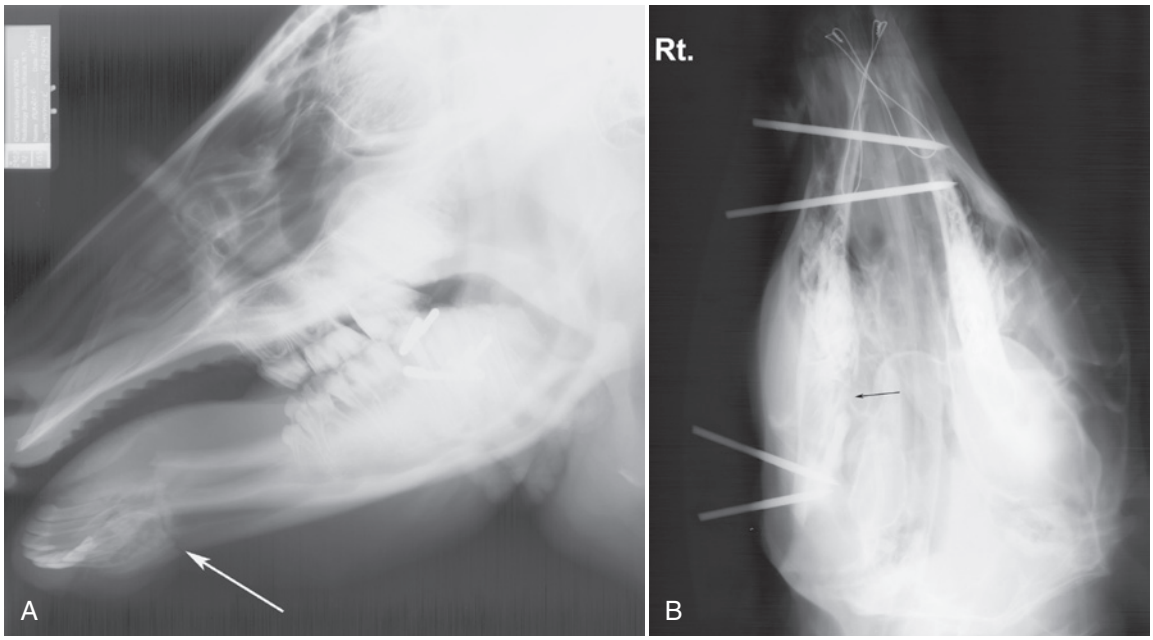


Figure 14-15 *A*, Lateral radiograph of 1-year-old Ayrshire heifer with bilateral rostral mandibular fracture (*white arrow*) and caudal right mandibular fracture (visible on dorsoventral view). *B*, Dorsoventral radiograph that shows repair of a caudal right-mandibular fracture (*black arrow*) with a Type I fixator. Converging intramedullary pins are placed on either side of the fracture and are stabilized by a connecting rod made of a 2.5-cm scavenger hose filled with acrylic. The rostral bilateral mandibular fracture is repaired with two figure-8 orthopedic wires.



Figure 14-16 A newborn Ayrshire calf with a bilateral open displaced mandibular fracture. The fracture is just at the junction of the body and pars incisica of the mandible.

thus resulting in significant displacement that requires treatment (Figure 14-15*A*). These fractures are open and often already infected upon presentation. Teeth and soft tissue will be damaged to a certain extent depending on the force used to correct the malposition (Figure 14-16). Although it prevents these calves from suckling, they are bucket fed effectively and can survive quite a few days before being presented. In adult ruminants or in any cases in which significant displacement is present, reduction and immobilization are indicated. In all cases, stabilization reduces pain and allows eating to be resumed more quickly.

In mature cattle, unilateral mandibular branch fracture of the pars molaris seems more frequent. Age, location of the fracture, and involvement of the molar teeth will influence the choice of treatment and prognosis. However, frequent movement of the jaw during rumination causes serious implant cycling and must be considered in reduction and stabilization techniques.

The treatment goal is to reduce the fracture into normal or near-normal anatomic alignment and to stabilize the fracture. One should remember that eating or ruminating applies disruptive forces against the fracture and the tension side is on the oral surface of the mandible, maxilla, and incisive bone. Implants should be placed on the tension side.

Fracture of the vertical ramus of the mandible is rather rare in ruminants and is often treated conservatively.

Surgical Options for Fractures

Surgical options to reduce and immobilize a fracture of the mandible, maxilla, or incisive bone are acrylic splints, wires, U bars, Kirchner apparatus, and internal plates. The techniques are described in the following discussions. In general, using the simplest treatment method is far better. Some fractures of the rostral mandible are stabilized with a wire applied in a figure-8 fashion around the incisors on either side of the fracture is sufficient. Obstetric fractures are very unstable because the extremities of the bone fragments are eburnated, the soft tissue damaged and under constant movement. Therefore a more stable fixation technique must be used to favor healing and return to normal function. The incisive dental alveola as well as the teeth can be severely damaged, and wiring them is not possible (Figure 14-17). If cost is an issue and the fracture not severely open and infected, a muzzle with small wood splints along the mandible branches or a casting technique have been successfully used in neonates with obstetric fractures.



Figure 14-17 Intraoral radiographic view of the mandible: an obstetric fracture of the mandible involving the incisors alveoli.

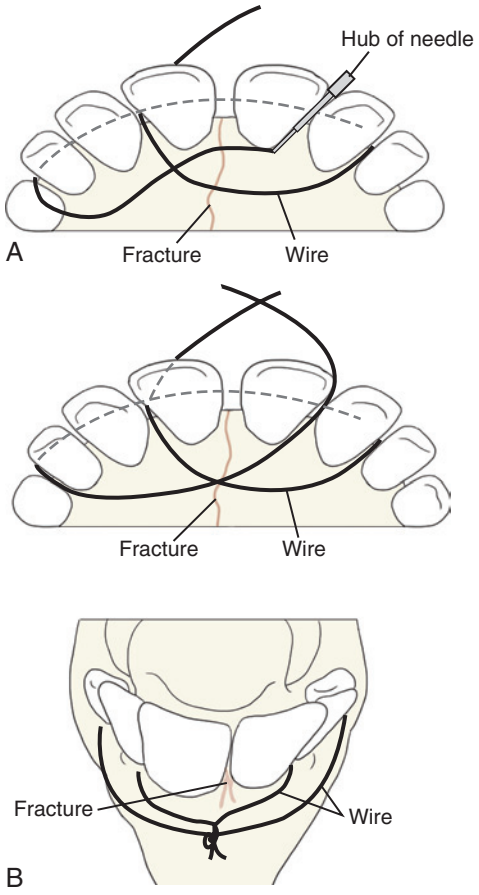


Figure 14-18 *A*, An orthopedic wire is guided between the teeth bases with a 14-gauge needle. *B*, The wire is placed in a figure-8 pattern around the base of one or more teeth on either side of the fracture.

Figure-8 Wiring

This technique consists of placing an orthopedic wire (1 to 1.2 mm) around the base of one or more teeth on either side of the fracture in a figure-8 pattern (Figure 14-18*A* and *B* and Figure 14-19). A 14-gauge needle can be placed to help pass the wire between two teeth (see Figure 14-18*A*). Given the coronal structure of cattle teeth, a drill is rarely needed to make a canal through which the wire is passed. The knot is twisted and secured on the rostral aspect of the mandible. If the fracture extends caudal to the four incisors (canine teeth) or extends into the interdental space, the wire is secured caudal to the first molar or, less desirable, a canal is drilled into the bone (incisive or mandibular) in the interdental space (Figure 14-20) between the incisors rostral and caudal to the fracture.

Intraoral Acrylic Splinting

It can be used to provide additional stability to a figure-8 wire fixation or by itself. Use of intraoral acrylic splinting has the advantage of being placed on the tension surface of the mandible. Although dental acrylics are available, for economic reasons the acrylic[1] used to secure blocks on cattle claws is often used. Because of the exothermic properties of this nondental acrylic, a layer of petroleum gel is applied to the buccal mucosa to protect the soft tissue before the acrylic is applied. Orthopedic-grade acrylic or bone cement[2] is easier to manipulate than the claw acrylic and has far less exothermic reaction. Because of limited access to the fracture and constant movement of the jaw and tongue, surgical reduction and stabilization are better performed with the animal under general anesthesia, preferably with nasotracheal intubation.

Intraoperative splinting can be achieved by adding the acrylic onto the wires after they have been placed to secure the fracture/dental elements or by first forming the acrylic splint and then wires are drilled into it to secure it. In the latter application, the acrylic is first molded to the incisive part of the mandible and along the branches in the interdental space ending just rostral to the premolars. The acrylic must be the right thickness to sustain constant movement without interfering with tongue movements and normal occlusion. After curing, the splint is removed and sharp edges are smoothed (Figure 14-21*A*). The splint is fit again on the mandible. Holes through the acrylic are drilled between the incisors where orthopedic wires (18 gauge) will be threaded to secure the rostral portion of the splint (Figure 14-21*B* to *D*). Then two wires will be threaded around each mandibular body in the interdental space with a 14-gauge needle. Each wire encircling the splint and the body of the mandible will be tightened at the ventral aspect with the knot folded and embedded subcutaneously (see Figures 14-21 and 14-22).

Ayral and Desrochers described the use of a polymethylmethacrylate stent on 13 ruminants (11 calves, 1 goat, and 1 wapiti). Twelve were discharged from the hospital. Antibiotics were given up to 2 weeks postoperatively. Of those 12, only one had a major complication (necrosis of one ramus) and was euthanized. Removal of the splint was usually performed at 4 weeks. A large callus, with fistula tracts along the orthopedic wire, was a constant finding. Long-term survival information was obtained on 10 animals. According to the owner, the growth rate and production were normal. Three animals had some deformation of the mandible.

[1]Technovit, Jorgensen Laboratories, Loveland, CO, USA.
[2]Simplex P bone cement, Stryker, Kalamazoo, MI, USA.



Figure 14-19 A 15-month-old Holstein heifer caught her lower jaw between bars, fracturing her mandible at the symphysis. *A*, There is a large gap between the two branches of the mandible from the fractured symphysis. *B*, Incisors have been wired to reduce the fracture.

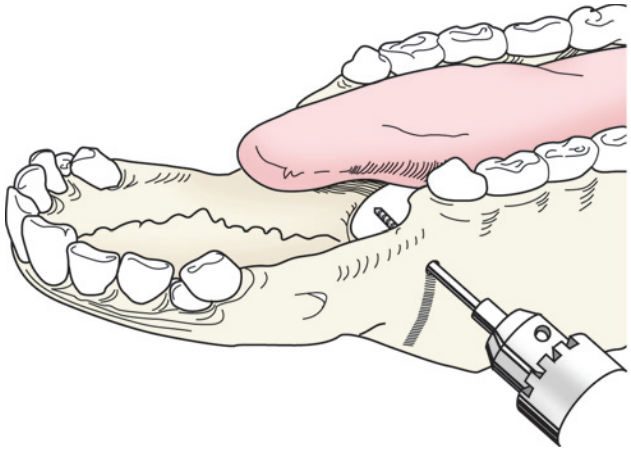


Figure 14-20 A 3.2-mm drill bit is used in the interdental space to make a canal through which the orthopedic wire is passed.

Screw Fixation

Screws can be used to stabilize any rostral mandibular fracture. Aside from the risk of penetrating the root of the incisors or canine teeth, the costs and need for specialized equipment are strong deterrents for using this technique. Nevertheless, screw fixation is an effective means of stabilizing a fracture (see Chapter 15 for details on internal fixation). The authors have used screw fixation of mandibular fractures in large bulls.

Screws should be applied in a lag fashion at approximately 90 degrees to the fracture plane. Using a drill guide to protect the soft tissue, the surgeon overdrills the proximal fragment through stab incisions with an appropriate-size drill bit (4.5 mm or 5.5 mm, respectively, for cortical screws of these diameters). An insert is placed, and the distal far fragment is drilled with a 3.5- or 4-mm drill bit, respectively, for the previously mentioned screw diameters. If 6.5-mm partially threaded cancellous screws are used, a 3.5- or 4-mm drill bit is used through the proximal and distal fragment. The drilled hole length is measured, and a screw that length minus the fracture gap is measured. After a tap the same size as the screw diameter is used, the appropriate length screw is inserted and tightened. In young animals, a washer under the screw head may be needed. Screws may be used in combination with figure-8 wires using tension band principles.

U Bar

This technique is rarely used because of its difficulty in application. A smooth, round ¼-inch (6.35-mm) rod is bent into the shape of a U. Holes are drilled into this rod to allow passage of orthopedic wires. The U bar is inserted on the outside of the mandible or maxilla (Figure 14-23). Orthopedic wires are passed around the base of various incisors and molar teeth and secured to perforations in the U bar. This is readily done around the incisors but is particularly difficult when securing the wire to the molars. Because ruminants have a small commissure, one needs to pass a 14-gauge needle through the cheek and guide it between the teeth of interest. The wire is placed through perforations in the U bar after it has been secured between the molar teeth. A small buccostomy that avoids the commissures of the lips is sometimes needed, but it increases the technique's morbidity rate.

Kirschner-Ehmer

The primary indication for this technique is a fracture of the mandible caudal to the symphysis. Type I or II immobilization can be used. With general anesthesia, the animal is placed in dorsal recumbency unless additional fixation is required through the oral cavity; in the latter case, lateral recumbency is selected to keep the fractured side uppermost. The goal is to place two intramedullary pins (4.8 or

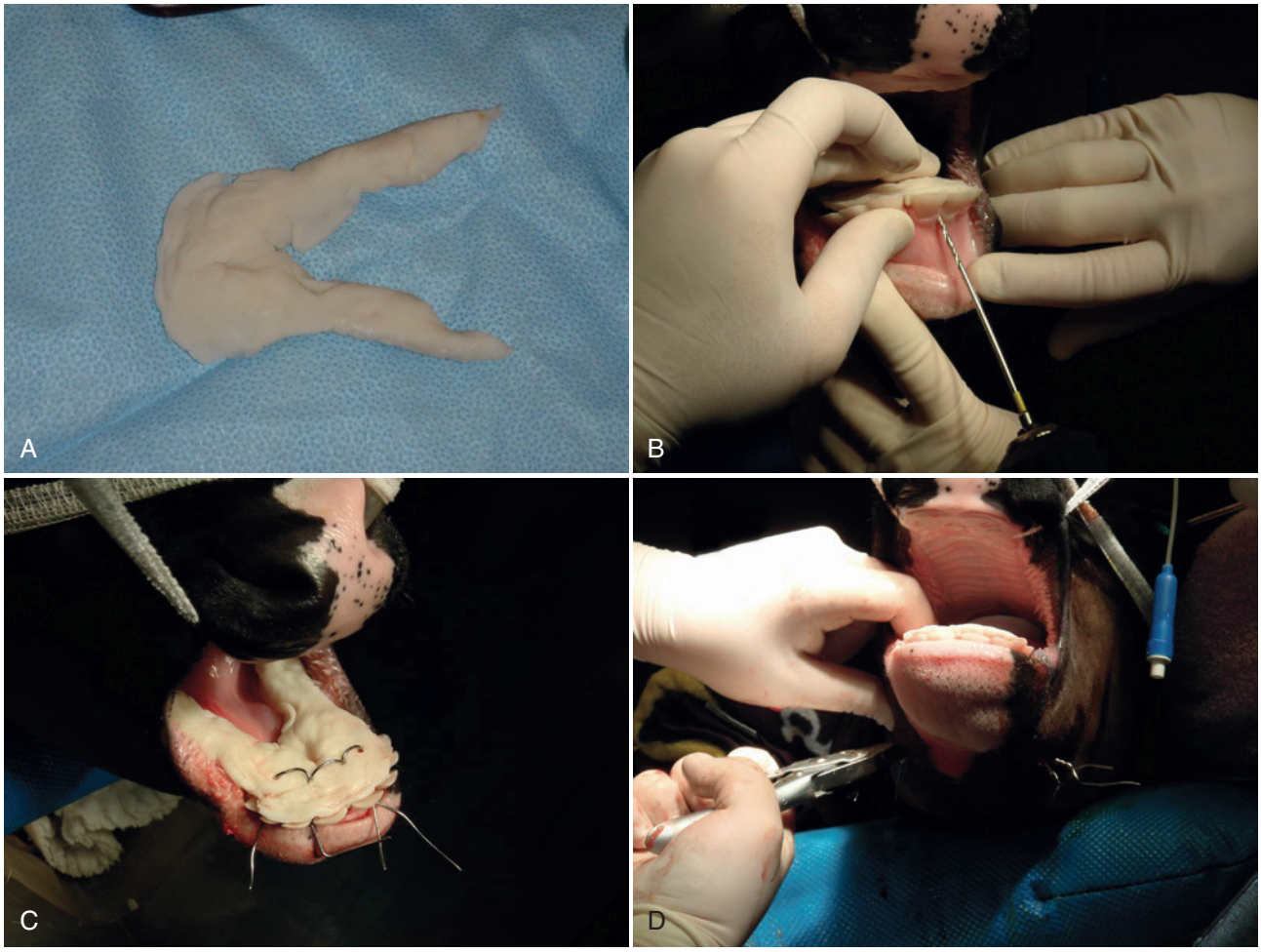


Figure 14-21 Placement of a splint made with orthopedic-grade acrylic. *A*, The acrylic is molded to the mandible, cured, and smoothed. *B*, A drill is used to make holes through the splint passing between the base of the incisors. C, Stainless steel wires are in place between the incisors and ready to be tightened. *D*, The wires are passed around the mandible branches and the splint and tightened ventrally.

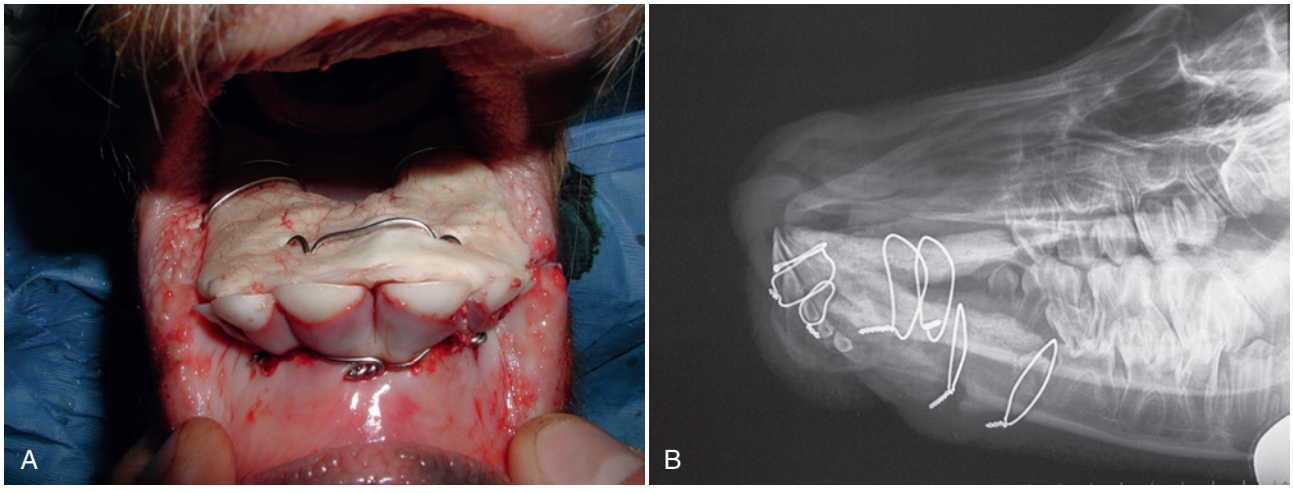


Figure 14-22 *A*, The oral acrylic splint is secured. *B*, Lateral radiographic view 3 weeks postoperatively. The splint and wires are still in place.

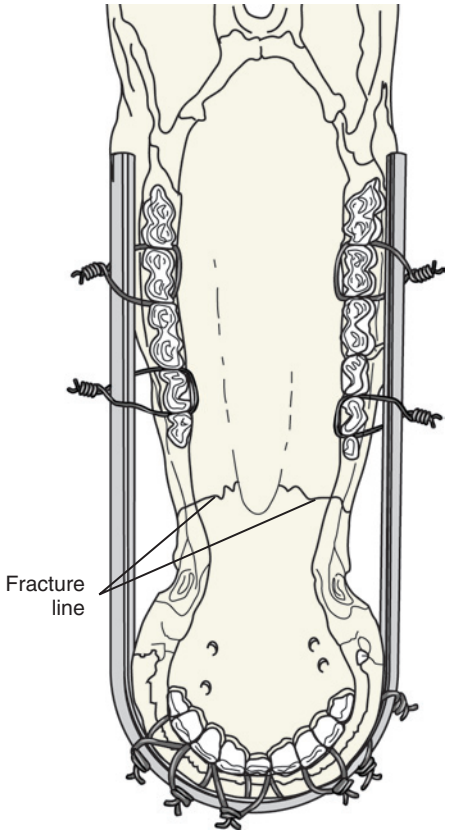


Figure 14-23 Drawing that shows placement of the U bar used to treat caudal mandibular fractures.

6.3 mm) on each side of the fracture through stab incisions placed on the lateral and ventral aspect of the mandible. After the stab incisions, the soft tissue is retracted with a curved hemostat or drill guide to protect the soft tissue overlying the mandible. Using a smaller drill bit than the intramedullary pins, the surgeon drills a hole into the lateral and ventral aspect of the fractured mandible (Type I fixator) on the rostral end of the fracture. The drill hole must be placed in the ventral third of the mandible to avoid tooth roots. Radiographic guidance is helpful in preventing later complications. An intramedullary pin, preferably a positive profile pin, is then placed. A second intramedullary pin is placed at a converging angle. The procedure is repeated on the caudal mandibular fragment. The pins are stabilized by a connecting rod made from a 2.5-cm scavenger hose filled with acrylic (see Figure 14-15*B*). The connecting rods are wrapped with bandage material[3] to fill the defect between the connecting rod and mandible. This prevents the object from inadvertently violating this space and causing disruption of the repair. Alternatively, a commercially made connecting rod can be used, but this is usually not economically justifiable. In all cases, the pins must be cut close to the connecting rod, and a rubber hose or other protective material is used to cover their sharp ends.

If bilateral fractures of the mandible exist, the pins are passed through both mandibles (Type II fixator), and connecting bars are placed on both sides. In a retrospective study on obstetric fractures, Aksoy et al. described an economic alternative to external fixators for rostral mandibular fractures with transmandibular pins and fiberglass casting as side bars. The treatment was successful in 8 out of 10 calves.

A pinless external fixator[4] was successfully used to stabilize unilateral mandibular fractures involving tooth roots. The system consists of pinless clamps in different sizes and geometries. The clamps are applied to the bone cortex (without penetrating the medullary cavity and alveoli) and fixed in place by tightening a nut. The tips of each clamp have sharp teeth or trocars to be anchored in the bone. The universal clamps connect to a connector bar, thus creating an external fixator. The advantages of the technique are that it avoids penetrating the medullary cavity and damaging the tooth root as well as its ease of application and minimal surgical time. The pinless system's disadvantage compared with the previously described techniques is its increased cost. In a case series of seven animals between 1 and 5 years, six of them survived. The fixator was removed 33 to 54 days after the surgery based on radiographic evaluation of the callus. Bone sequestration was a common problem requiring surgical debridement under deep sedation.

Plating

This surgical option is rarely used in ruminants because of the cost of implants and satisfactory outcomes achieved with other methods. If elected, plates are applied as follows. Under general anesthesia, a linear skin incision is made along the ventrolateral aspect of the mandible. The incision is extended to the mandible. A single narrow dynamic compression plate is placed on the ventral aspect of the mandible. In this position, the plate is actually applied on the compression site of the fracture, but given the position of the cheek teeth no alternative is available (Figure 14-24*A* to *B*). Plates can also be used on the lateral or medial aspect (more difficult but more cosmetic) of the vertical ramus of the mandible. The plates are applied by using an appropriate drill guide so that they compress the fracture site (see Chapter 15). Screws should be carefully placed, ideally under fluoroscopic or radiographic guidance, to ensure they do not enter any cheek tooth's root, particularly in young animals.

In all cases, postoperative antibiotics (7 to 10 days) and a short course of analgesics are recommended. Once to twice daily the mouth is lavaged with mild antiseptic to remove accumulated debris around the implants and/or in the fracture site. If intramedullary pins are used, the incision site around the pins is cleaned with an antiseptic solution, and a dressing is applied to minimize the risk of osteomyelitis. The connecting bars and clamps are protected with foam pipe insulation. A soft diet is recommended for 10 to 14 days.

Most mandibular fractures heal rapidly enough to allow implant removal at 1 to 2 months after surgery, although radiographic confirmation of healing can take up to 4 months. Except for screws and plates, implants are always removed. Plates and screws can be left in place if the fracture has healed and no evidence of foreign body (implant) reaction or infection is present. Implants are removed under general anesthesia.

Complications

Although most fractures heal uneventfully, complications include early implant loosening, osteomyelitis, sequestration, and tooth root abscess. Implant loosening is rarely a problem because oromaxillary fractures stabilize relatively quickly. Depending on the clinical condition of the fracture when loosening occurs, implants are either removed or replaced (Figure 14-24*C* and *D*).

[3]Powerflex, Andover Coated Products, Salisbury, MA, USA.

[4]Pinless External Fixator, Synthes, Paoli, PA, USA.

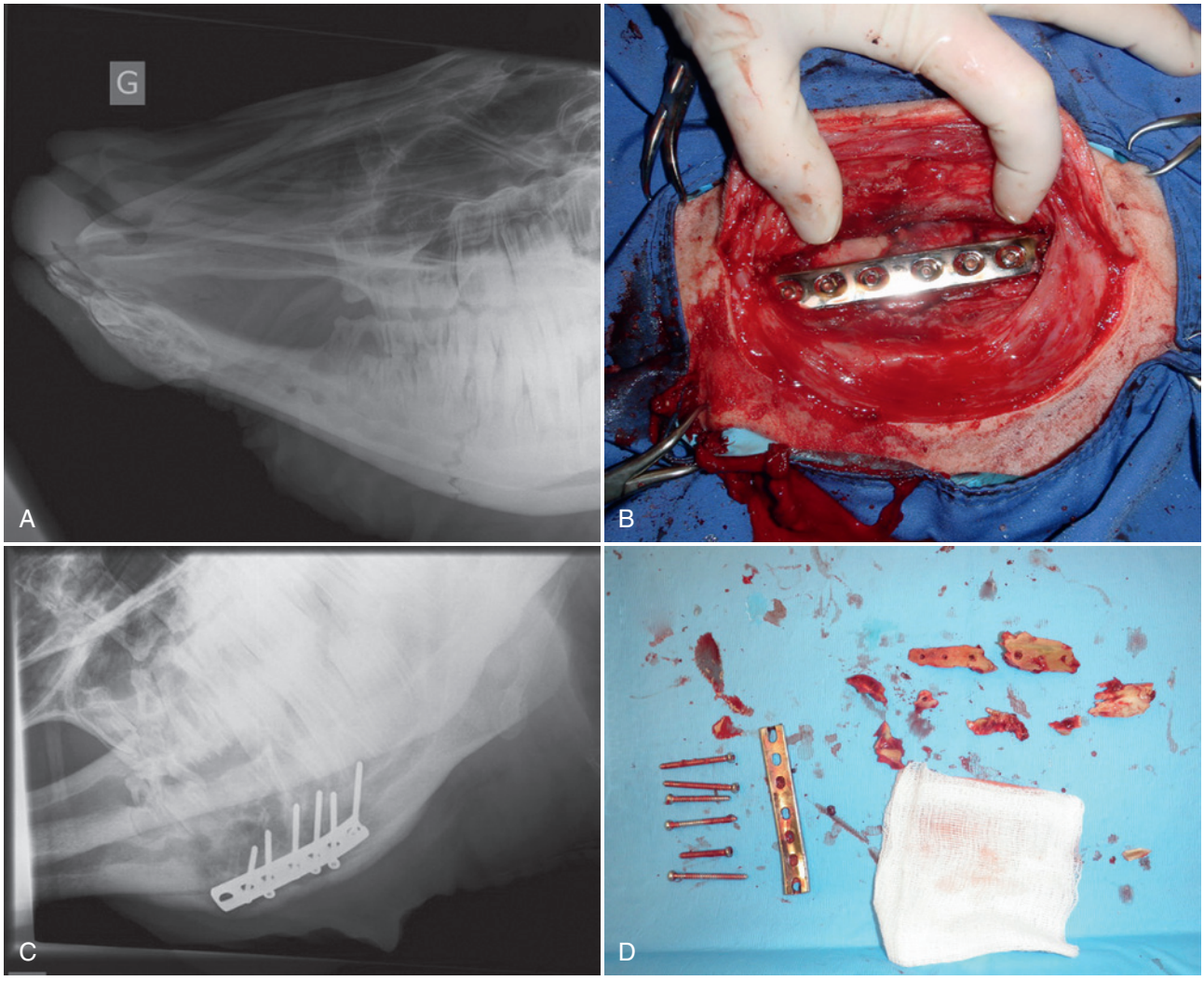


Figure 14-24 A 17-month-old Holstein heifer was presented for a left mandibular mass nonresponsive to antibiotics. *A*, Lateral radiographic view of the mandible. There is a transverse mildly displaced fracture of the left body of the mandible involving the last premolar and the first molar. *B*, A 7-hole dynamic compression plate was applied to the ventrolateral aspect of the left mandible. *C*, Lateral radiographic view 5 weeks postoperatively. There is evidence of osteomyelitis and implant loosening, but the fracture was healed and the branch solid. *D*, The implants were surgically removed under general anesthesia and mandible debrided removing sequestrum. One tooth was extracted.

Osteomyelitis, sequestration, and tooth root abscess are treated with surgical debridement and curettage under general anesthesia or deep sedation. Systemic antibiotics are needed for osteomyelitis cases. Tooth root abscesses are treated by excision as described earlier (see Chapter 9).

Osteomyelitis

Other than osteomyelitis secondary to fracture, trauma can result in soft tissue damage, periosteal devitalization, and secondary infection. Treatment involves surgical debridement and antibiotics described in complications of internal fixation (Chapter 15).

A sporadic cause of mandibular or maxillary osteomyelitis is actinomycosis infection (lumpy jaw) in cattle and sheep (see also Chapter 9). Pathologically, this results from an opportunistic infection by *Actinomyces bovis* after trauma. Animals present with a painful bony swelling that progresses if untreated and eventually shows an eroded ulcerated area devoid of skin and progressively increasing facial deformation (Figure 14-25). After biopsy of the mass, the diagnosis is made by Gram stain evaluation where sulfur granules are observed. The sulfur granules of actinomycosis are large and oval or horseshoe shaped. There are also a number of gram-positive, filamentous, or short rodlike hyphae beneath clubs. The radiographic appearance of this lesion is typical: an enlarging osseous mass with a honeycomb appearance (Figure 14-26). These masses have reportedly resolved solely through medical treatment consisting of penicillin G (22,000 IU/kg once per day) or florfenicol (20 mg/kg intramuscularly every 48 hours or 40 mg/kg subcutaneously every 72 hours) and isoniazid (10-20 mg/kg once per day) for 30 days. Alternatively, one may use oxytetracycline (LA-200; 200 mg/mL): 10 mg/kg subcutaneously or intramuscularly every 48 hours) and monitor renal values closely. In addition, sodium iodine is administered (30 g/450 kg intravenously [IV] in a liter of saline) every 2 to 3 days until signs of toxicity (i.e., iodism—lacrimation, dry skin: head, neck, and shoulder) are noted.



Figure 14-25 **Mandibular osteomyelitis caused by actinomycosis infection (lumpy jaw) in a Holstein-Friesian cow.** Note ulcerative lesion on the mandible. (Courtesy of Dr. Mary Smith.)

In extensive cases of mandibular actinomycosis, surgery can be used as adjunct therapy. Under general anesthesia, the protruding pyogenic granuloma can be removed and sections of infected bone curetted. Antibiotic therapy must be continued because surgery alone is not curative. As an alternative to parenteral administration of antibiotics, local implantation of beads containing penicillin G (see Chapter 15) (after debridement) has been used with success in a limited number of cases.

Neoplasia (see also Chapter 8)

Tumors of dental origin (odontoma and ameloblastoma or adamantinoma) have been reported in cattle and sheep (also see Chapter 9). In addition, hamartomas are sometimes seen (Figure 14-27). The term *hamartoma* refers to a mass composed of normal cellular elements that originates from the tissue where it is found. Unlike normal tissue, hamartomas are poorly organized and are believed to be developmental abnormalities rather than true neoplasms. They have been seen on the maxilla but are more common on the rostral aspect of the lower jaw. Their position interferes with mastication. These are usually seen in young animals (<3 years of age). Osteosarcoma and lymphosarcoma should be considered if a hard swelling on the mandible or maxilla is detected on physical examination. It can be differentiated from *Actinomycosis* because of the latter's characteristic radiographic pattern and typical presence of skin ulceration and pyogenic granulomas. A primary hemangiosarcoma of the left hemimandible was described in a 2-year-old Jersey bull with pulmonary metastasis. In all of the aforementioned cases, the diagnosis is confirmed by histopathological evaluation of a biopsy.

The key to successful management is early surgical resection. Early treatment has a better chance of success (lesion dependent) because the lesion can be entirely removed without significant mandibular loss. If treatment is delayed too long, the tumor will invade the mandibular symphysis and require a rostral mandibulectomy, a treatment with significant morbidity.

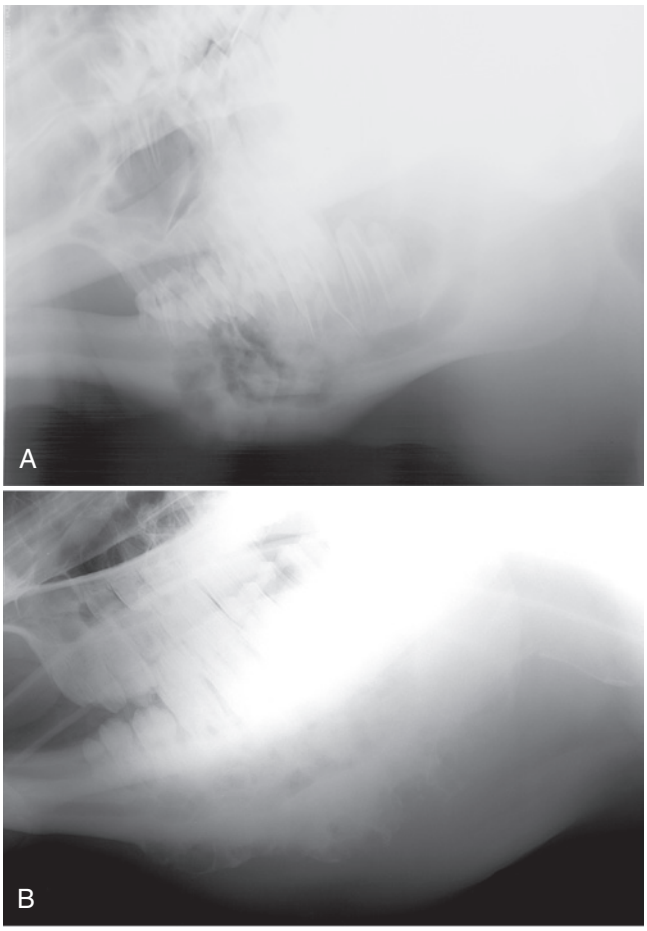


Figure 14-26 ***A*** **and** ***B*****, Typical radiographic appearance of** ***Actinomyces*** **osteomyelitis in two cows.** Note the honeycomb appearance of the enlarging osseous mass. (Courtesy of Dr. Nathan Dykes.)



Figure 14-27 **Oral mass (hamartoma) in a young calf.**

To perform mass removal the animal is anesthetized and placed in lateral recumbency with the mass uppermost. Depending on the type of tumor, the mass is transected at its junction on the mandible/maxilla with a surgical blade,

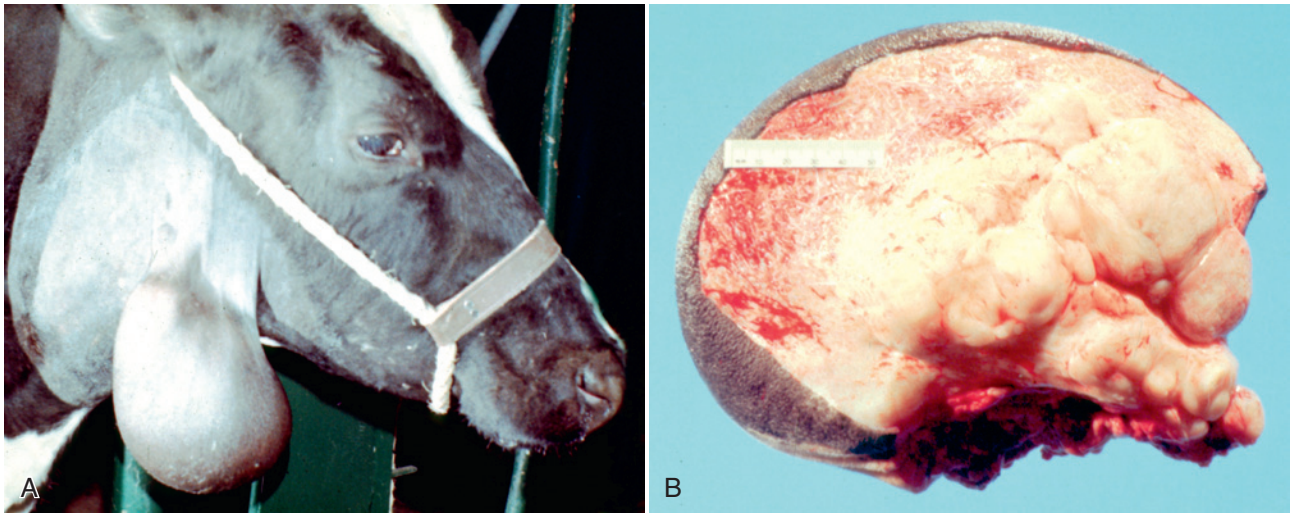


Figure 14-28 *A*, Large unilateral swelling in the cervical area seen in a cow. The swelling is firm but is not painful. *B*, Appearance of neurofibroma on cross section. (Courtesy of Dr. Donald Smith.)

oscillating saw, Gigli wire, or osteotome. A partial hemimandibulectomy may be required for en bloc mandibular resection in certain tumors. All abnormal bone/tissue is removed or curetted. The gingiva is sutured with absorbable sutures in a simple interrupted pattern wherever possible, and the rest of the defect is left to heal by second intention. Postoperatively, antibiotics (7 to 10 days) and a short course of analgesics are recommended. The mouth is lavaged with water or mild antiseptic once or twice daily.

An unusual but characteristic swelling seen in young (1 to 2 years) cattle is a neurofibroma (see Chapter 8). Typically it consists of a mucocutaneous lesion(s) in young cattle around the head and neck (Figure 14-28*A*). They present as nonpainful masses that enlarge progressively in size. The mass results in a cosmetic defect and gets traumatized because of its location and size. It has been suggested that this is a heritable defect caused by a mutation at the bovine neurofibromatosis Type 1 locus. Ultrasound examination reveals a multilobular appearance to the mass and when cut in cross-section reveals the typical appearance shown in Figure 14-28*B*. Needle aspiration fails to yield purulent material. The diagnosis can be confirmed by biopsy and is usually treated by surgical excision. The author has treated such lesions by excision, as biological progression in untreated patients can cause clinical problems, especially in periorbital lesions.

The animal is anesthetized and placed in lateral recumbency. A fusiform incision is made around the base of the mass. The neck of the mass is identified and isolated via blunt dissection and ligation of transected vessels. Following transaction closure is routine, except in lesions involving the eyelid, for which careful reconstruction is required. Recurrences have not been encountered in our limited experience but are biologically possible.

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ESOPHAGEAL SURGERY

Susan L. Fubini and Anthony P. Pease

Only a few diseases have been documented that cause esophageal disorders in the bovine, the most common being foreign body obstruction. Other differential diagnoses include esophageal diverticula, esophageal stricture, esophageal ulceration, esophageal perforation, hypoplasia of the esophageal musculature, megaesophagus, and esophageal obstruction by an extraesophageal mass. One study estimated that esophageal disorders in the bovine account for 0.8% of the clinical cases.

ESOPHAGEAL ANATOMY

The bovine esophagus measures 90 to 105 cm from the pharynx to the cardia. Because the rumen is closely related to the diaphragm, no appreciable intraabdominal portion of the esophagus exists. In sheep, the esophagus measures about 45 cm long.

In the cranial third of the bovine neck, the esophagus travels dorsal to the trachea. From the third to sixth cervical vertebrae, it moves left of the trachea. By the thoracic inlet, the esophagus has traveled to the dorsolateral surface of the trachea. It courses in the mediastinum, passing dorsal to the base of the heart and tracheal bifurcation. The esophagus crosses the aortic arch and continues caudally through the esophageal hiatus at the level of the eighth or ninth intercostal space.

Structures that accompany the cervical esophagus include the carotid sheath, recurrent laryngeal nerve, tracheal lymphatic trunk, and deep cervical lymph nodes. In the caudal mediastinum, the esophagus is adjacent to the dorsal and ventral trunks of the vagus nerve. Dorsally, it is in proximity to the large caudal mediastinal lymph nodes. These nodes can become enlarged and exert pressure on the vagal trunks.

The esophagus comprises four layers that include the outer adventitial layer (tunica adventitia), muscular layers (tunica muscularis), submucosa (tela submucosa), and mucosal layer (tunica mucosa). In the thoracic esophagus the adventitial layer is replaced by a serosal covering (tunica serosa), which is formed by the mediastinal pleura. In ruminants, except at the cranial and caudal ends, the tunica muscularis comprises outer and inner spiral layers of striated muscle fibers that run throughout the length of the esophagus. At the cranial and caudal ends, the inner muscle layer consists of circular fibers, whereas the outer layer consists of longitudinal fibers. The outer layer of elliptical fibers at the pharyngeal end of the esophagus is incomplete ventrally, where it attaches to the cricoid cartilage. At this site, the overlapping pharyngeal and esophageal musculature forms a pharyngoesophageal sphincter.

The tela submucosa consists of loose connective tissue, which allows longitudinal folds to form in the tunica mucosa when the esophagus is contracted. A thick layer of stratified squamous epithelium lines the esophagus. Blood is supplied from the cranial thyroid, common carotid, and the bronchoesophageal and reticular arteries. Branches of the cranial and middle thyroid veins, the caudal part of the external jugular vein, and the cranial vena cava provide venous drainage. Esophageal veins drain into the azygous veins, reticular vein, and left ruminal vein. Esophageal branches of the vagus nerve innervate the cranial half of the esophagus. The caudal half is innervated by esophageal branches off the recurrent laryngeal and vagal nerves.

Because the esophagus courses medial to the left jugular groove, a visible and palpable bulge is evident in the left jugular groove when a bolus is swallowed or an orogastric tube is passed.

CLINICAL SIGNS OF ESOPHAGEAL DISEASE

Obstructive esophageal disease, or choke, is typically manifested in cattle by bloat and salivation. The salivation can be exacerbated by foreign material. Gaseous distention of the rumen results from the inability of the cow to eructate and release gas. The animal's head and neck are extended. Coughing is common and the tongue often protrudes. Retching is sometimes seen. The animal is often dehydrated and may be anxious or very agitated. Cattle lose tremendous quantities of saliva, which contains a large amount of bicarbonate; therefore cattle often develop metabolic acidosis with an esophageal obstruction.

DIAGNOSIS OF ESOPHAGEAL DISEASE

Physical examination findings are used to diagnose esophageal disease along with endoscopy, radiography, and ultrasound examination.

The cow's vital signs should be assessed along with hydration status. Pharyngeal trauma and rabies must be considered and kept in mind as differential diagnoses. The laryngeal area and neck should be palpated for swelling, cellulitis, or subcutaneous emphysema. An oral examination should be performed to evaluate the pharynx and rule out cleft palate, dental disease, foreign bodies, or neoplasia.

The lower airway should be auscultated carefully to determine whether there is any sign of aspiration pneumonia.

Passage of a stomach tube through a Frick speculum would be the next step to help localize an intraluminal obstruction The tube should be passed gently to avoid damage to the potentially compromised mucosa.

Esophagoscopy

Esophagoscopy is indicated to help localize an obstruction, identify obstructing material, and assess damage to the esophagus, especially when the problem has been resolved. A 2- or 3-meter flexible fiberoptic endoscope permits evaluation of the entire esophagus in most animals. The cow should be restrained, ideally in a chute and head gate, to protect the examiner and equipment. If possible, the endoscope is passed through to the cardia and the esophagus insufflated with air and examined while the endoscope is being withdrawn. The normal esophagus has longitudinal mucosal folds. The mucosal folds and swallowing artifacts should not be construed as abnormal. Because of saliva accumulation and the tendency for the esophagus to collapse periodically, it is easy to miss or overinterpret a lesion. Therefore any lesion found should be reexamined by repeatedly passing over the area to eliminate any artifacts.

Bovine Esophageal Radiology

Survey and contrast radiographs are recommended to characterize lesions in the bovine esophagus (Figure 14-29). Fluoroscopy can be used to evaluate the swallow reflex in farm animals, but the difficulty in restraining patients can be technically challenging. Esophagography is considered the method of choice for evaluating bovine esophageal disorders.

Survey radiographs should be obtained to determine an adequate radiographic technique and help classify the disorder based on dilation of the esophagus with gas before contrast material is administered. Lateral survey radiographs of the neck can be obtained by using a regular screen or a digital cassette and film holder. Stocks are recommended to eliminate the need for a handler to hold the patient. Exposure factors of 20 to 40 mAs and 70 to 77 kVp at 90-cm focal distance have been described for radiographs of the cervical esophagus. For the thoracic portion of the esophagus, an exposure factor of 90 mAs and 90 to 96 kVp can be used with a 1:20 grid or 50 mAs without a grid. Ventrodorsal and dorsoventral radiographs of patients that weigh more than 60 kg are usually not diagnostic because of the large amount of superimposed musculature, the spine, and difficulties obtaining radiographs, because positioning would probably require general anesthesia. Left and right lateral radiographs of the thoracic cavity have been recommended in place of a ventrodorsal or dorsoventral radiograph. To image the thoracic portion of the esophagus, high-speed film-screen combinations (or digital cassettes) and larger x-ray units are required to achieve adequate exposure. The published exposure factor for thoracic radiographs in a bovine is 21 to 42 mAs and 78 to 118 kVp with a 1:7 grid. With the digital technology, grids are less important but can still be used.

Contrast administration in the esophagus (esophagography) is relatively easy in the bovine. Barium suspension (60% w/vol) is administered via an oroesophageal or nasal esophageal tube placed in the cranial third of the esophagus or cranial to the obstruction. Barium suspension is preferred because of the ease of administration compared with paste and lack of inflammatory response if some barium is aspirated. Iodinated (injectable) contrast medium can cause a severe inflammatory process if aspirated due to the hypertonicity. Barium paste (70% w/vol) is preferred if mucosal ulceration is suspected because the paste coats and better delineates the mucosal surface. Barium has been documented to cause a granulomatous response if it dissects into the soft tissues; therefore iodinated contrast medium can be considered if esophageal perforation is suspected. However, in those cases generally barium is still used because the risk of granuloma formation is less severe than the pulmonary edema seen with iodinated contrast medium aspiration.

No standard dose for esophagography in the bovine exists. However, 300 mL to 3 L of a barium suspension can be administered, and the contrast can be given at full strength, but the general preference is to dilute 1:1 with water, thus making a 30% w/vol suspension. The amount administered should be altered based on the suspected disorder. For example, an esophageal obstruction does not require the same volume as does a flaccid megaesophagus does. Radiographs should be obtained as soon after contrast administration as possible. Multiple radiographs during the procedure should be obtained so that the procedure can be stopped when diagnostic despite the amount of contrast medium given.

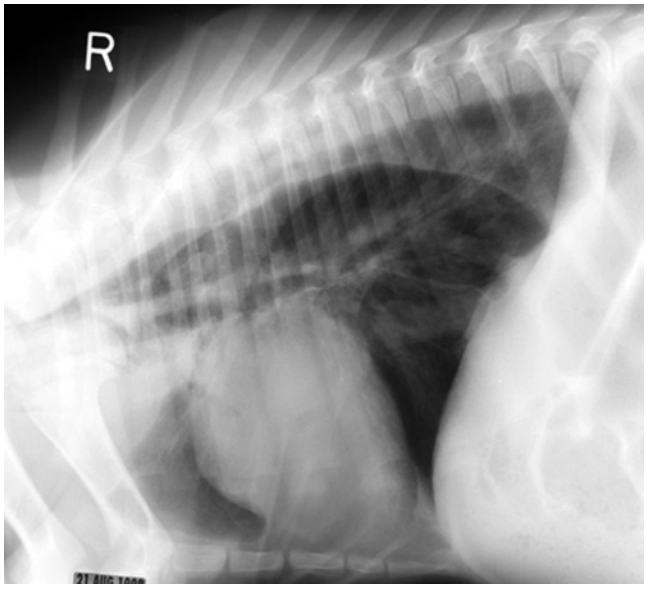


Figure 14-29 Right-lateral thoracic radiographs of a calf with megaesophagus. Note that the esophagus is markedly dilated with gas and fluid. A tracheal stripe sign is present. (Courtesy of Dr. Peter Scrivani.)

SURGICAL CONSIDERATIONS

Unfortunately, esophageal surgery in any species is fraught with complications. Most of the esophagus does not have a serosal covering, which is important in forming a fibrin seal. Furthermore, the esophageal lumen is not "clean"; constant movement occurs during swallowing, and its location causes tension on any suture line. The proximity of the recurrent laryngeal nerve to the esophagus can have deleterious effects on manipulations. Some procedures, such as a standing cervical esophagotomy, can be performed by using sedation and local anesthesia. For more extensive manipulations, general anesthesia is preferable.

Most esophageal disorders can be managed conservatively; thus few reports of surgical intervention in the ruminant esophagus exist. A lateral or ventrolateral approach is typically described for performing a cervical esophagotomy; a left-sided rib resection is usually performed on the thoracic esophagus. General anesthesia and positive-pressure ventilation are essential for a thoracotomy.

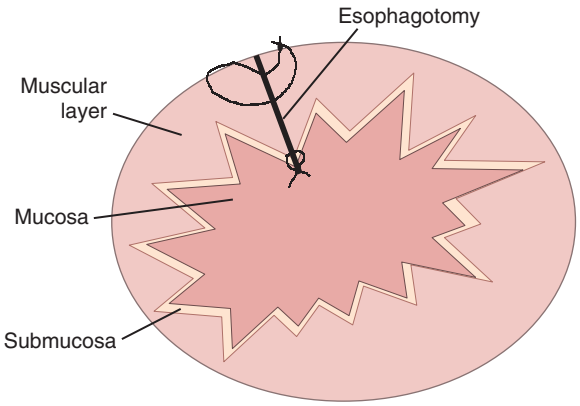


Figure 14-30 Schematic representation of surgical closure of the esophagus.

A longitudinal incision is used to incise the esophagus. Once the muscular coat is incised, the esophagus separates into two layers: the elastic inner layer, which is composed of mucosa and submucosa, and the outer muscular layers and adventitia. The inner layer provides the greatest tensile strength during esophageal closure. Preservation of blood supply, aseptic technique, apposition of tissues without tension, and appropriate preoperative and postoperative management are essential for a successful outcome.

Esophageal Closure

Primary esophageal closure involves a two-layer technique. The mucosa and submucosa are closed together in either a simple continuous or simple interrupted pattern. A nonabsorbable (for example, polypropylene or nylon) or long-lasting absorbable (for example, polyglactin 910, polydioxanone, or polyglyconate) suture material is used (Figure 14-30). It is recommended that the knots be tied within the esophageal lumen to prevent contamination of the wound by ingesta migrating along suture tracts. The muscular layer can be closed by using either an absorbable or nonabsorbable noncapillary suture with a simple interrupted or mattress pattern (see Figure 14-30). A suction drain[5] may be placed to allow evacuation of contaminated exudate. The lack of serosal covering may contribute to complications after surgery, including leakage and dehiscence.

In 1988 Dallman suggested that the holding layer of the canine esophagus might be the submucosa. If this is true, suturing the submucosa and muscle in one or two layers and avoiding penetration of the mucosa could reduce the incidence of complications in esophageal surgery.

Foreign Body Obstruction

Foreign body obstruction, or "choke," a common esophageal disorder in cattle, results from incomplete mastication and rapid ingestion. Cattle produce large quantities of saliva, which makes a smooth-skinned potato or apple difficult to masticate, so it can slip into the pharynx and esophagus. Other common sources of obstruction include cabbage, beets, turnips, and ears of corn. Infrequently, sharp foreign bodies such as glass or irregular metallic objects can be swallowed and lodged in the esophagus.

The clinical signs of choke mentioned earlier include ruminal tympany, excessive salivation, coughing, tongue protrusion, and extension of the head and neck. The animal may be dehydrated and anxious.

[5]J-Vac Drain, Johnson & Johnson, New Brunswick, NJ, USA.

Obstructions in the cervical esophagus can usually be palpated externally. After rabies has been ruled out, a thorough oral examination should be performed to evaluate the pharynx and check for any foreign bodies. Passage of a nasogastric tube helps determine swallowing ability and localize the obstruction site. If the esophagus is filled with fluid proximal to the obstruction, visualization can be difficult.

Plain radiographs can show esophageal distention with gas or deviation of the esophagus (see Figure 14-29). Feed material impactions (Figure 14-31*A*) or radioopaque foreign bodies may show up on plain survey films. Contrast studies help delineate nonmetallic foreign bodies (Figure 14-31*B*). Gas accumulation in the soft tissues adjacent to the esophagus (Figure 14-32) may indicate an esophageal perforation or rupture. If choke is present, a soft tissue opacity may be seen within the esophagus contrasted by gas (see Figure 14-31*A*). If choke is present for more than 48 hours, gas within the esophageal wall may be detected as a result of necrosis of the mucosa. If the obstruction is present in the cervical portion of the esophagus, the trachea and larynx may be ventrally displaced. Contrast radiography can be used; however, the obstruction is usually palpated and diagnosed during passage of an orogastric or nasogastric tube. Esophagography is more useful for evaluating the mucosal wall for strictures or perforation after the obstruction has been cleared. If esophagography is performed, the cranial portion of the obstruction will be delineated, and contrast medium may be detected in the trachea because of aspiration.

Extraesophageal masses diagnosed in the bovine include hematoma, cervical abscess, and extraesophageal tumors. Primary esophageal tumors have not been reported, and congenital abnormalities of the esophagus are extremely rare. We have seen one calf with chronic bloat associated with a tracheoesophageal fistula (Figure 14-33). Extraesophageal lesions usually displace the larynx, trachea, and esophagus ventrally. On survey radiographs, gas is occasionally detected in the cervical esophagus. If contrast medium was administered, ventral deviation of the esophagus with mild dilation and difficulty swallowing the barium suspension can be observed.

The initial treatment of choke is aimed at resolving the ruminal tympany by using a needle attached to a suction apparatus. Alternatively, a small trocar or cannula can be used to decompress the rumen. The animal should be held off feed and water to lessen the risk of aspiration pneumonia until the obstruction is removed.

Spontaneous resolution of an esophageal obstruction may occur with or without sedation. If the object is in the proximal or midcervical portion of the esophagus, it may be gently moved into the proximal esophagus and eventually the oral cavity. The cow should be restrained in a stanchion or chute while the operator gently places his or her fingers into the jugular furrow just distal to the obstruction. Steady uniform pressure should be applied, especially when the esophageal musculature is relaxed, to slowly move the foreign body toward the pharynx. Once the foreign body reaches the proximal esophagus, it may be possible to grasp the foreign object with the help of a mouth speculum and by pulling the tongue out of the oral cavity. Mild sedation (xylazine at 0.01 to 0.02 mg/kg IV) can be helpful as well.

A wire snare has been used with success in some instances to encircle and retrieve foreign objects in a more distal obstruction. This procedure does risk damaging the esophageal mucosa.

The thoracic esophagus widens slightly, making it possible to use a smooth stomach tube to advance some distal thoracic obstructions into the rumen where foreign materials

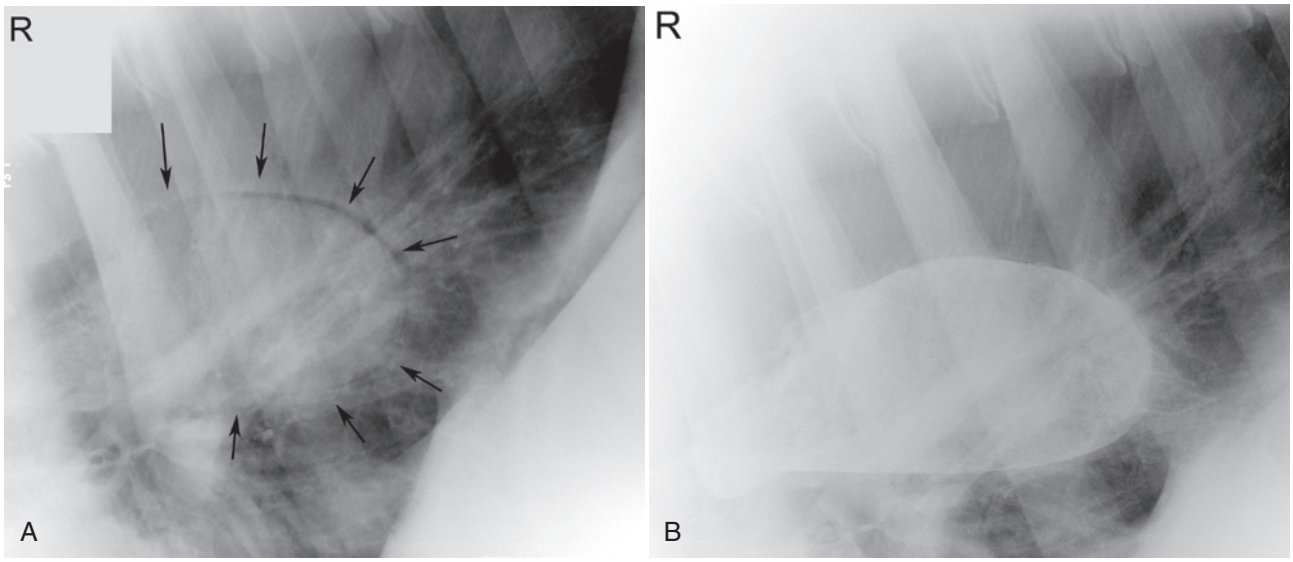


Figure 14-31 Five-year-old shorthorn cow with esophageal obstruction. *A*, Right-lateral thoracic radiograph showing soft tissue density in the esophagus. Note air density (*black arrows*) outlining the junction of the obstruction and the esophageal wall. *B*, After barium administration, which emphasizes the size and shape of the esophageal obstruction.

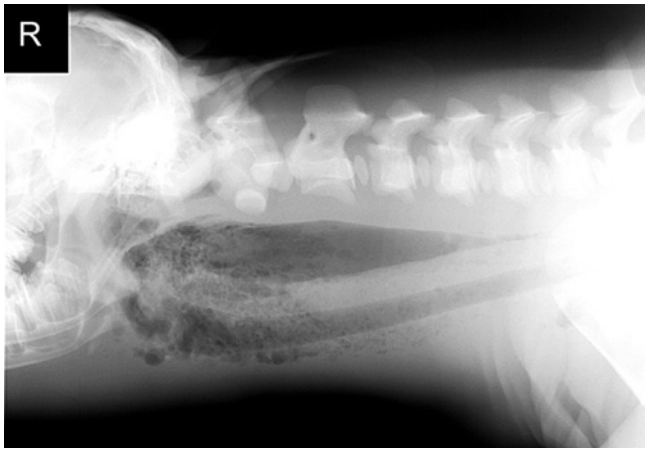


Figure 14-32 Right-cervical radiograph of a calf with a cranial cervical esophageal rupture. Note accumulation of gas in the subcutaneous tissues. (Courtesy of Dr. Ned Dykes.)

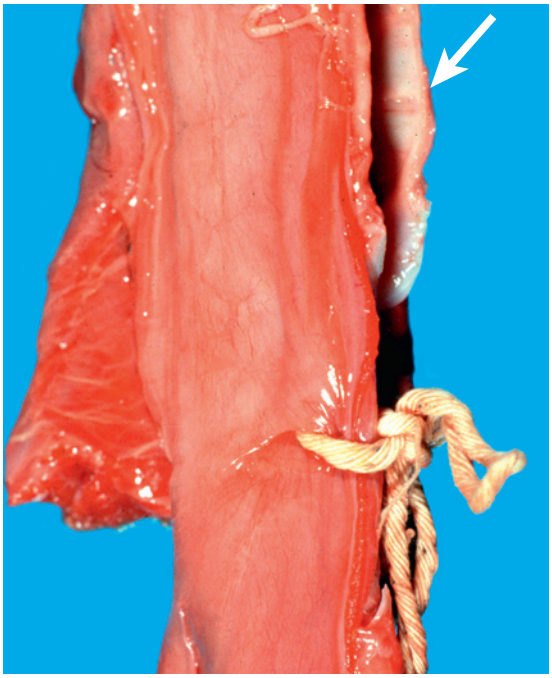


Figure 14-33 Tissues from a calf with chronic bloat associated with a tracheoesophageal fistula. *Arrow* shows lumen of the trachea while rope is seen exiting through the esophageal mucosa.

can be retrieved via rumenotomy. Ideally, the site should be observed first via esophagoscopy to determine whether such manipulations would be detrimental (for example, if the obstruction has sharp edges).

Repeated warm-water lavage may help break up feedstuff in a feed impaction. The animal should be sedated with the head lowered to prevent aspiration pneumonia during the warm-water lavage. Alternatively, a large-diameter, malleable endotracheal tube may be passed through the nose into the esophagus, where the cuff is inflated, and a smaller nasogastric tube is passed through the lumen of the endotracheal tube to perform the lavage. This technique allows lavage fluids to drain through the endotracheal tube, minimizing the risk of aspiration. Although it may take several hours and repeated attempts to dissolve an impaction, gentle manipulation is essential to minimize further damage to the esophagus.

If the feed impaction cannot be resolved in the standing animal or the patient cannot be adequately restrained, other techniques are used. The endotracheal tube technique can be performed with the cow under general anesthesia. Esophagoscopy with the cow standing can be used. If all manipulative attempts fail, surgery, such as an esophagotomy, should be considered because prolonged obstruction can cause permanent mucosal damage. After the obstruction is removed, the esophagus should be evaluated to assess mucosal damage.

Cervical Esophagotomy

The cow is restrained in stocks or chute to perform a standing procedure or positioned in right lateral recumbency if using sedation or, ideally, general anesthesia. The stomach tube is placed to the level of the obstruction before anesthesia. The neck is prepared for aseptic surgery.

After approaching the esophagus, pediatric Balfour retractors are applied to obtain exposure of the esophagus. The affected area is isolated from the surgical field using moist sponges. The esophagus is incised, and the foreign body is removed. The incision should be made in healthy esophageal tissue if possible. If the esophageal wall has a normal appearance, primary closure is recommended as described previously. Food and water are withheld for 48 hours after surgery, and maintenance IV fluid therapy is instituted. If considerable dead space exists, a closed suction drain is advisable for the first 48 to 72 hours. If the esophageal wall is compromised, it should be allowed to heal by second intention with daily wound care. If the animal loses too much feed material and water through the esophageal defect and cannot maintain body condition, a rumen fistula can be placed. The animal can then be fed via rumen fistula until the esophageal defect is small enough to allow oral alimentation.

Transthoracic Esophagotomy

Isolated reports of successful transthoracic esophagotomy procedures in ruminants have been made. General anesthesia and positive-pressure ventilation are essential. The animal is placed in right lateral recumbency. A 35- to 40-cm skin incision is made over the seventh or eighth rib. Usually, it is necessary to perform a partial rib resection by dissecting under the rib 4 cm proximal to the costochondral junction. Blunt dissection is done along the pleural surface of the rib; thus a Gigli wire can be passed and worked in a proximal direction. While the site is lavaged with warm saline, the Gigli wire transects the rib. The distal portion of the rib is easily removed at the costochondral junction. All soft tissues are packed off with moist, sterile bath towels. A Penrose drain or umbilical tape loops can be placed around the esophagus and used for manipulation. The esophageal incision and closure are as previously described. A chest drain is placed before closing the thoracic cavity. The parietal pleura are closed, followed by muscle, subcutaneous tissues, and skin.

Esophageal Perforation or Laceration

Esophageal perforation or rupture is caused most often by overzealous use of an instrument to dislodge an obstruction. The foreign body itself can also cause pressure necrosis of the esophageal wall. Other causes include pharyngeal trauma, extension of a soft tissue infection, and cervical trauma.

Affected animals usually develop impressive subcutaneous emphysema. They are inappetent and depressed. Swelling develops at the site of the rupture and can progress to a sizable infection of the surrounding area. Migration of infection down fascial planes to the mediastinum and thoracic cavity can be catastrophic (see Figure 14-7). The diagnosis can be confirmed with esophagoscopy, ultrasound, or a contrast radiographic study. On survey radiographs, irregular gas opacities may be detected in the soft tissues of the neck, surrounding the esophagus and trachea, and/or within the mediastinum. If esophagography is performed, iodinated contrast medium should be used to delineate the perforation but may be cost prohibitive. For large patients barium suspension can be used (diluted 1 : 1 with water) as long as the potential complication of granuloma formation is explained to the client. If the esophagus is perforated, contrast medium is detected in the soft tissues outside the esophagus.

Tissues healthy enough to be closed after esophageal perforation are rare, but primary closure can be attempted with a lesion less than 12 hours old. Closed suction drainage should be used to avoid serum and blood accumulation at the surgical site. Therapeutic antibiotics, nonsteroidal antiinflammatory drugs, and tetanus prophylaxis are administered. If primary closure is not possible, ventral drainage is provided, and the wound is allowed to heal by contraction and epithelialization. Adequate ventral drainage is mandatory to prevent septicemia and cellulitis extending along fascial planes and causing lower airway disease—possibly generalized septicemia. The patient can be fed via a rumen fistula. Healing these tissues can be a long, drawn-out process and is rarely warranted.

Stricture

Stricture or stenosis of the esophagus can occur after extramural or intramural lesions, extramural compression, or extension of an infectious process. Stenosis secondary to a developmental abnormality such as a persistent right aortic arch is rare but has been reported. Other extramural causes of compression include lesions in the cranial abdomen, such as an abscess or adhesion that results in a narrowing of the esophageal hiatus. Rarely, esophageal granulomas can occur secondary to *Actinobacillus* or *Arcanobacterium pyogenes* infection or neoplasia. Healing after esophageal rupture and surgery can all result in stricture.

Full-thickness mucosal or submucosal defects heal predominantly by contraction and fibrosis. The resulting annular lesions are categorized as the following three types, depending on the location, duration, and fibrosis: 1) mural lesions involve only the adventitia and muscularis; 2) esophageal rings or webs involve only the mucosa or submucosa; and 3) annular stenosis involves all layers of the esophageal wall. The survey radiographs are usually normal, unless the condition is chronic and a focal dilation has formed cranial to the stricture. An esophageal stricture appears as a focal narrowing of the lumen that persists on sequential radiographs. Strictures should not be confused with peristalsis; therefore multiple radiographs should be taken to confirm the diagnosis. A double-contrast esophagram can be performed by placing a cuffed orogastric tube (such as an endotracheal tube) proximal to the stricture and administering barium suspension, followed by a similar volume of room air. A radiograph is obtained while the esophagus is distended.

Nonsurgical Management

Clinical and experimental studies in horses indicate that stricture formation may occur as soon as 15 days after circumferential mucosal loss. The lumen diameter is not expected to change for 30 days, but between 30 and 60 days the lumen diameter increases, with the greatest change occurring between 30 and 45 days. Therefore acute equine strictures are managed with antibiotic therapy, nonsteroidal antiinflammatory drugs, and frequent feedings with small quantities of a pelleted mash. By extrapolation, we recommend similar guidelines for ruminants.

Bougienage and pneumatic or hydrostatic dilators have been successful in humans with chronic esophageal strictures. These techniques have been used very little to date in domestic or farm animals. It would be possible to feed a ruminant via a rumen fistula when managing an esophageal stricture.

Surgical Management

Surgery can be considered if the stricture diameter does not change by 60 days and clinical signs are progressive. To some extent, the nature of the esophageal stricture dictates the method of surgical correction. Described surgical methods

include esophagomyotomy, partial esophageal resection, complete resection and anastomosis, esophagoplasty, esophageal replacement, muscle or synthetic patch grafting, and fenestration of the cicatrix through an esophageal fistula.

Esophagomyotomy

Esophagomyotomy is indicated for an esophageal stricture that involves only the muscularis and adventitia. A nasogastric tube is positioned before surgery. The esophagus is approached and gently freed from surrounding tissues, and the strictured area is identified. One or more longitudinal incisions are made in the esophageal musculature without incising the mucosa. The nasogastric tube should be able to easily cross the surgical site inside the mucosa. The musculature can be separated from the mucosa around the entire circumference of the esophagus if necessary. The myotomy may or may not be sutured. The remainder of the surgical incision is closed and drained in a routine manner.

Partial Esophageal Resection

Partial esophageal resection combines a longitudinal esophagomyotomy with a mucosal resection. The procedure is ideal for strictures confined to the submucosa and mucosa but may also be used for full-thickness strictures. A longitudinal esophagomyotomy is performed, and the diseased submucosa and mucosa are identified and resected. If the lesion is confined to the submucosa and mucosa, only the muscular layer and adventitia are closed. The mucosa is closed only if achievable without excessive tension. It is advantageous to suture the muscularis because the mucosa can then regenerate along the inside of the muscular tube.

Complete Esophageal Resection

Esophageal resection and anastomosis have been recommended if the stricture involves all layers and the muscularis is damaged extensively and is useless as a scaffold for mucosal regeneration. Minimizing tension on the anastomosis is essential for a favorable result.

A routine approach is made to the esophagus. Healthy tissue cranial and caudal to the lesion is transected. A two-layer anastomosis is performed by closing the submucosa and mucosa in a simple continuous or interrupted pattern and the muscular layer in a simple interrupted pattern. Gentle tissue handling and careful use of retractors are essential to avoid damage to the carotid sheath, vagosympathetic trunk, and recurrent laryngeal nerve.

After surgery, extraoral alimentation can be through a rumen fistula in an adult cow, an esophagotomy tube distal to the surgery site in a young ruminant, or by daily passage of a nasogastric tube.

Fenestration through a Cicatrix

A final option for surgical repair of an esophageal stricture involves an esophagostomy, followed by fenestration of the mucosal and submucosal cicatrix. The esophagostomy heals as a traction diverticulum, thereby increasing the lumen size. The animal can again be fed via a rumen fistula or via a tube placed in the esophagostomy site.

ESOPHAGEAL DIVERTICULUM

Occurrence and Diagnosis

Esophageal diverticula is the second most common esophageal disorder in the bovine. There are two types of esophageal diverticula and both are usually acquired conditions. *Traction (true) diverticula* results from contraction of periesophageal fibrous scar tissue, often secondary to a wound or previous surgery. Traction diverticula are usually asymptomatic. *Pulsion (false) diverticula* results from protrusion of mucosa and submucosa through a defect in the esophageal musculature. These diverticula may result from external trauma, fluctuation in esophageal intraluminal pressure, and overstretch damage to esophageal muscle fibers by impacted foodstuffs. Affected animals are often dysphagic but able to drink. They may regurgitate after eating. Coughing, salivation, and ruminal distention are typical. The diverticulum may enlarge over time and become evident as a large swelling in the neck, which results in dysphagia or choke. Esophagoscopy helps define the relative size of the opening of the diverticulum. This disorder can usually only be seen during esophagography as a focal accumulation of contrast material. Occasionally, an esophageal stricture can be detected just caudal to the focal dilation. If a diverticulum is present within the thoracic portion of the esophagus, the most common clinical sign is regurgitation. In one study, 86% of cases with thoracic diverticula had radiographic evidence of pneumonia.

Treatment

Repair of a pulsion diverticulum involves mucosal inversion with reconstruction of the muscular layer or diverticulectomy. The former is preferred because the mucosa is left intact, which minimizes the risk of postoperative leakage, infection, or fistula formation.

Esophageal Fistula

Esophageal fistulas may result from healing esophagotomy incisions or after esophageal perforation. They are diagnosed with contrast radiographs. Clinical signs include cervical swelling, fever, and dysphagia. The lesions may be difficult to demonstrate with esophagoscopy, and passage of a nasogastric tube is usually possible. Most fistulas heal once ventral drainage is established. If healing does not occur, resection of the sinus tract and closure of the stoma may be necessary.

Esophageal Ulceration

Ulcerations in the esophagus are typically lesions associated with viral-diarrhea complex. Esophagography may assist with early detection and diagnosis before results obtained from serology. Barium paste (70% w/vol) is generally used and is placed on the tongue of the calf. Ulcerations will appear as a filling defect along the longitudinal lines of the mucosa.

Mucosal damage can also follow resolution of an esophageal obstruction. These are treated with time and a diet avoiding long-stemmed rough hay. As mentioned earlier, extrapolation from equine studies indicates possible increase in the diameter of a traumatized esophagus for as long as 60 days.

Megaesophagus

Sporadic reports of segmental and generalized megaesophagus in cattle have been documented. Affected animals are dysphagic, salivate, and cough. Aspiration pneumonia is common. The esophagus is dilated on imaging studies, and the longitudinal folds of mucosa are not evident. This disorder is usually described in weanling calves that have an atonic esophagus that accumulates solid food that may occlude the esophagus and cause bloat. However, one case has been described in an adult heifer. Regardless of age, survey radiographs reveal air or an air-fluid interface within an atonic esophagus (see Figure 14-29). Esophagography shows a large accumulation of contrast material in the esophagus. In the adult case report, a large amount of eosinophils were present in the esophageal wall, and a roundworm larval migration that impaired esophageal function was suspected.

Treatment is supportive. Animals should be frequently fed small amounts of easily digestible feeds. White muscle disease should be ruled out. Long-stemmed hay should be avoided. Antibiotics are indicated for pneumonia. The prognosis is unfavorable.

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APPROACHES TO THE BOVINE ABDOMEN

Linda A. Mizer

ANATOMY

The conformation of the bovine abdomen varies with age, weight, and physiologic condition. Normally it is bilaterally symmetric. The extent of the abdominal cavity is not readily apparent because a large portion is contained within the rib cage. The abdominal cavity is bounded cranially by the diaphragm, caudally by the pelvic inlet, dorsally by the lumbar vertebrae and epaxial musculature, and laterally and ventrally by the abdominal musculature. The abdominal wall musculature is made of broad expansive sheets that attach by means of aponeurosis-forming connective tissue structures such as the linea alba and prepubic tendon. The abdominal muscles have many functions such as containing abdominal viscera, assisting respiration, stabilizing the pelvis, and flexing the vertebral column. The abdominal musculature also permits generation of an abdominal press necessary for defecation, micturition, and parturition. The abdominal wall is elastic in nature, allowing it to adjust to varying volumes.

The skin is thickest over the flank of the cow and becomes thinner over the ventral portion of the abdomen. The most prominent feature of the bovine flank is the paralumbar fossa. The paralumbar fossa is outlined by the transverse processes of the lumbar vertebrae, internal abdominal oblique muscle, and thirteenth rib (Figure 14-34). Abdominal muscles and



Figure 14-34 Right-paralumbar fossa.

their aponeuroses form the main fibromuscular support of the ventral and lateral walls of the abdomen. The four pairs of muscles involved in the makeup of the abdominal wall are the external abdominal oblique, internal abdominal oblique, transversus abdominis, and rectus abdominis. The most important nerves of the flank are the last thoracic, first lumbar, and second lumbar nerves. The caudal intercostal nerves innervate the floor of the abdomen ventral to the costal arch. Knowledge of these nerves is important in providing local anesthesia as part of performing a laparotomy. The ventral portion of the abdominal wall receives its blood supply from the cranial and caudal epigastric arteries and branches of the internal thoracic and external pudendal arteries. The flanks receive their blood supply from parietal branches of the aorta, the most important of which, from a surgical point of view, is the deep circumflex iliac artery.

The most extensive and superficial muscle of the flank is the external abdominal oblique muscle. The fibers of this muscle course in a caudoventral direction. However, in the area of the paralumbar fossa the fibers are seen in a more horizontal direction. This muscle terminates in an extensive aponeurosis near the lateral border of the rectus abdominis muscle. The external abdominal oblique originates on the lateral aspect of the thorax from the fourth or fifth rib. It inserts on the tuber coxae, prepubic tendon, and linea alba by means of aponeurotic tissue. The aponeurosis of the external abdominal oblique blends with the aponeurosis of the internal abdominal oblique muscle to form the external sheath of the rectus abdominis muscle.

The internal abdominal oblique muscle is immediately under the external abdominal oblique. This muscle is well developed and occupies the entire flank region from the tuber coxae to the last rib. The internal abdominal oblique originates from the tuber coxae, lumbar transverse processes, and thoracolumbar fascia. Its fibers are directed cranioventrally. The fibers of the internal abdominal oblique insert into the costal cartilages or via an aponeurosis that fuses with that of the external abdominal oblique, which forms the external sheath of the rectus abdominis, which inserts into the linea alba.

The transversus abdominis muscle forms the deepest layer of the abdominal wall musculature. It is the least extensive and thinnest. The transversus abdominis arises from the transverse processes of the lumbar vertebrae and the medial aspect of the last ribs. It forms an aponeurosis at the lateral edge of the rectus abdominis muscle, becomes the inner sheath of the rectus abdominis, and ultimately inserts into the linea alba. The fibers run transversely at right angles to those of the rectus abdominis muscle. The transversus abdominis is covered on the inside by the transverse fascia and peritoneum.

The rectus abdominis muscle is confined to the ventral aspect of the abdomen and travels on either side of the linea alba. It originates from the costal cartilages of the ribs and sternum and inserts on the cranial pubic ligament. The fibers of the rectus abdominis are oriented in a sagittal direction. The rectus abdominis muscle lies within an aponeurotic sheath that is formed by the aponeuroses of the external abdominal oblique, internal abdominal oblique, and transversus abdominis muscles.

The linea alba is formed from the aponeuroses of the external abdominal oblique, internal abdominal oblique, and transversus abdominis. The linea alba extends from the xiphoid process and inserts on the prepubic tendon. It consists of dense connective tissue composed of sheets of collagen bundles and fibroblasts. The fibers of each sheet cross between each other, which adds to its mechanical strength. The thickness and width vary depending on the location relative to the umbilicus. The linea is much thicker and wider at the level of the umbilicus. It becomes thinner and narrower as it courses cranially.

APPROACHES TO THE ABDOMEN

When deciding on an approach to the bovine abdomen, the surgeon must consider the large size of the abdominal cavity and viscera and the fact that the viscera has mesenteric and omental attachments that limit mobility. Some portions of the intestinal tract can be exteriorized, some only palpated, and other portions are inaccessible (Figure 14-35). The surgeon must also consider the disease process when choosing an approach so that the organ(s) of interest can be accessed. Thus a careful diagnostic workup before surgery is imperative. Other factors such as value of the animal, available facilities, temperament of the patient, and experience of the surgical team all influence the chosen approach.

Most abdominal surgeries can be performed as standing procedures in the adult bovine patient by using local or regional anesthesia. Use of sedation or tranquilizers when performing standing surgery is not advisable because the cow might lie down during the procedure. However, in some instances general anesthesia or recumbency, sedation, and a local anesthetic are appropriate. For example, exploration of the small intestine in a valuable cow that is uncomfortable and reluctant to stand may warrant a recumbent approach. Use of perioperative antimicrobials and/or antiinflammatories is at the discretion of the surgeon.

Left-Paralumbar Fossa Celiotomy

This approach can be used to gain access to the rumen, reticulum, spleen, diaphragm, reproductive tract, bladder, left kidney, and abomasum in the case of a left-displaced abomasum. The cow should be restrained in stocks, a head gate, or a mobile restraining chute such as the Ohio Bovine Transporter (Figure 14-36). Securing the cow's tail so that it does not contaminate the surgical field during prepping or surgery is advisable. The left flank should be clipped and aseptically prepared, and local or regional anesthesia should be used to desensitize the surgical area. Sterile draping should follow.

The location of the skin incision is typically centered over the paralumbar fossa. The location can vary somewhat depending on the disease process. The skin incision is begun 6 to 8 cm ventral to the transverse processes of the lumbar vertebrae and 4 to 6 cm caudal to the last rib. The incision is made in a dorsoventral direction for a length of 20 to 25 cm. In the case of a cesarean section, the incision can be started more caudal in the paralumbar fossa and lower in the flank and will need to be longer in length (Figure 14-37). Once the skin and subcutaneous tissue have been incised, the external abdominal oblique muscle will be visible. Hemostasis is maintained by using hemostats and ligatures if necessary. All instruments and sponges should be moved off the surgical field before entry into the abdomen.

The external abdominal oblique muscle is incised in the same direction and for the same distance as the skin incision. The fibers of the internal abdominal oblique are now visible. This muscle layer is incised in the same manner as the external abdominal oblique. Because of the muscle fibers' direction, a tendency exists to incise the internal abdominal oblique muscle layer too far forward in the incision. The operator should strive to stay in the middle of the incision. The transversus abdominis muscle is encountered next. To prevent damage to underlying viscera upon entering the abdomen, it is helpful to "tent" the transversus abdominis by

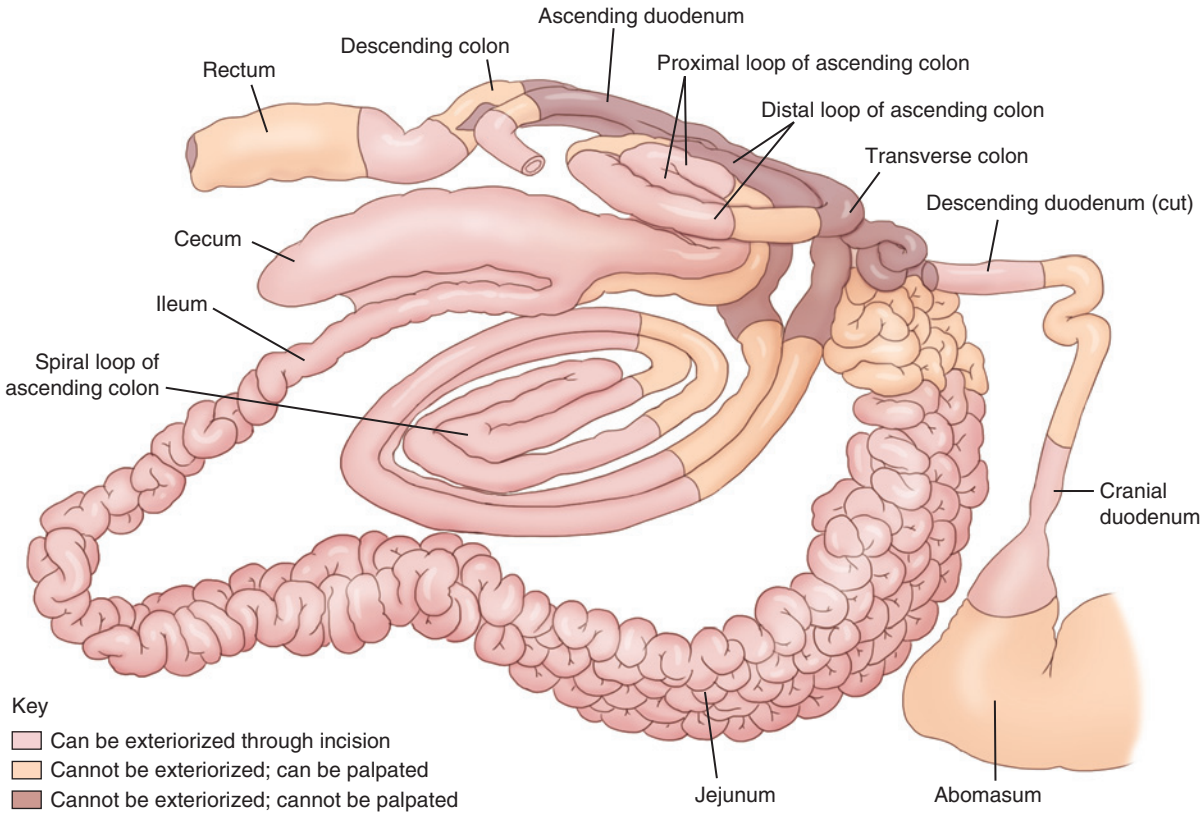


Figure 14-35 Schematic representation of the portions of the intestinal tract that can be exteriorized, some that are only palpated, and other portions that are inaccessible. (Reproduced with permission from Smith DF: Bovine intestinal surgery: Part 1. *Mod Vet Pract* 65: 853–857, 1984, p 855, Fig 2.)



Figure 14-36 The Ohio Cattle Transporter (Bud Corporation, Columbus, Ohio).



Figure 14-37 Left-paralumbar fossa incision (cesarean section).

using thumb forceps and to incise the muscle and peritoneum the length of the incision by using Mayo scissors.

A sterile impervious sleeve should be used to palpate the abdominal cavity. A systematic approach should be used when exploring the abdomen. Because inflammatory conditions are more likely to be in the cranial abdomen, the caudal abdomen is usually explored first. The reproductive tract, bladder, ureters, lymph nodes, and inguinal rings should be palpated. The left kidney is large and covered by fat. It is easily palpable in the left caudal abdomen almost on midline, adjacent to the descending colon.

On the left side of the cranial abdomen, the rumen, spleen, reticulum, and diaphragm should be palpated. The

presence of adhesions or abscesses in the area of the reticulum and diaphragm should be ascertained. The surgeon can palpate portions of the right side of the abdominal cavity by going behind the rumen and forward. The quality of the right-sided exploratory from the left side will depend on the size of the rumen and the cow's body size. A more thorough and informative exploratory of the right side of the abdomen can be done from the right side.

Closure of the flank laparotomy incision is done in four layers. The peritoneum and transversus abdominis are closed together with an absorbable suture (No. 1 or 2 in size) in a simple continuous pattern. The internal abdominal oblique and external abdominal oblique muscles are closed separately with an absorbable suture (No. 1 or 2 in size) in a simple continuous pattern. Between each layer of the closure, lavaging the muscles with sterile saline is advisable. The skin is closed with a nonabsorbable suture (No. 1 in size), a Ford interlocking pattern, and a few simple interrupted sutures at the ventralmost aspect of the incision. The simple interrupted sutures can be removed to facilitate drainage should an incisional infection develop (Figure 14-38).

Right-Paralumbar Fossa Celiotomy

This right-paralumbar fossa approach can be used to gain access to the pyloric part of the abomasum, the majority of the small and large intestines, the reproductive tract, the urinary bladder, and the kidneys. The restraint, preparation, and approach are the same as described in the left-paralumbar approach. If a pyloropexy is anticipated, the initial incision is made closer to the last rib in a more ventral location as described for the left-paralumbar fossa celiotomy (Figure 14-39).

A systematic approach to the abdominal exploratory is necessary. Again, exploration of the caudal abdomen first is recommended. This includes the reproductive tract, urinary bladder, left kidney, and descending colon. Cows typically urinate when the bladder is palpated.

In the cranial abdomen, the reticulum and diaphragm should be palpated for the presence of adhesions or abscesses. The omasum is identified caudal and medial to the reticulum. It should be filled with firm ingesta. The liver should be checked for rounded edges or irregularities. It is normal for the edges of the right lobe of the liver to be more rounded than the left lobe. The gallbladder is often enlarged in cattle that are anorectic. The position of the abomasum should be along the right body wall. The fundus and body of the abomasum normally contain fluid-consistency ingesta whereas the feed material in the pyloric portion is typically drier and doughier. The pylorus is palpable as a firm structure at the level of the costochondral junction of the ninth and tenth ribs. Normally it can be exteriorized along with 6 to 8 cm of distal abomasum. The cranial portion of the duodenum leaves the pylorus and courses toward the liver. This portion of the duodenum is covered by the superficial sheet of the greater omentum. The cranial part of the duodenum in a fat cow may be totally obscured by fat. The descending duodenum can be seen just deep to the abdominal incision, running horizontally across the abdomen. The right kidney is dorsal to the cranial portion of the descending duodenum underneath the last two ribs.

To examine the intestinal tract distal to the abomasum, the omental sling is pulled forward; the surgeon palpates the viscera, most of which is contained in the supraomental recess. The apex of the cecum is exteriorized after identifying it as a blind sac of intestine 4 to 8 cm in diameter and located near the pelvic inlet. In some cows, the apex normally is rotated in a ventral direction. The ileocecocolic junction and proximal colon can be exposed when the greater omentum is moved cranially. Once the cecum is exteriorized and rotated cranially (180 degrees), the spiral colon can be examined. The distal flange of the small intestine is examined by tracing the ileum orad. The distal flange should be replaced in the abdomen, and the surgeon should palpate the small intestine proximally to the duodenojejunal junction. If an abnormality is felt or suspected, that portion of the small intestine can be exteriorized and examined. The descending colon and rectum should be palpated. The surgeon can examine the left side of the abdomen by advancing his or her arm caudal to the omental sling and dorsal to the rumen. The spleen can be palpated in the upper left quadrant of the abdomen.

Factors that affect the surgeon's ability to examine the gastrointestinal tract include size of the animal, fat content, distention of a viscus, stage of pregnancy, and the length of the surgeon's arms.

Closure of the right-flank celiotomy incision is the same as described for the left-paralumbar fossa approach.



Figure 14-38 Drainage from an incisional infection. (Courtesy of Dr. Chris Beinlich.)



Figure 14-39 Right-paralumbar fossa incision.

Right-Paramedian Celiotomy

Access to the cranial abdomen is achieved with this approach. It is used primarily for correction of displacement of the abomasum, abomasal volvulus, or access to the reticulum. Rarely, a caudal paramedian celiotomy is used in a bull to access the urinary bladder. The incision is located 4 to 6 cm lateral to the ventral midline and 6 to 8 cm caudal to the xiphoid (Figure 14-40). The length of the incision is approximately 15 to 20 cm. The cow should be positioned and restrained in dorsal recumbency (Figure 14-41). The area from the xiphoid to caudal to the umbilicus is clipped and aseptically prepared, and local anesthesia is used to desensitize the surgical field. A sterile drape is placed and secured over the incision site. The skin and subcutaneous tissues are incised. Branches of the subcutaneous abdominal vein may need to be ligated to provide hemostasis. Often the caudal portion of the pectoral muscle is encountered at the rostral aspect of this approach. This muscle is divided to expose the external sheath of the rectus abdominis muscles. The external sheath is incised sharply for the length of the incision. The rectus abdominis muscle is exposed and incised along its fibers with a combination of sharp and blunt dissection. Thumb forceps are used to tent the internal sheath of the rectus abdominis muscle, and Mayo scissors are used to incise this layer. Once the incision has entered the abdominal cavity, the surgeon can use his or her fingers to protect underlying viscera while extending the incision.

An impervious sleeve is used for the abdominal exploratory. The abomasum is usually positioned under the incision unless it is displaced or the rumen is gas distended. The rumen and abomasum are identified and gas decompressed. This can help the ventilatory capacity of the cow and provide more room for surgical manipulations. The liver is palpable on the right side of the abdomen, the spleen on the left. The diaphragm is swept to check that it is intact. The omasum is present lateral to the abomasum and typically has firm ingesta. The abomasum is exteriorized with gauze sponges and the greater curvature followed from the pylorus to the reticulum (Figure 14-42). Access to the remainder of the intestinal tract is very limited, and another approach should be chosen if other abdominal organs need to be examined.

The peritoneum and internal sheath of the rectus abdominis muscle are closed together. If an abomasopexy is to be performed, the seromuscular layer of the abomasum is included in this layer closure. The suture material used for this layer can be a nonabsorbable or absorbable material (No. 2 or No. 3 in size), depending on the surgeon's preference. The rectus abdominis muscle is closed with an absorbable suture material (No. 1 or 2 in size) in a simple continuous or interrupted pattern. The external sheath of the rectus abdominis muscle is the holding layer of the closure. Closure of this layer is accomplished by using an absorbable suture material (No. 2 in size) in a simple continuous or interrupted pattern. Closure of the skin is performed by using a nonabsorbable suture material (No. 1 in size) in a Ford interlocking pattern (Figure 14-43).

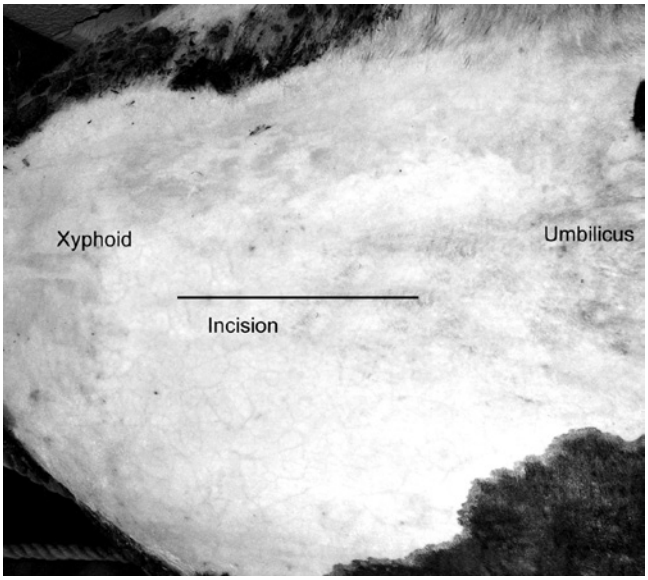


Figure 14-40 Diagram that shows the location of a right-paramedian incision.



Figure 14-41 Cow positioned and restrained in dorsal recumbency (using sedation and casting rope).

Ventrolateral Celiotomy

This approach is especially useful in accessing the uterus for a hysterotomy in the case of an emphysematous fetus. The incision is made laterally to the subcutaneous abdominal vein (milk vein) and extends caudally, curving dorsally,

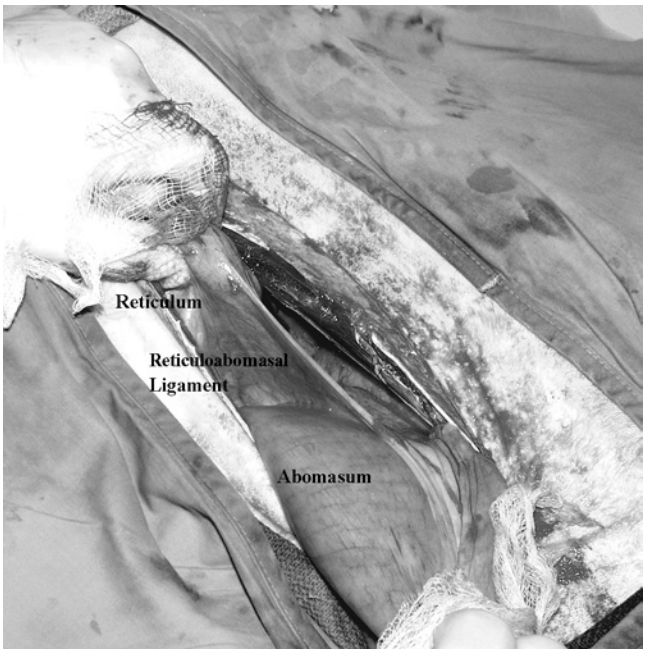


Figure 14-42 Exposure of the abomasum, reticuloabomasal ligament, and reticulum through a right-paramedian incision.

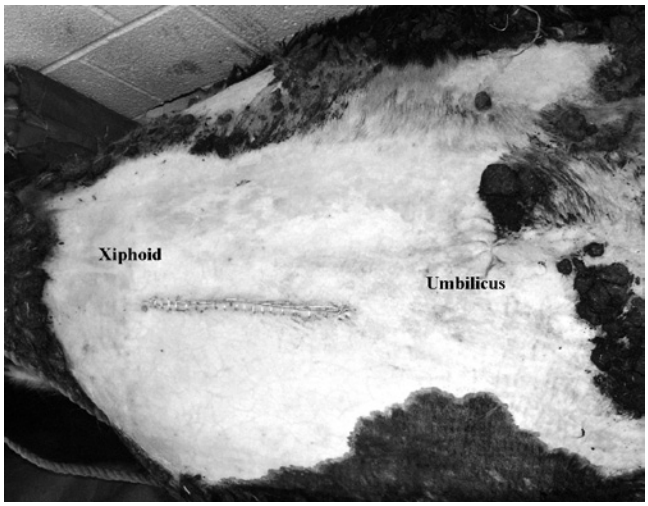


Figure 14-43 Skin closure of a right-paramedian incision.



Figure 14-44 Left-ventrolateral celiotomy incision.

staying lateral to the attachment of the udder. The length of the incision depends on the amount of exposure needed (Figure 14-44). The subcutaneous abdominal vein should be marked with sutures before positioning the cow in lateral recumbency. This is helpful to avoid lacerating the vein during the approach because its location will not be as obvious when the cow is recumbent. The cow is restrained in lateral recumbency with the upper hind limb abducted and secured so the inguinal area and base of the udder are accessible. The area from the xiphoid cartilage to the inguinal region should be clipped and aseptically prepared. Local anesthesia should be used to desensitize the region, and the surgical site should be draped for aseptic surgery. The skin incision is made and the subcutaneous tissues are divided to expose the external sheath of the rectus abdominis muscle. This layer is sharply incised, thereby exposing the rectus abdominis muscle, which is opened along its length by splitting muscle fibers with a combination of sharp and blunt dissection. Extreme caution should be used when entering the abdominal cavity. The gravid uterus is usually beneath the peritoneum. The internal sheath of the rectus abdominis muscle is elevated by using thumb forceps and then incised by using Mayo scissors. The surgeon's fingers work best to protect underlying viscera when opening this final layer. The incision can be lengthened cranially or caudally to provide the necessary exposure. This approach provides excellent



Figure 14-45 Ventral midline cesarean section.

exposure to the uterus at the expense of a time-consuming and difficult body wall closure. The caudal aspect of the incision will not have as many layers as the cranial portion of the incision because caudally the abdominal muscles are largely aponeurotic. The layers at the cranial aspect of the incision will include the peritoneum, rectus abdominis muscle, and internal and external sheaths of the rectus abdominis muscle. The external sheath of the rectus abdominis muscle is the holding layer for closing this incision. The surgeon can close the internal sheath of the rectus abdominis muscle with an absorbable suture (No. 2 in size) in a simple continuous pattern. However, this layer often does not hold sutures well; therefore the suture can tear through the tissues. One can choose not to close this layer and begin by closing the rectus abdominis muscle with an absorbable suture material (No. 2 in size) in a continuous or interrupted pattern. The external sheath of the rectus abdominis muscle is closed by using an absorbable suture material (No. 2 or No. 3 in size) in an interrupted or simple continuous pattern. This fascial layer is the most critical for providing body wall support. Tension-relieving suture patterns such as near-far-far-near can be used if necessary. Finally, the skin is closed with a nonabsorbable suture material (No. 1 in size) in a Ford interlocking pattern. Lavage of the soft tissue between closure layers is advisable. Seroma and periincisional edema are very common with this approach.

Ventral Midline Celiotomy

Ventral midline celiotomy can be used for cesarean section (Figure 14-45). In cattle that have very large and branching subcutaneous abdominal veins the surgeon can avoid them by using this approach. The linea alba is composed of dense fibrous tissue that provides a secure closure and makes enlarging the incision, if necessary, easy. The cow is restrained in dorsal recumbency, and the ventral abdomen from the umbilicus to the udder and extending to the folds of the flank is clipped, aseptically prepared, and draped for surgery. Local anesthesia is used to desensitize the area. The skin incision is started at the umbilicus and extended caudally. The incision is continued through the subcutaneous tissue to the level of the linea alba. A small incision made through the linea alba and peritoneum, carefully avoiding underlying viscera, provides access to the abdomen. In some instances substantial retroperitoneal fat must be dissected before the peritoneum can be seen. The surgeon can use a finger to determine whether adhesions are present at the entry incision. The incision through the linea alba is continued caudally. The surgeon can use an instrument such as a thumb

forceps to protect underlying viscera as the incision is extended. A sterile impervious sleeve should be used for exploration. When using a ventral midline celiotomy for cesarean section, some operators advocate tilting the cow 45 to 60 degrees to facilitate delivery of the calf. This approach may be especially useful for fractious beef cattle.

Closure of the incision should be in three layers. The linea alba is closed with No. 2 or No. 3 absorbable suture material in a simple continuous pattern or an interrupted pattern. The subcutaneous layer is closed using No. 0 absorbable suture material in a continuous pattern. The skin is closed using No. 1 nonabsorbable suture in a Ford interlocking pattern.

Right Paracostal Approach

This approach provides access to the abdomen through the low flank. It can be used to gain access to the abomasum in adult cattle and calves. Because of the smaller and more mobile gastrointestinal tract in calves a more thorough exploratory can be performed in comparison to that for adult cattle. The animal is placed in left lateral recumbency under general anesthesia. The area is clipped, prepped, and draped in routine fashion. The skin incision is made parallel and 5 to 10 cm (in adults) caudal to the last rib. The length of the incision will vary depending on the surgical exposure needed. After the skin and subcutaneous tissues are incised the aponeurosis of the external abdominal oblique is exposed and incised in the direction of the skin incision. The muscular portion of the internal abdominal oblique may be encountered dorsally and the aponeurotic portion ventrally. This depends on the location of the incision. Once the internal abdominal oblique muscle/aponeurosis is incised in the direction of the skin incision the transversus abdominis should be tented with thumb forceps and incised with Mayo scissors. Access to the abdomen is completed by incising the peritoneum and transversus abdominis together.

Closure of the incision is accomplished by suturing the transversus abdominis and peritoneum as the first layer with an absorbable suture material. The suture size will depend on the size of the animal. The subsequent muscle/aponeurotic layers should be closed separately with an absorbable suture material of appropriate size. The skin is closed using a nonabsorbable suture material in a Ford interlocking pattern. The closure of the aponeurosis of the external abdominal oblique muscle is the strongest layer of this closure.

Left Oblique Celiotomy

A left oblique celiotomy has been recommended for cows requiring cesarean section (see Chapter 16). The skin incision starts 10 cm ventral to the transverse processes of the lumbar vertebrae and angles forward to finish at the level of the costochondral junction. The abdominal oblique muscles are sharply incised in the same direction. The transversus and peritoneum are tented as for the other approaches and are incised with scissors.

It has been suggested that this approach extends farther cranial and ventral than the classical flank approaches, thus permitting superior manipulation and exteriorization of the uterus. In 18 standing cows, closure of the abdomen was easily accomplished. Three cows developed incisional complications, and persistent anesthesia of the body wall was noted.

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SURGERY OF THE RUMINANT FORESTOMACH COMPARTMENTS

Wade Walker

ANATOMY AND PHYSIOLOGY

The three nonglandular forestomach compartments in the cow are the rumen, reticulum, and omasum. The abomasum is the true "stomach" and has a glandular mucous membrane. The rumen occupies most of the abdomen's left side; its long axis extends from ribs seven to eight to the pelvis. The reticulum lies against the diaphragm left of midline opposite the sixth to eighth ribs, and the omasum is right of midline at the ventral aspect of ribs 7 to 11. The abomasum lies mostly right of midline and extends from the xiphoid area to the ninth or tenth intercostal space in the nonpregnant cow. The cardia opens dorsal to the fundus of the reticulum. The reticular groove is located on the right wall of the reticulum and joins the reticuloomasal orifice. The omasal groove is on the left wall of the omasum and joins the omasoabomasal orifice.

In the newborn calf, the abomasum is twice as large as the rumen. The rumen becomes about nine times as large as the abomasum over the first year of life as a result of the mechanical stimulus of roughage in the diet and the chemical charges associated with fermentation.

The vagus nerve, which is made up of 90% sensory fibers, is the primary innervation of the forestomach compartments and abomasum. The dorsal vagal trunk innervates the rumen, caudal aspect of the reticulum, omasum, and visceral surface of the abomasum. The ventral vagal trunk supplies the reticulum, parietal side of the reticuloomasal junction, omasum, and abomasum.

The forestomach compartments, especially the rumen, are sites of microbial fermentation. The rumen or reticulum movement allows mixing of ingesta as well as regurgitation, eructation, and passage of ingesta into the omasum. The omasum acts as a pump that aspirates ingesta and transfers it to the abomasum. The abomasum behaves similarly to the stomach of a nonruminant. Digestive enzymes in the abomasum are responsible for the next phase of digestion.

ETIOLOGY AND PATHOGENESIS

Disorders of the rumen and forestomach compartments in adult cattle can result from a variety of causes, including

those that are dietary, inflammatory, and/or mechanical. A diet inadequate in roughage, coarse feed, and grain overload are examples of dietary causes of forestomach disease. Cattle's indiscriminate eating habits make them susceptible to inadvertent ingestion of foreign bodies with subsequent penetration of a forestomach compartment. Foreign-body ingestion results in localized reticuloperitonitis, which is called *traumatic reticuloperitonitis* (TRP). Wires account for approximately 70% of ingested foreign bodies. Nails and steel objects make up the other 30%. Regardless, most foreign bodies are ferromagnetic, which argues for therapeutic or prophylactic administration of magnets. The use of magnets placed in feeders or administered prophylactically to cattle explains why the prevalence of TRP has noticeably decreased in the past two decades.

Acute TRP results in stasis of the forestomach compartments. If the foreign body continues to migrate, many disease entities can result, including perforation of a gastrointestinal viscus, pericarditis, and myocarditis. A more chronic possible sequela to TRP is the formation of adhesions that physically interfere with the vagal nerve, thus resulting in permanent forestomach dysfunction. Another sequela to TRP is cranial abdominal or thoracic abscess formation. In addition to clinical signs associated with chronic infection, the cranial abdominal abscess can result in mechanical obstruction of the reticuloomasal passage and forestomach dysfunction until it is treated. Depending on its size and location, a thoracic abscess may impair ventilation or result in cardiac signs if compression of the pericardium occurs. Other causes of forestomach dysfunction are seen when trichobezoars or ingested foreign bodies, such as plastic bags or placenta, cause a mechanical obstruction by lodging in the reticuloomasal orifice. In addition, neoplasia, predominantly lymphosarcoma, can affect vagal innervation by infiltration or, more commonly, involvement of the pyloric area, thus mechanically obstructing the abomasum. Finally, it must be remembered that the vagus nerve can be damaged or inflamed in areas other than the abdomen (including the pharynx, larynx, esophagus, and thoracic cavity), so a disease process near the vagal nerve in any of these locations can result in ruminal dysfunction and is termed *vagal indigestion*. It follows that many forestomach disorders that are termed *vagal indigestion* are not caused by actual damage to the vagal nerves but may be mechanical, inflammatory, or functional disorders that result in an outflow obstruction. Regardless, clinical presentation of vagal indigestion encompasses most common forestomach disorders.

VAGAL INDIGESTION

Historically, vagal indigestion has been classified two ways by different authors. Hoflund's classification is as follows:

Type 1—functional stenosis between reticulum and omasum with atony of the rumen and reticulum
Type 2—functional stenosis between reticulum and omasum with normal or hypermotile rumen and reticulum
Type 3—permanent functional stenosis of the pylorus with atony or retained activity of the reticulum
Type 4—incomplete pyloric stenosis

Ferrante and Whitlock's classification is as follows:

Type 1—failure of eructation or free-gas bloat
Type 2—omasal transport failure
Type 3—abomasal impaction
Type 4—partial obstruction of the stomach

Hoflund's classification was introduced after experimentally sectioning various segments of the vagal nerve. In our experience with Ferrante and Whitlock's classifications, the clinical differentiation between Types 3 and 4 is unclear. We have modified the Ferrante and Whitlock classification based on our clinical experience to align it better with treatment strategies.

Cornell Classification of Vagal Indigestion in Cattle

Type I involves failure of eructation, which results in gaseous distention of the rumen. This may result from mechanical obstruction of the esophagus and cardia. Type I indigestion may also result from physiologic disturbance of the eructation mechanism associated with diet or immaturity. Treatment entails placing a rumen fistula to remove the obstruction and/or ruminal gas until normal physiologic function returns.

Type II involves failure of omasal transport that results in distention of the reticulum and rumen with gas and well-mixed feed and fluid. The causes are multiple and range from mechanical intraluminal obstruction of the reticuloomasal orifice, mechanical extraluminal obstruction of the reticuloomasal groove by a mass (abscess) and adhesions, and neurogenic denervation of the ruminoreticulum innervation (that is, the vagal nerve). Efforts should be directed toward identifying and removing the cause. A left-paralumbar fossa exploratory and rumenotomy are typically required.

Type III involves failure of normal abomasal outflow, which results in dilation of the forestomach compartments with fluid and ingesta; the abomasum is filled with fluid or firm ingesta. This may be caused by neurologic or neuromuscular deficits of the abomasum caused by damage to its innervation (vagal nerve, long pyloric nerve); mechanical obstruction of the pylorus or proximal duodenum; coarse feed or adhesions (secondary to TRP) that result in abomasal impaction; or severe abomasal volvulus that caused neuromuscular damage to the wall of the abomasum. Treatment entails right paralumbar fossa or paracostal celiotomy to correct the primary problem if possible.

Clinical Findings

General clinical signs include decline in milk production and appetite. Rumen motility is decreased or absent, and ruminal distention may occur. Feces become scant. With chronic cases, feed intake and fecal output decrease. Milk production is low and a rough hair-coat develops. Chronic left-flank distention and weight loss may become apparent. Other clinical signs are related to the initial causes of forestomach dysfunction. Cattle affected with acute traumatic reticuloperitonitis often have fever with mild elevations in heart and respiratory rates. The decline in milk production and appetite is sudden. A sharp cranial abdominal pain may be noted when xiphoid pressure is applied or the withers are pinched. By 3 to 4 days, the abdominal pain and pyrexia may subside to some extent as the inflammatory reaction lessens and the cow localizes the process.

From a surgical perspective, forestomach disorders manifest in three main ways. In the three types of vagal indigestion (Cornell classification as described previously), clinical signs of outflow obstruction from the rumen and/or forestomach compartments occur. These can be detected clinically by external examination of the contour of the abdomen, ultrasound and rectal examination, and identification and characterization of the source of the distended abdomen: which organ is distended and is the source of distention fluid or gas. Type I animals develop distention high and low in the left-paralumbar fossa and if untreated eventually develop respiratory dyspnea caused by compression of the diaphragm.



Figure 14-46 Cow with distention high and low in the left-paralumbar fossa and low in the right as the rumen distends as seen in Type II and III vagal indigestion forestomach disorder.

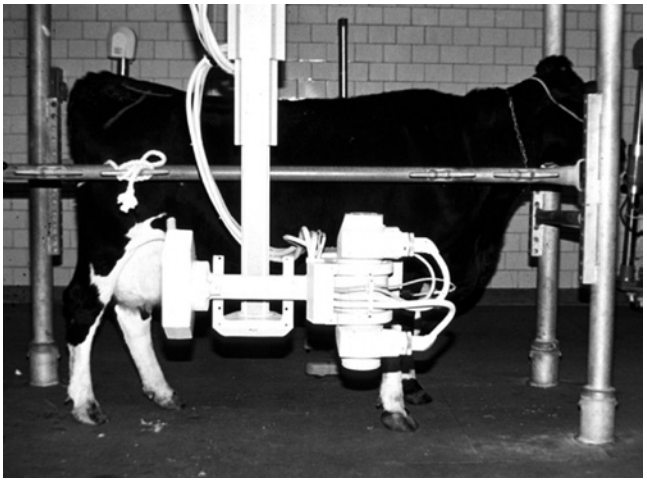


Figure 14-47 A dairy cow in place for a standing radiographic study of the cranial abdomen.

Simultaneous auscultation with percussion and rectal examination identify the rumen as being gas distended. Cattle with Type II and III vagal indigestion develop abdominal distention high and low in the left-paralumbar fossa and low in the right as the rumen distends (Figure 14-46). Rectal examination identifies the rumen as being distended by liquid ingesta and gas. In addition, enlargement of the ventral sac of the rumen extending to the right side of the abdomen is identified. Distention of the abomasum differentiates Type II from III and can be assessed by ultrasonography. Cattle may have bradycardia (heart rate <60 beats/min) with both these types of disorders, presumably because of increased vagal tone and anorexia.

Once the diagnosis of a forestomach disorder is made, signs of the primary cause of the disease should be sought. For Type I disorders, signs of esophageal obstruction such as head extension and salivation may be present. In Type II, carbohydrate overload could lead to fluid distention of the rumen and reticulum, low ruminal pH, and metabolic acidosis. Lesions of the reticulum that involve the vagus nerve are typically located on the right or medial wall of the reticulum and include TRP (presence of radiodense foreign body in the cranial abdomen), adhesions in the cranial abdomen (ultrasonographic or surgical findings), reticular and liver abscesses (ultrasound or radiographic examination, elevated serum total protein), and neoplasia—such as lymphosarcoma—located around the reticuloomasal junction.

Type III vagal indigestion can be associated with a primary abomasal impaction, a foreign-body obstruction, a pyloric lymphosarcoma, or a functional duodenal obstruction. It can be related to previous surgery for abomasal volvulus that caused a stretch or ischemia of the vagal nerves. In many instances, a specific diagnosis can only be made after a left-paralumbar fossa exploratory celiotomy and rumenotomy is performed.

Clinical Pathology

In cattle with acute TRP, a neutrophilia (neutrophils >4000/μL) with a left shift is typically seen. Plasma fibrinogen levels are often elevated (>1000 mg/dL; normal, 300 to 600 mg/dL). With chronic disease, elevations in total protein and serum globulins are expected. One author reported that total protein elevation was so important that an elevation above 10 g/dL in cattle with abdominal disease was highly suggestive of TRP. Acid-base and electrolyte abnormalities will vary depending on the location of the obstruction (Type I to III), duration of disease, and nature of treatment given. Therefore cows with acute, untreated Type I vagal indigestion generally have no electrolyte disturbance. Severe cases or those suffering from ventilation failure associated with severe abdominal distention require immediate attention. Cattle with Type II initially have no electrolyte disturbance. Over a few days, hypokalemia occurs because of decreased feed intake and extracellular fluid shifts. Apparently, ruminal function can no longer maintain the normal plasma/rumen chloride gradient; therefore rumen chloride ions increase. This leads to a hypochloremic, hypokalemic metabolic alkalosis. Type III indigestion has chloride ions sequestered (to various degrees) in the abomasum so hypochloremic, hypokalemic metabolic alkalosis is typical.

Abdominal fluid analysis may help determine whether there is an inflammatory process in the abdomen. The technique is described in the physical examination chapter (Chapter 1). Elevations in white blood cells (>6000 cells/μL) and total protein (>3.0 g/dL) indicate an inflammatory response. It is important to remember that cattle are efficient in localizing an infectious abdominal process, so the amount of abdominal fluid can vary in different regions of the abdomen. Therefore ultrasound examination is useful to increase the value of abdominocentesis in cattle.

Radiography can help identify perforating foreign bodies in the reticular area. With the animal standing, a horizontal beam is centered on the reticulodiaphragmatic region in the cranioventral abdomen/caudoventral thorax (Figure 14-47). Radiographs obtained allow the identification of radiopaque foreign bodies and gas/fluid interfaces typical of an intraabdominal abscess (Figure 14-48*A* and *B*). However, false negatives and false positives are possible. Diagnosis of a foreign-body penetration can only be made with certainty if the foreign body can be seen beyond the confines of the reticulum (Figure 14-49). In one study, if a foreign body was detected as superimposed within the reticular wall and not on the floor of the reticulum, the probability of perforation was almost 100%. Another report of radiographs of the reticulum in a large number of cattle showed that the most

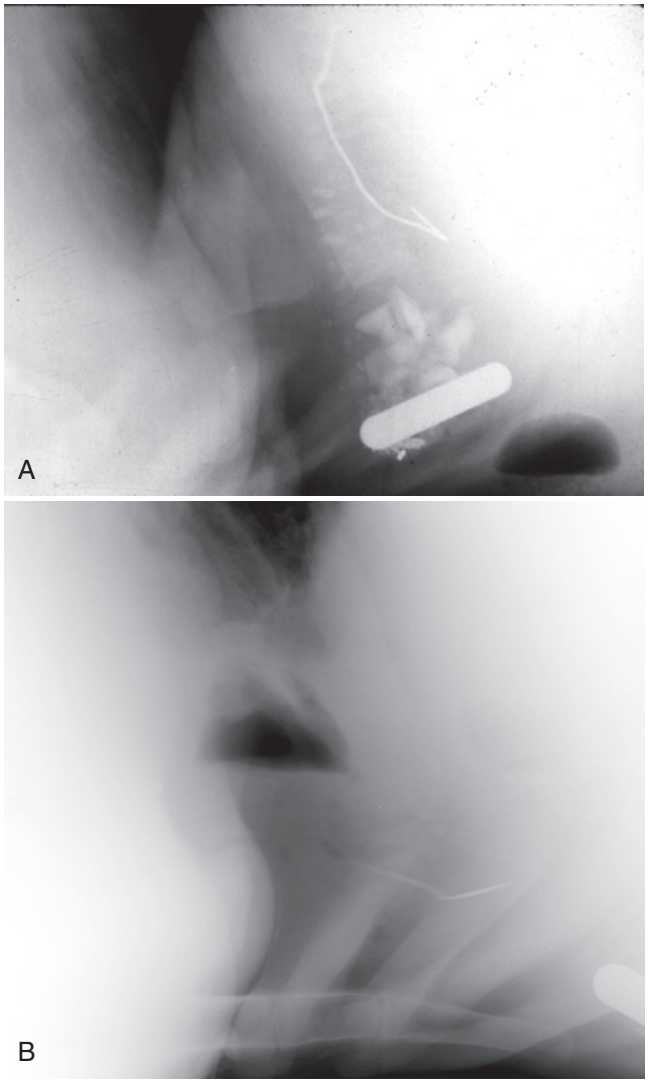


Figure 14-48 *A*, Radiographs of the cranial abdomen of a cow with traumatic reticuloperitonitis allows identification of radiopaque foreign bodies and gas-fluid interfaces typical of an intraabdominal abscess. *B*, Radiographs of the cranial abdomen of a cow with traumatic reticuloperitonitis and thoracic abscess. Note that the foreign body is in the thoracic cavity and there is a gas/fluid interface typical of a thoracic abscess. (Courtesy of Dr. Stephanie Nykamp.)

reliable features of a perforating foreign body were those that were positioned atypically and had abnormal gas shadows and depressions in the cranioventral margin of the reticulum. Obtaining standing lateral, horizontal-beam radiographs on an adult cow requires specialized equipment (machines capable of 125 kVp and 40 mAs). Another less convenient option is to place the cow in dorsal recumbency with the beam centered over the same area. Penetrating foreign bodies do not move with the ingesta; thus they become surrounded by gas in the reticulum. A foreign body seen in the ventral aspect of the reticulum while the animal is in dorsal recumbency (Figure 14-50) confirms the penetrating foreign-body diagnosis. A portable unit can yield diagnostic radiographic films of the reticulum with the animal in dorsal recumbency, but not with the animal standing. (Equipment would need capabilities of 75 kVp and 30 mAs; more details are in Chapter 2.)

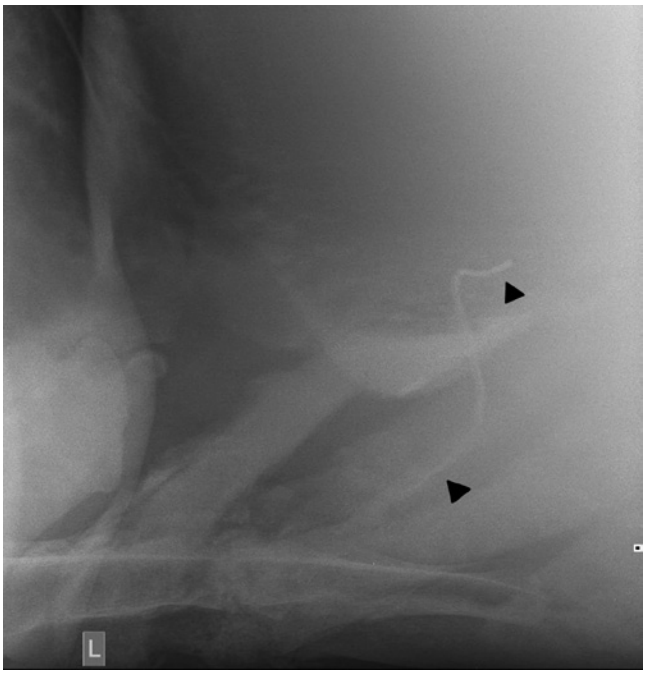


Figure 14-49 Radiograph of the cranial abdomen of a cow with a metallic foreign body within the reticulum and penetrating ventrally into an abdominal abscess causing localized peritonitis (*black arrowheads*). Note there is no magnet in the reticulum.



Figure 14-50 Radiographs of the cranial abdomen of a cow with suspected traumatic reticuloperitonitis. Even though no foreign body is seen, the image quality obtained when a cow is in dorsal recumbency prohibits any certainty that no penetrating foreign body or abscess is in the area.

Ultrasound examination of the normal reticulum has been described (Braun, 1993). In another report the same author described diagnosis of a cranial abdominal abscess in five cattle examined with a 3.5-MHz linear transducer. An example of this is given in Figure 14-51. Abscesses such as these can be drained either with percutaneous drain placement or via rumenotomy into the rumen as described later. The abscesses can be followed after surgery, with ultrasound, to determine the success of the drainage procedure.

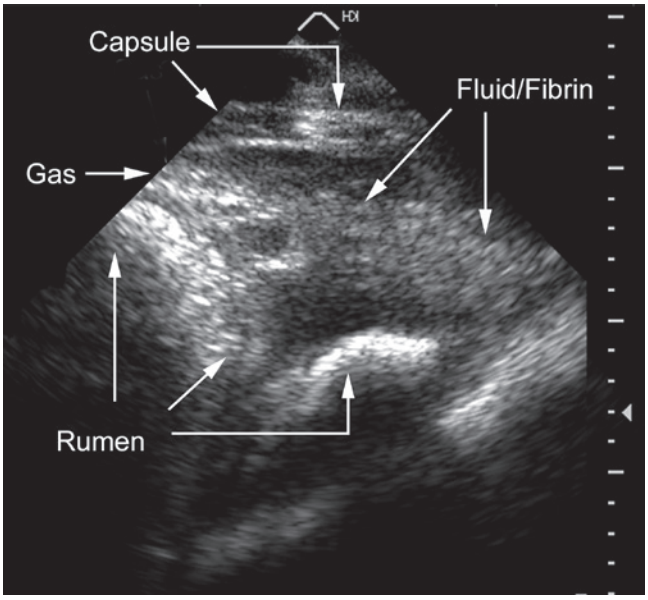


Figure 14-51 Transverse sonogram made on the ventral midline of the cranial abdomen obtained from an adult Holstein cow with a 2- to 4-MHz convex probe. Between a forestomach compartment and the body wall, a peritoneal abscess cavity contains fibrin, fluid, and gas. Surrounding this cavity is a well-circumscribed capsule.

Medical Treatments

Type I medical treatment is directed at gas decompression of the rumen. Orogastric intubation is performed first to ensure a patent digestive tract oral to the reticulum-rumen. If an obstruction is found in the esophagus, attempts should be made to push the obstruction into the rumen by using a stomach tube and water. Care must be taken to prevent inadvertent aspiration of lavage fluid and secretion into the trachea (that is, the head is kept low and a conservative amount of fluid is used only if necessary). Dietary changes are instituted if no obstruction or other abnormality is found during examination.

In Types II and III, a search is made for the cause. In traumatic reticuloperitonitis cases, medical treatment is directed at preventing perforation of the reticulum and treating the septic reticulitis and peritonitis. Oral administration of a good-quality magnet fixes ferromagnetic foreign bodies. A magnet administered orally falls into the cranial sac of the rumen, but normal ruminal contractions usually bring the magnet to the reticulum. Foreign bodies still partially in the lumen of the reticulum that have injured the reticular wall are attracted to and fixed to the magnet, thus preventing their migration from continuing and most times returning the foreign body into the lumen of the reticulum. Ancillary therapy includes stall confinement, fluid therapy, and broad-spectrum antibiotics. In approximately half the cases, the perforating foreign body does not remain in the wall of the reticulum but returns to the lumen, which makes medical treatment of traumatic reticuloperitonitis successful.

Use of a magnetic metal retriever to remove ferromagnetic foreign bodies has been advocated by some. This instrument consists of a large magnet attached to a wire cable that passes through a plastic tube. It is passed orally through the esophagus into the reticulum where the magnet attracts ferromagnetic foreign bodies. Concern about esophageal and pharyngeal trauma has limited this instrument's popularity.



Figure 14-52 Stainless steel trocar.

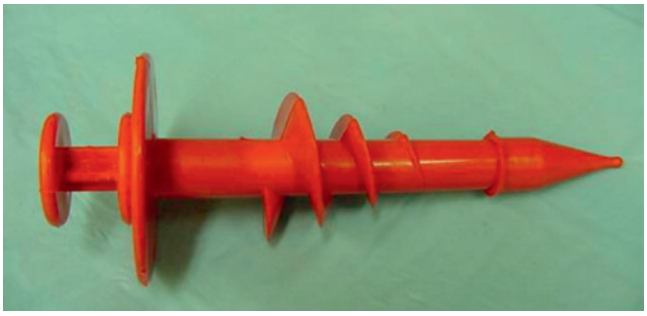


Figure 14-53 Corkscrew plastic trocar

In cases of abomasal impaction (Type III), mineral oil and other laxatives can be administered in an attempt to relieve the impaction. Water restriction can occur in a cold climate from freezing, so one should ensure a good water supply. Other causes of Types II and III forestomach disorders usually require surgical intervention.

SURGICAL TREATMENT

Three surgical approaches are used to treat cattle with vagal indigestion. For Type I vagal indigestion (failure of eructation and free gas bloat), placing a rumen trocar, cannula, or fistula is indicated (Figures 14-52 and 14-53). Left flank celiotomy and rumenotomy are used as a diagnostic procedure for Type II and III vagal indigestion in cases of traumatic reticuloperitonitis in which an animal fails to respond to conservative therapy or if a perireticular abscess is suspected. A right flank, right-paramedian (in lateral recumbency), or right paracostal celiotomy is used in type III vagal indigestion as a diagnostic procedure, to treat abomasal impaction, or to manage pyloric obstruction and dysfunction.

Left-Flank Celiotomy

The left flank is prepared for aseptic surgery with the patient restrained in standing stocks. Anesthesia is achieved by infiltration with a local anesthetic in a line block, inverted-L block, or paravertebral block.

A 20- to 25-cm dorsoventral skin incision is made 4 cm caudal and parallel to the last rib and 6 to 8 cm ventral to the transverse process of the lumbar vertebrae. It is important to locate the incision as close to the ribs as possible to

allow a more complete examination of the cranial abdomen. The few centimeters gained over a midparalumbar incision may be critical when the surgeon's arm is placed through thevincision and rumenotomy to palpate the reticulum and reticuloomasal canal, especially in a large cow. However, one must be careful not to place the incision any closer to the ribs than described previously, because rumenotomy is a clean-contaminated procedure and postoperative incisional infection with osteomyelitis is possible. The subcutaneous tissues, external and internal oblique muscles, transversus muscle, and peritoneum are incised in the same plane. When possible, a sterile, impervious sleeve should be used for palpating the abdominal cavity. The caudal abdominal cavity is explored first, including the urinary bladder, uterus, left kidney, dorsal and ventral sacs of the rumen, and intestinal mass. To reach the cranial abdomen the arm is passed ventral to the superficial layer of the greater omentum and directed cranially to locate the pylorus and pyloric part, body, and fundus of the abomasum, the omasum, and the reticulum. All parts of the reticulum must be palpated to verify whether adhesions and/or abscesses are present. The right side of the reticulum and left lobe of the liver (Figures 14-54 and 14-55), where abscesses are most often found, must be critically evaluated. The diaphragm, apex, and parietal surface of the spleen are also palpated.

Any adhesions found in the cranial abdomen must be assessed with gentle palpation to avoid disruption and minimize the risk of spreading inflammation. Adhesions in the cranial abdomen are more typical of traumatic reticulitis as the cause of peritonitis. Adhesions along the ventral body wall are more likely to be caused by perforating abomasal ulcers. If extensive cranial abdominal adhesions or ruminal distention prevent adequate palpation, a rumenotomy should be performed. Two procedures have been used to secure the rumen to the skin: the rumen board, or Weingarth apparatus, and suturing the rumen to the skin. The rumenotomy site is in the dorsal sac of the rumen using both techniques.

Rumenotomy with the Rumen Board or Weingarth Apparatus

Because use of the rumen board and Weingarth apparatus is similar, only use of the rumen board will be described.

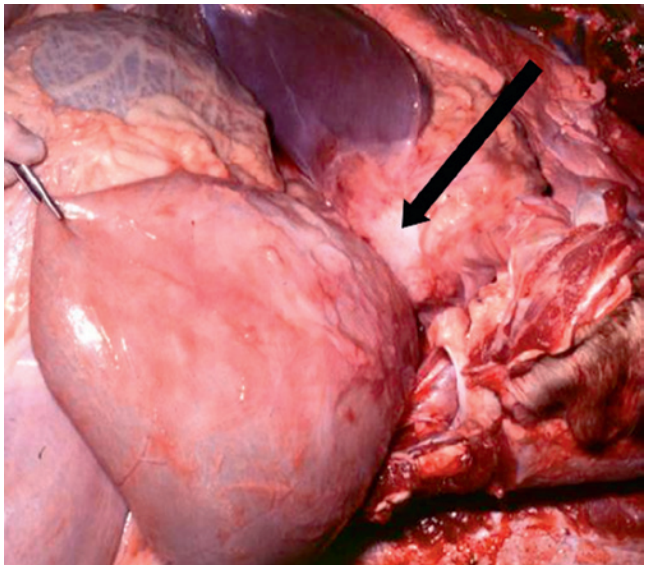


Figure 14-54 Postmortem specimen viewed from the right side. The reticulum is reflected caudally. Note the abscess (*arrow*) adjacent to the ventral part of the left lobe of the liver.

The wall of the dorsal sac of the rumen is grasped with two large noncrushing rumen forceps at a 12 and 6 o'clock position. These forceps are hooked on the dorsal and ventral aspect of the rumen board. This allows exteriorization of a portion of the rumen wall (Figure 14-56). The rumen wall is incised dorsally. The rumen hooks are implanted in the cut edges of the rumen and attached securely to screws and nuts placed at regular intervals along the rumen board. The incision is continued ventrally, and the hooks are placed at regular intervals to secure the rumen wall to the rumen board down to the level of the ventral forceps (Figure 14-57). This procedure can be done quickly without assistance. Care must be taken during intraruminal palpation not to contaminate the inner surface of the board, which is in direct contact with the abdominal cavity. Placing a wound ring[6] before exploring the lumen of the rumen helps decrease contamination.

Rumenotomy after Suturing the Rumen Wall to the Skin

The goal of rumenotomy is to obtain a good seal between the skin and rumen, so that even if ruminal contents escape the incision, no abdominal contamination will occur. As one makes the seal, it is important to exteriorize a generous part of the rumen so the rumenotomy incision can be closed without disrupting the rumen-to-skin seal. Otherwise, the seal will have to be undone to close the rumen, which increases the possibility of abdominal contamination. The dorsal sac of the rumen is grasped by an assistant and exteriorized with forceps or moist sponges. Starting at the dorsal aspect, the rumen is sutured (usually with a nonabsorbable monofilament #1 suture) to the skin with a simple continuous pattern and to the rumen with a Cushing-type pattern (Figure 14-58). A cutting needle should be used so

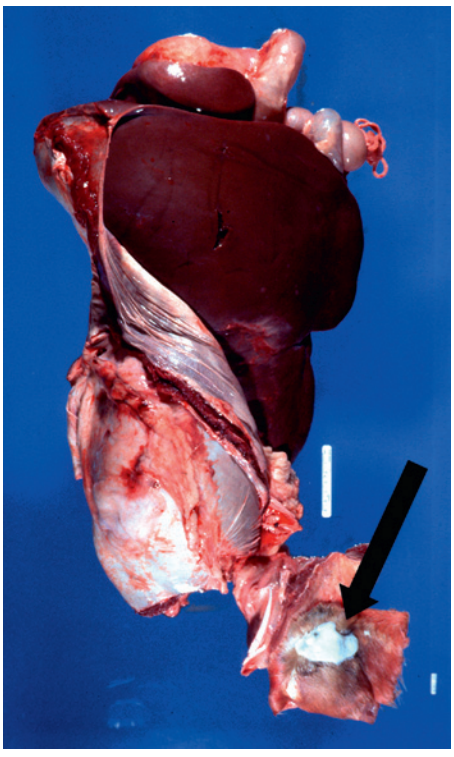


Figure 14-55 Postmortem specimen that shows an abscess adjacent to the left lobe of the liver with a draining tract at the skin (*arrow*).

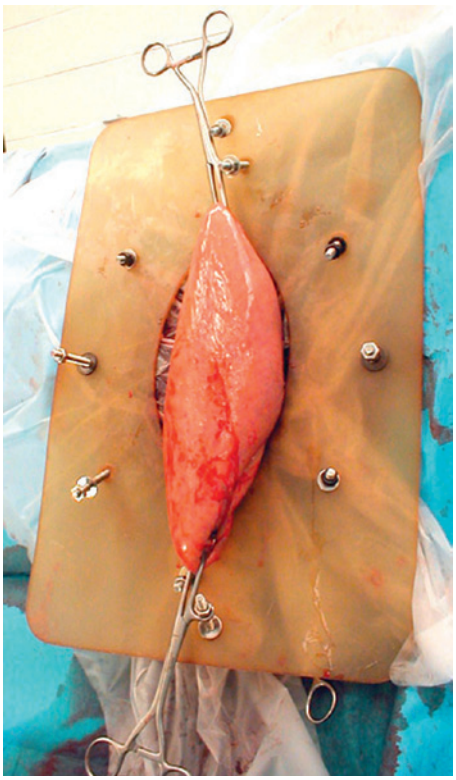


Figure 14-56 Rumen forceps are hooked on the dorsal and ventral aspect of the rumen board. This allows exteriorization of a portion of the rumen wall.

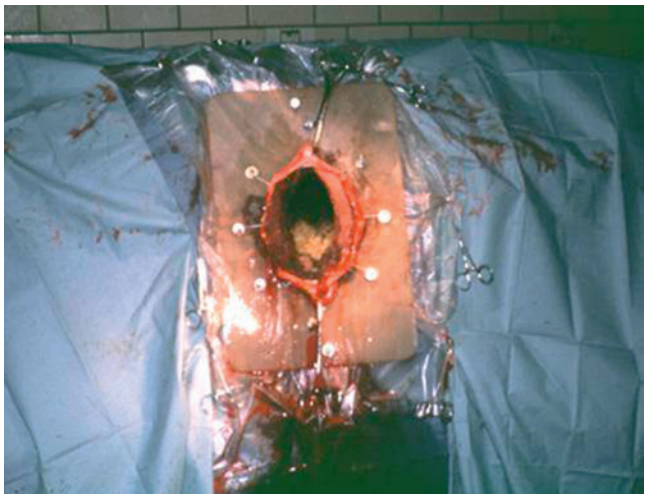


Figure 14-57 Rumen hooks are implanted in the cut edges of the rumen and attached securely to screws and nuts placed at regular intervals along the rumen board.

that the skin is more easily penetrated. At least two suture lines are used in order to prevent a purse-string effect (12 to 7 o'clock and 5 to 12 o'clock in clockwise fashion). The suture lines are overlapped at the ventral aspect of the incision in order to prevent gapping and abdominal contamination. Care should be taken not to penetrate the ruminal mucosa, although the author has not recognized complications when penetration has occurred.

Once the rumen has been sutured to the skin, the site is checked to verify a good "seal" between rumen and skin. An

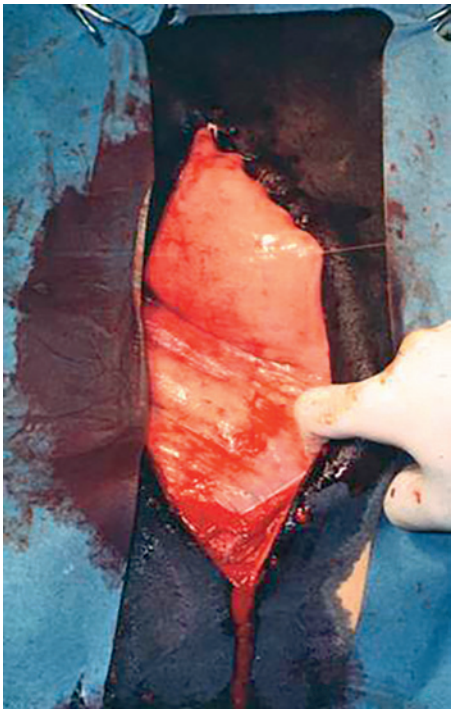


Figure 14-58 The rumen is sutured to the skin with a Cushing-type pattern to form a seal between the rumen and the skin.

incision is made in the rumen, starting 3 cm ventral to the dorsal commissure and extending ventrally to 3 cm dorsal to the ventral commissure, with care taken not to inadvertently incise the sutures that form the rumen and skin seal. A rumen shroud or wound ring[6] is placed in the incision to protect the incised ruminal wall and to prevent ingesta from accumulating at the junction of the rumen and skin (Figure 14-59).

Transruminal Exploration

After the rumen has been stabilized and incised, enough contents should be emptied to permit a thorough exploration. If the contents of the rumen are mostly fluid it is possible to drain them by creating a siphon with a large-bore stomach (Kingman) tube. The position, size, and consistency of the reticulum, omasum, and abomasum can be defined by transruminal palpation. The ruminoreticular fold, esophageal orifice, and omasal orifice should be palpated for lesions.

The reticulum is meticulously explored for foreign bodies. If all parts of the reticulum cannot be palpated, more ruminal ingesta can be removed to reduce the cranial displacement of the reticulum caused by ruminal distention. A guarded prognosis should be given when a perforating foreign body is found and the thoracic cavity has been penetrated. Exploration of the reticulum should be continued in case there is more than one foreign body present; all foreign bodies should be removed regardless of whether they are penetrating. Normally the reticulum can be inverted into the rumen by manually grasping its cranioventral aspect. If a penetrating foreign body is not found, the surgeon should try to invert the reticulum. This helps determine the presence, location,

[6]Steri-Drape TM, wound edge protector, 3M Health Care, St. Paul, MN, USA.



Figure 14-59 A rumenotomy has been performed and a plastic wound protector applied. Solid contents of the rumen are removed manually.

and extent of adhesions. The surgeon's finger must probe all the honeycomb cells of the reticulum at the site of adhesions in search of foreign bodies. The surgeon can also sweep the reticular wall with a magnet in an attempt to find ferromagnetic foreign bodies. Another possible enhancement of diagnostic capabilities is to carry an ultrasound probe (5-MHz sector scanner) into the lumen of the rumen in a rectal sleeve. In all but the largest cows, the left hand can usually reach through the reticuloomasal orifice into the omasal canal to evaluate the consistency of omasal contents. In some cases, the abomasal lumen can be entered by directing one's hand ventrally from the omasal orifice. The leaves of the abomasum normally feel very smooth and slippery upon palpation. Adhesions that limit reticulum mobility would be typical of TRP. The ventral sac of the rumen adhered to the body wall is more typical of localized peritonitis after a perforated ruminal or abomasal ulcer.

Occasionally, an abscess will be found tightly adhered to the reticular wall. These feel like a ball. A spherical mass with uniform consistency can be imaged with ultrasound. Lack of experience may cause confusion in differentiating an abscess from the omasum. An abscess can be distinguished from the omasum by identifying the reticuloomasal groove and using several fingers to delineate the omasum. The presence of purulent material in the abscess can be confirmed by inserting a 14-gauge needle, connected by an extension set to a syringe, through the reticular wall into the mass adhered to the reticular wall to aspirate the abscess. Once the abscess has been positively identified, it can be lanced into the reticulum, where the abscess is tightly adhered to the reticular wall. A scalpel blade is secured by umbilical tape to the surgeon's hand before it is introduced through the rumen into the reticulum (Figure 14-60). After the abscess is lanced, the abscess cavity is inspected for a foreign body.

If the abscess is not tightly adhered to the reticulum wall, the rumenotomy site and abdomen are closed and a ventral (midline or paramedian) exploratory celiotomy is performed to either resect or drain the abscess. A 28 French trocar

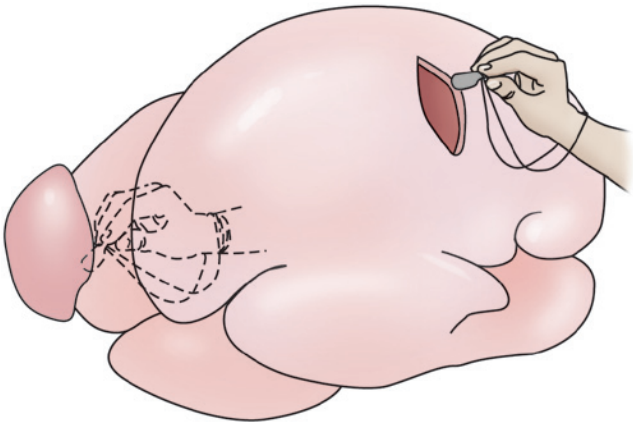


Figure 14-60 A schematic diagram that shows a scalpel blade secured to a surgeon's hand as the surgeon prepares to drain a cranial abdominal abscess adhered to the reticulum.

catheter[7] is inserted into the abscess for drainage lateral to the ventral incision. The catheter must be carefully inserted so that it does not penetrate the mammary vein, which is often collapsed when a cow is in dorsal recumbency. The catheter must be passed through the adhesions or omentum to prevent abdominal contamination if leakage occurs around the catheter. This latter procedure could also be done percutaneously using ultrasonographic guidance with the cow standing. After the drain's intended entry point is identified, local anesthetic is placed at that site. A short (1-cm) incision through the skin and external sheath of the rectus abdominis is made with a blade. The drain is placed into the opening and guided into the abscess. Holding the drain by its shaft near the skin, not at the end, is important so that it does not enter the abdomen any deeper than desired once it has passed the resistance of the internal sheath or abscess wall. The only difference between the surgical and ultrasound-guided approach is that ultrasound cannot ensure the catheter is passing through adhesions, so any purulent contamination around the drain may result in localized peritonitis. However, economic and medical reasons may justify a nonsurgical approach for placing a drain. The trocar is then removed from the catheter, and the catheter is clamped. The catheter is secured to the skin (Figure 14-61). The ventral incision is closed (if performed), and the animal is allowed to stand, after which the catheter is unclamped and the abscess drained. The catheter is flushed daily until drainage is minimal (approximately 10-14 days), at which time the catheter is removed.

Closure

After gross contamination has been removed, the rumen wall is closed with No. 2 absorbable monofilament sutures with a two-layer closure, the second of which should be an inverting pattern (Figure 14-62). The surgery site is thoroughly lavaged with sterile physiologic fluids, and all soiled instruments are discarded. If the rumen was sutured to the skin, the suture is cut and one quadrant at a time is freed. A moist sponge is used to wipe off ingesta trapped between the rumen and skin. The surgeon removes the contaminated sleeves and applies fresh sterile gloves.

[7]Pleur-evac Thoracic Catheter; Teleflex, Teleflex Incorporated, Morrisville, NC, USA. www.teleflex.com.

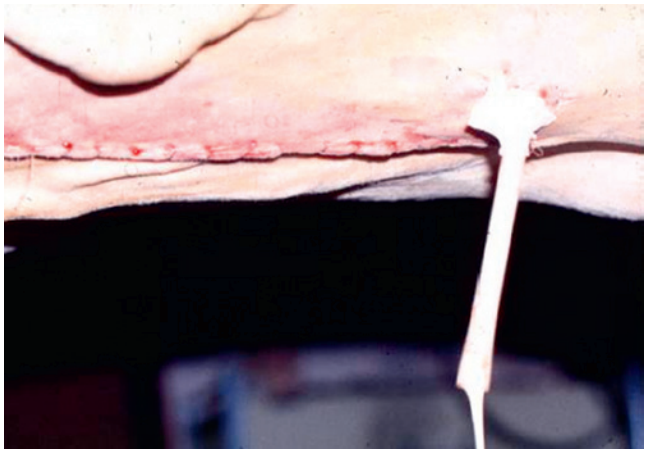


Figure 14-61 Drainage of a liver abscess through a 28 French Foley catheter placed adjacent to a right-paramedian celiotomy.

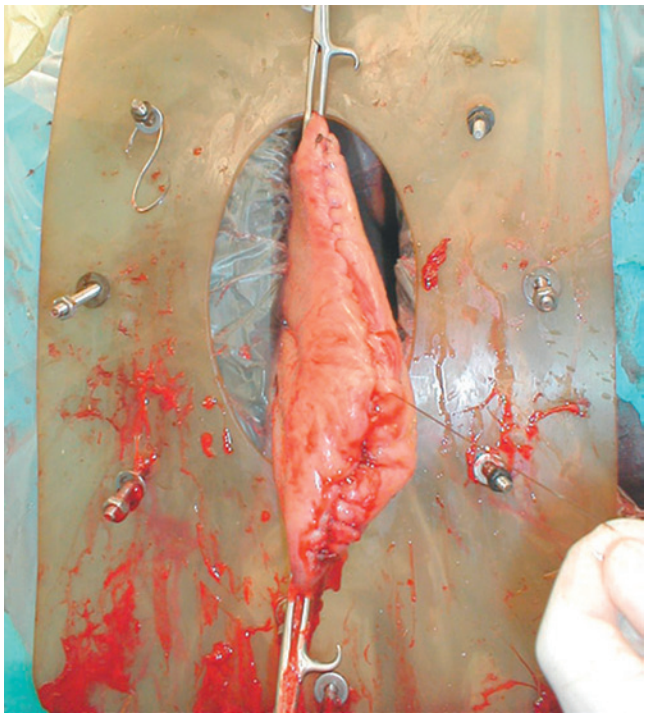


Figure 14-62 The rumen is closed with a two layer pattern. The outer layer should always be inverted.

The abdominal musculature is usually closed in two or three layers by using a simple continuous pattern of absorbable sutures in the muscle layers. The skin layer is closed with a continuous Ford interlocking pattern. It is wise to close the ventral aspect of the skin incision with two to three simple interrupted sutures. The possibility of incisional infection is obvious, and drainage can be easily obtained by removing these ventral two to three sutures if necessary.

Postoperative Management

Antibiotics are administered systemically to treat the septic reticuloperitonitis. Oral or IV fluids may be needed to correct dehydration and metabolic alkalosis, if present. Rumen transfaunate can be given to reestablish normal flora and stimulate ruminal motility.

Postoperative complications include swelling and discharge at the incision site. Because of the nature of the surgery, contamination of the incision site occurs easily. If recognized, these infections respond well to ventral drainage.

Prognosis

The prognosis depends on the location of the reticular perforation. If the foreign body has penetrated the diaphragm, a poor prognosis should be given; septic pericarditis, myocarditis, and thoracic abscesses are possible sequelae. If perforation involves the right wall of the reticulum, a guarded prognosis is given; adhesions that involve the ventral branch of the vagus nerve may result in vagal syndrome Type II or III. A favorable prognosis is given when the perforation does not affect the thoracic cavity and right side of the reticulum. Single abdominal abscesses (reticulum, liver) also carry a favorable prognosis if they can be drained or resected. Unfortunately, liver abscesses have a fairly high (30%) recurrence rate. Extensive adhesions in the cranial abdomen are not necessarily associated with a poor prognosis in the author's experience. If the adhesions do not involve the vagus nerve, ruminal motility does not appear to be greatly impaired by the presence of adhesions. This may be because the rumen wall is protected from restricting adhesions by the superficial layer of the greater omentum.

Placement of a Commercial Rumen Fistula in Adult Cattle

Application of commercial rumen fistulas is commonly performed in research to assess alterations of ruminal microflora and in the hospital setting to obtain ruminal transfaunate from a healthy donor. The left-paralumbar fossa is clipped and prepared for aseptic surgery. Perioperative antibiotics are administered. An approximately 15-cm vertically oriented elliptical skin incision is made in the midparalumbar fossa, starting 6 cm ventral to the transverse processes. This incision length is appropriate for a 10-cm fistula.[8] It is critical that the length be precise to ensure a snug fit with the fistula. The incision is extended sharply, and the subcutaneous tissues are dissected away with Mayo scissors until the elliptical piece of skin is excised (Figure 14-63*A*). The external abdominal oblique, internal abdominal oblique, and transversus abdominis muscles are sharply dissected parallel to the long axis of the skin incision. Large Russian forceps are used to delineate the facial planes between muscle layers and protect from excessively deep dissection with the scalpel blade. The peritoneum is tented and incised with scissors.

The peritoneum and transversus abdominis are sutured to the dermis as a first layer of closure with a No. 1 synthetic absorbable monofilament suture on a large cutting needle in a simple continuous pattern. This is performed in four overlapping segments to prevent a purse-string effect and gapping between suture lines. This effectively creates a muscular ring about 12 cm in length that will snug down around a 10-cm fistula, thus preventing leakage of ruminal contents. For the second layer, a portion of the dorsal sac of the rumen is gently exteriorized using penetrating towel clamps and anchored at four quadrants to the subcutaneous tissues or dermis by using a No. 1 absorbable monofilament suture material (Figure 14-63*B*). If secured to the dermis a cutting needle is essential. A good seal is further obtained by adding a circumferential suture from the seromuscular layer of the rumen to the dermis in four suture lines. The suture lines overlap and are applied with a Cushing pattern in the rumen

[8]Bar Diamond, Inc., Parma, ID, USA. www.bardiamond.com.

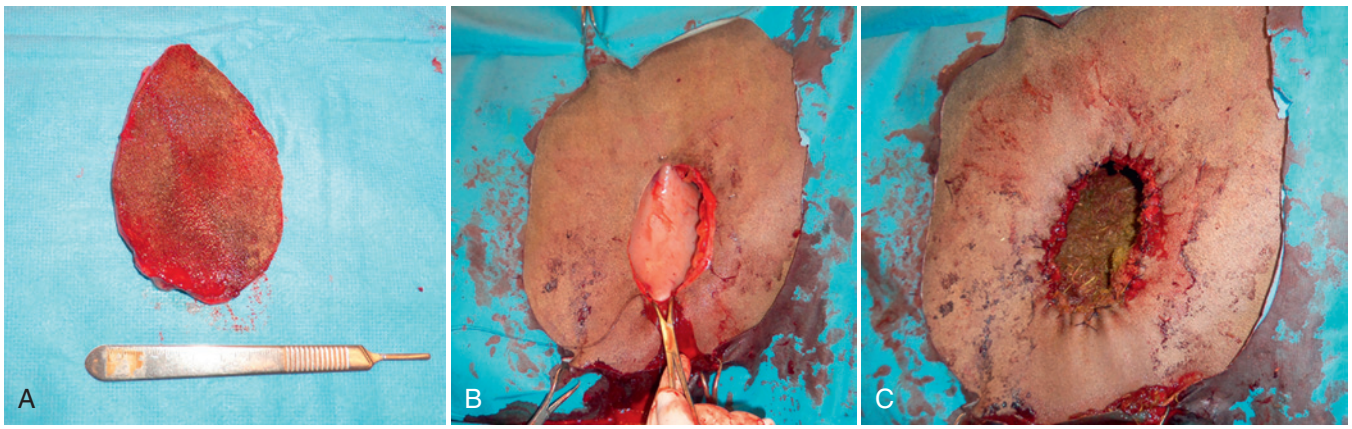


Figure 14-63 *A*, The resected vertically oriented elliptical flap of integument that is resected before securing the rumen to the body wall. *B*, The seromuscular layer of the dorsal sac of the rumen is tacked to the subcutaneous and dermal tissue in four quadrants. *C*, Apposition of the ruminal mucosa and the epidermis in a simple interrupted fashion circumferentially.

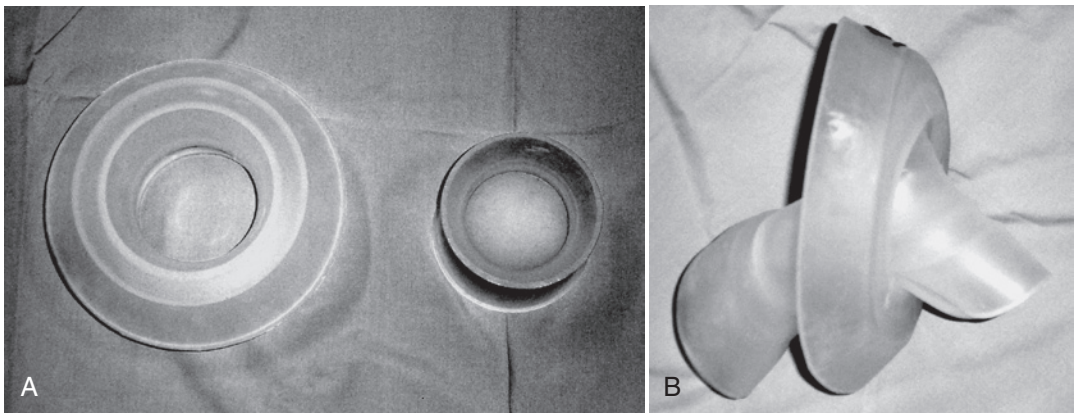


Figure 14-64 *A*, Commercial rumen fistula and plug. *B*, The top part of the inner flange of the fistula is passed through the lumen of the cannula, toward the outside flange, to form a cone to facilitate insertion through the surgically created stoma.

and a simple continuous pattern in the dermis. This will prevent abdominal contamination with rumen contents. For the third layer, the rumen is incised and the mucosa sutured to the skin in an interrupted pattern with a slowly absorbing No. 1 to 2 monofilament suture material (polydioxanone) on a cutting needle. The interrupted sutures should be approximately 1 cm apart (Figure 14-63C). This provides the stoma to insert the commercial fistula.

Placing the fistula can be very difficult because the site has been prepared to ensure a tight fit. The fistula can be warmed in very hot water to improve pliability (Figure 14-64*A*). The inner flange of the fistula is inverted into the outer flange (Figure 14-64*B*) to serve as an entry into the stoma. After being placed through the surgically created opening, the inner flange is rotated into its correct position (Figure 14-65).

After surgery the site should be cleaned daily and the cow should be kept on antibiotics for 5 to 7 days. Some pressure necrosis is inevitable between the cannula and the rumen-to-skin seal, but over time this will improve; the site will enlarge slightly to accommodate the fistula.

TEMPORARY RUMEN FISTULA

The purpose of a temporary rumen fistula is to allow rapid egress of gas or ruminal contents during episodes of acute bloat, as well as the ingress of therapeutic or nutritional components when oral access is restricted. Patients suffering from oral or esophageal obstruction, mandibular fracture, frothy bloat, systemic illness resulting in inappetance, and other ailments limiting ingestion and eructation can benefit from a temporary rumen fistula.

The procedure is performed similar to that of a commercial rumen fistula but to a smaller degree. The left-paralumbar fossa is clipped and prepared for aseptic surgery. Perioperative antibiotics are administered. An approximately 5 × 3-cm vertically oriented elliptical skin incision is made in the center of the midparalumbar fossa starting 6 cm ventral to the transverse processes. This incision length is appropriate for a 35- to 20-mL syringe casing. The incision is extended sharply through the skin, and the subcutaneous tissues are dissected away with Mayo scissors until the elliptical piece of skin is excised. Muscle layers and the peritoneum are tented and vertically incised with Mayo scissors. Sharp dissection is not advised because the rumen is typically distended with gas, increasing the chances of inadvertent penetration.

A 14-gauge needle attached to an extension set is inserted into the rumen for gas decompression. The peritoneum and transversus abdominus is sutured to the deep dermis in two overlapping simple continuous lines using a No. 1 to 0 absorbable monofilament on a cutting needle. Penetrating towel clamps are used to exteriorize the rumen at the most dorsal and ventral aspect of the skin incision. The seromuscular



Figure 14-65 Postoperative placement of a commercial rumen fistula in a cow.



Figure 14-66 A 35-mL syringe casing is secured into the temporary rumen fistula using stent sutures and umbilical tape in four quadrants.

layer of the rumen is tacked to the subcutaneous tissue or dermis at four equidistant sites. Two overlapping suture lines are applied with a Cushing pattern in the rumen and a simple continuous pattern in the dermis to create a seal. Finally, a 4-cm longitudinal incision is made into the rumen and the mucosa is sutured to the epidermis in a simple interrupted fashion using a No. 1 to 0 absorbable monofilament suture on a cutting needle with bites approximately 0.5 to 0.8 mm apart. To secure the syringe case in the fistula, four 1-cm in diameter stent sutures are placed through the skin 1 cm away from the defect with No. 1 nonabsorbable suture at 12, 3, 6, and 9 o'clock. The end of a 35- to 20-mL syringe case is amputated and rasped to remove sharp edges. Four punctures are made into the surface of the capped end that corresponds to the stent sutures. The beveled end of the syringe is placed into the incision and umbilical tape is used to secure the syringe casing to the loops of umbilical tape in the skin (Figure 14-66). Depending on the progress of the patient, a smaller-gauge syringe casing can be inserted every 3 to 4 days. The fistula will fibrose and seal after the removal of a 1-mL syringe casing.

LACTIC ACIDOSIS

The consumption of a large amount of rapidly fermentable concentrate feed or a sudden diet change to such food can result in severe indigestion. This syndrome has been termed *lactic acid indigestion*, *grain overload*, *rumen overload*, and *acute carbohydrate engorgement*.

This is a condition most commonly seen in feedlots but that can occur in other instances such as inadequately mixed rations or cattle getting loose in the feed room. Within 6 hours of ingestion, the easily fermentable concentrate is broken down to lactic acid isomers of both the D and L forms. The L isomer is used rapidly, whereas the D isomer persists and results in D-lactic acidosis. *Streptococcus bovis* is the primary organism responsible for this conversion. The pH of the rumen contents decreases to 4.5 to 5.0, at which time microbes other than *Streptococcus bovis* have been destroyed. Rumen stasis occurs. *Streptococcus bovis* continues to exist at this low pH and produces more lactic acid. Rapid accumulation of lactic acid in the rumen osmotically draws water into the rumen, thus accentuating the cow's dehydration. In addition, the acidic fermentation produces excessive amounts of volatile fatty acids, which are absorbed and contribute to a metabolic acidosis. Eventually, the rumen mucosa is damaged, allowing transudation of protein into the rumen. Affected cattle are inappetent, dehydrated, and tachycardic, with a sudden decline in milk production. The rumen is distended and fluid filled. Eventually diarrhea develops and untreated animals become weak and recumbent.

A sample of rumen fluid in the acute stages will show a pH of 4.5 to 5.0 (normal is 6.5 to 7.0). This may be less evident with time because the rumen contents are buffered by the high bicarbonate content of swallowed saliva. A severe metabolic acidosis with neutropenia is typical.

The prognosis and treatment plan will depend on the duration of the insult. In the acute stage, a rumenotomy may be indicated to empty as much foodstuffs as possible. Recommendations for surgery include an animal with a rumen pH of 5.0 or less, a heart rate greater than 100 beats per minute, dehydration greater than 8%, and marked rumen distention, which indicates a severe grain overload. The rumen is emptied and lavaged with water several times to remove as much lactic acid as possible. Additional therapy includes laxatives, fresh hay in the rumen, repeated rumen transfaunates if available, parenteral calcium, nonsteroidal antiinflammatory drugs, and IV fluid therapy. Intravenous fluids should be balanced electrolyte solutions such as lactated Ringer's solution, and supplemental sodium bicarbonate is added if acidemia is

suspected or confirmed by acid-base/electrolyte values. Prognosis for these cattle is guarded.

Other treatments may be attempted for animals that show less severe signs and higher rumen pH values or if such a significant number of animals are affected that rumenotomies for all is precluded. These include rumen warm-water lavage with a Kingman tube, antacid solutions such as 2 to 4 quarts of milk of magnesia, fluid therapy, and calcium solutions. Other empirical treatments include antihistamines, penicillin solutions administered via a stomach tube in an effort to reduce the number of *Streptococcus bovis* organisms in the rumen, and roughage-only diets until the animals recover. Vitamin B supplementation is indicated because of thiaminase production by microorganisms, and broad-spectrum antibiotics may be given to prevent untoward sequelae.

Surgery may not benefit cattle in which signs have been present for more than 24 hours because the amount of rumen mucosal injury has been determined. Cattle affected with lactic acidosis that survive the acute phase and whose rumen pH returns to normal are still at risk for sequelae to the chemical rumenitis that has occurred. Over the next several days, bacterial opportunists such as *Fusobacterium necrophorum* may invade the areas of chemical damage and cause a bacterial rumenitis. This can progress to a bacterial and/or mycotic rumenitis that can enter the portal circulation and cause embolic infection of the liver, lungs, brain, or other viscera.

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SURGERY OF THE ABOMASUM

Ava M. Trent

INTRODUCTION

If dairy or beef cattle are part of your practice responsibility, you will need to be familiar with the physiology and anatomy of the abomasum and be prepared to address related surgical problems. Normal function of the abomasum is essential for the health and productivity of all cattle. Altered abomasal function is the most common indication for abdominal surgery in adult dairy cows and is an occasional indication for abdominal surgery in beef cattle, dairy bulls, and beef and dairy calves. Fortunately, diagnosis and surgical management of the most common abomasal disorders can be achieved in a field setting with a solid understanding of abdominal anatomy, abomasal physiology, and basic surgical principles.

ABOMASAL PHYSIOLOGY AND ANATOMY

The abomasum is the most distal of the four stomach compartments in cattle. However, the size, position, source of ingesta, and digestive functions change dramatically from birth to early adulthood, creating different diagnostic and therapeutic challenges for the veterinarian. In the neonatal calf, the abomasum is the primary functioning stomach compartment. At birth, it is the largest of the four compartments with a volume twice that of the combined ruminoreticulum. It fills the right cranioventral abdomen, extending caudally on and to the right of midline to a point well beyond the 13th rib. In the young calf, stimulation of pharyngeal receptors by milk components and suckling diverts all milk through the reticular groove into the abomasum, bypassing the poorly developed rumen. As the calf begins to consume solid feed, the ruminoreticular compartments assume a more active role in digestion and begin to increase in size. At 8 weeks of age, the volume of the abomasum is approximately equal to that of the ruminoreticulum, and by 12 weeks of age the ruminoreticulum is twice the size of the abomasum.

By the time a cow is 1.5 years old, all compartments have reached their mature total capacity of 95 to 230 L with relative volumes of 80% (rumen), 8% (abomasum), 7% (omasum), and 5% (reticulum).

Abomasal Function

The abomasum plays a critical role in digestion. Abomasal secretions and motility occur in coordination with the activities of the proximal and distal intestinal tract. Alterations in secretion or motility can result in significant disruption of digestion and major disturbances in systemic fluid and electrolyte balance. Conversely, systemic changes can lead to disturbances in abomasal motility. Fortunately, many of the local and systemic effects on abomasal function as well as the effects of abomasal dysfunction on local and systemic processes can be predicted through an understanding of abomasal function.

Secretions

The abomasum is the only stomach compartment with glandular mucosa that can secrete digestive juices, including hydrochloric acid, pepsin, and rennin. Alkaline chyme stimulates abomasal emptying, and acidic chyme inhibits emptying via release of local peptides and hormones. The uniquely long distance between the pylorus and the site where highly alkaline bile and pancreatic fluids enter the duodenum at the sigmoid flexure in ruminants helps maintain the low duodenal pH necessary for ruminant digestion.

In the adult ruminant, the abomasum functions in a manner similar to that of the simple stomach of monogastric animals. The luminal pH is maintained at a 3.0 level in healthy cattle by the physical features mentioned previously and by coordination of secretions with abomasal motility. The normally low pH of the abomasum does not support viable pathogenic microorganisms, although abomasal lesions can be colonized by a variety of opportunistic organisms. Secretion of digestive fluids is relatively continuous, but volume and acidity are affected by several local and systemic neurohumoral factors, including gastrin (increases fundic secretion of HCl and pepsin) and somatostatin (decreases gastrin secretion). The volume and acidity of secretions are also reduced when the abomasal or duodenal pH is decreased, flow of ingesta into the abomasum is prevented, or stimulation by the vagal nerve occurs. Distention of the abomasal body, injection of histamine, infusion of buffered fatty acids into the abomasal lumen, and stimulation by parasympathomimetic agents, such as atropine, increase the volume and acidity of secretions.

The relatively continuous nature and composition of abomasal secretions results in fairly characteristic changes in systemic fluid and electrolyte balances in adult ruminants with impaired abomasal outflow. Accumulation of hydrogen and chloride in the abomasal lumen leads to a hypochloremic metabolic alkalosis. Hyponatremia is common, even in the face of dehydration. Hypokalemia can result from reduced food intake, loss of potassium in milk, and a cellular exchange for hydrogen in the face of alkalemia. Paradoxical aciduria may occur in hypovolemic cattle with concurrent hypochloremic alkalosis, hypokalemia, and hyponatremia. The severity of the dehydration and electrolyte disturbances depends on the duration and degree of outflow disturbance and the presence or absence of vascular compromise. In cases of severe vascular compromise with tissue necrosis, as may be seen with prolonged abomasal volvulus, a metabolic acidosis may develop and result in the blood pH returning toward more normal values. Concurrent conditions may also superimpose metabolic disturbances. Specifically, severe ketosis or diarrhea may result in a metabolic acidosis despite changes directly resulting from altered abomasal outflow.

Motility

Abomasal motility and clearance in the adult are also regulated by local and systemic factors. Contractions (aborad and orad) must be coordinated with opening and closing of the pyloroduodenal junction and contraction patterns in the cranial duodenum to ensure appropriate timing for mixture and digestion of contents, as well as to clear ingesta into the distal intestinal tract. The strength of peristaltic contractions is normally greatest in the pyloric antrum, with variable strength contractions in the body and minimal activity in the fundic region. Whereas flow of ingesta from the ruminoreticulum into the abomasum is relatively constant, abomasal emptying appears to occur 18 to 20 times a day and corresponds to strong antroduodenal contractions.

Abomasal outflow reflects a balance between propulsive abomasal contraction and a braking action at the gastroduodenal juncture, often called the *duodenal brake*. The composition of chyme (specifically acidification), the volume of material entering the duodenum, and local and systemic neurohumoral mediators such as gastrin and somatostatin appear to inhibit abomasal outflow through this mechanism. Narcotic and alpha-2 adrenergic agents such as xylazine hydrochloride may also inhibit abomasal outflow by affecting the duodenal brake.

Motility is normally increased in anticipation of, during, and for several hours after a meal. Abomasal motility during periods between episodes of feed intake (interdigestive period) is dependent on the presence of motilin, a small peptide hormone. Motilin is secreted during the interdigestive period by gastric mucosa or by the duodenojejunal mucosa in many mammals and increases cyclically to stimulate short periods of strong gastric contractions and emptying. Erythromycin, as well as other macrolide antibiotics, appears to have a prokinetic effect on abomasal motility in calves and adult cattle by binding at the motilin receptor site. Recent research has identified the motilin gene site on bovine chromosome 23 (BTA 23). BTA 23 has been suggested to be a promising candidate gene in dairy cattle associated with breed predispositions for the development of left-displaced abomasum, a condition predisposed by altered abomasal motility.

Motility can be depressed by many local factors, including high-roughage meals, duodenal distention, introducing volatile fatty acids into the rumen, ruminal absorption of histamine, low rumen pH, and extreme or chronic abomasal distention. A variety of systemic factors have also been associated with decreased abomasal motility including endotoxemia, alkalemia, systemic histamine release, epinephrine release, prostaglandin I2, hyperinsulinemia, tumor necrosis factor, decreased cholinergic tone, decreased nitroxergic activity, and pain. Normal abomasal motility requires adequate serum levels of several key electrolytes. Decreases in serum calcium and potassium specifically are potential causes of depressed gastric and intestinal motility in many species. Although experimental depression of abomasal motility in cattle through hypocalcemia appears to require lower serum calcium levels than typically encountered in clinical cases, the potential role of hypocalcemia in combination with other depressant factors remains a concern. Ketosis is also associated with decreased abomasal motility, although whether ketosis is a cause or effect of hypomotility, or an incidental event, is unclear.

Abomasal motility is regulated by sympathetic and parasympathetic pathways as well as the enteric nervous system. The enteric pathways may be the most important method of control. Vagal nerve function plays a role in normal abomasal

motility, although it has been difficult to determine the specific nerves and pathways involved because local intrinsic control mechanisms can compensate and reestablish abomasal motility even after complete cervical vagotomy. Nonetheless, vagal nerve injury is commonly implicated as a cause of abomasal dysfunction.

SURGICAL CONDITIONS OF THE ABOMASUM

A variety of digestive and inflammatory conditions affect abomasal function. Two major categories of abomasal disorders either indicate the need for surgery or may be encountered during abdominal surgery. The first includes disorders recognized because of altered abomasal outflow. The second includes conditions associated with loss of abomasal wall integrity. These categories are not mutually exclusive.

Altered Abomasal Outflow

Most abomasal disorders are recognized because of a disturbance in normal abomasal outflow with resulting alterations in digestion, systemic fluid and electrolyte balances, and fecal production. Abomasal outflow can be altered by a wide range of mechanical and functional factors or, in many cases, a combination of both. The disorders can be grouped into two categories: those associated with repositioning of the abdomen in the abdominal cavity (i.e., displacements) and those that occur without a significant change in abomasal position.

Abomasal Displacement Syndromes

The abomasum has the capacity for major changes in volume and location. The abomasum is the most mobile of the forestomachs. It is suspended by the lesser omentum in the shape of a U, with restrictions of motion only at the cardia (proximal) and the sigmoid flexure (distal) (Figure 14-67). Three syndromes of abomasal displacement are commonly recognized: left displacement of the abomasum (LDA), right dilation/displacement of the abomasum (RDA), and right-side volvulus of the abomasum (RVA). The conditions called RDA and RVA may be two stages in a progression rather than separate syndromes, with RDA developing first and developing in some but not all cases into an RVA. A fourth displacement syndrome of cranial displacement of the abomasum between the liver and diaphragm has also been described as an incidental finding but is seldom recognized clinically and will not be discussed further in this text.

The abomasum can displace without volvulus to the left or right of its normal position by swinging, folding, or stretching of the lesser omentum and attached structures. The result is a partial outflow obstruction because the duodenum is compressed by stretching and, in the case of an LDA, by compression under the rumen. If the movement of the abomasum involves a rotation of structures around an axis through the lesser omentum, the resulting volvulus can produce complete outflow obstruction and compression of blood vessels and nerves as they pass through the twisted omentum.

The displacement syndromes are most common in high-production dairy cows but also appear sporadically in calves, dairy bulls, and beef cattle. Abomasal displacement to the left is by far the most common of the recognized displacement syndromes, representing 85% to 96% of all displacement conditions. In a study of over 100,000 cattle admitted to 17 veterinary teaching hospitals in North America, LDAs were 7.4 times more common than right abomasal volvulus. This ratio is somewhat lower than that reported in field studies, which presumably reflect a higher referral rate for abomasal volvulus than for left displacement.

Abomasal displacement conditions have some common features related to pathogenesis, effect, and treatment. Although the bulk of the research has focused on factors that predispose to left abomasal displacement, the etiopathogeneses of right-abomasal dilation and abomasal volvulus are thought to be similar. The potential for abomasal displacement exists whenever conditions support gas accumulation in the abomasum. Any of the local or systemic factors described herein (Abomasal Function) that alter abomasal motility can predispose to displacement.

Left Abomasal Displacement (LDA)—General Considerations

Definition and Incidence. Left displacement of the abomasum is a condition in which the body of the abomasum relocates to the left side of the midline between the rumen and left body wall although still maintaining flow from orad to aborad without complete luminal obstruction. It was first reported in the 1950s and is currently one of the most common surgical problems encountered in modern dairy herds, with an incidence of 0.35% to 4.4% in large North American population studies and as high as 15% in some herds. Reports in German Holstein populations in Germany indicate a prevalence of 1.2% to 2.6% with occurrence as high as 7.5% in single herds. The number of reported LDAs appears to have increased in production dairy cattle internationally over the past two decades, indicating an increase in incidence, in recognition, or both. Left displacements occur sporadically in beef cows and in beef and dairy calves and bulls. In data from over 100,000 admissions to 17 veterinary teaching hospitals in North America, dairy cattle were found to have an adjusted odds ratio of 95.2 of developing an LDA compared with beef cattle, and female cattle in general have a 29.1 adjusted odds ratio in comparison to male cattle.

Economic losses from LDA include decreased milk production and cost of treatment, as well as premature culling. Cows with LDAs are also at increased risk of complicated

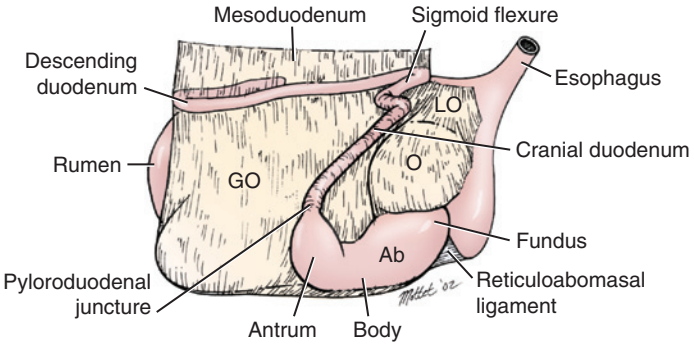


Figure 14-67 Schematic diagram representing the normal anatomic position of the abomasum in relation to adjacent viscera. Ab, abomasum; GO, greater omentum; LO, lesser omentum; O, omasum; Ret, reticulum.

ketosis and metritis, further increasing economic losses from treatment, decreased production, and premature culling. In a study of LDAs in German dairies, approximately 50% of cows with an LDA were culled within 1 year of surgery. Economic losses should also include replacement costs as cows are lost from the herd. Financial losses from LDAs in North America have been estimated to be as high as $220 million/year.

Predisposing Factors. A reduction in effective abomasal motility and an increase in accumulation of gas in the abomasum are considered to be prerequisites for the development of abomasal displacement in cattle. Predisposing factors are not well established in cattle other than in adult female dairy cows. Abomasal ulcers, foreign bodies, and geosediments have been reported as factors in the pathogenesis of LDAs in calves, mature bulls, and beef cows. However, a variety of factors have been implicated as predisposing factors for left abomasal displacement in dairy cattle and fall roughly into the categories of lactation stage, anatomy, genetics, nutrition, metabolism, and management/environment.

Stage of Lactation. The majority of LDAs in adult dairy cows occurs early in the lactation period. One large study reported an incidence of 57% in the first 2 weeks postpartum, 80% within the first month, and 85% to 91% within the first 6 weeks postpartum. Several recent studies have implicated the transitional period (2 weeks prepartum to 4 weeks postpartum) to be critical in development of LDA. Many of the anatomic, nutritional, metabolic, and management factors described in the following occur in the transitional period and combine to decrease abomasal motility and increase gas accumulation to create an increased risk for abomasal displacement. In addition, many periparturient disorders such as endotoxemia, mastitis, retained placenta, stillbirth, and metritis have been identified as predisposing factors for LDA in some studies. However, the association is not consistent, and some or all may prove to be concurrent and not causally related events.

Anatomy. Several anatomic changes that occur in the periparturient period increase the potential for the abomasum to displace to the left. In late pregnancy the large uterus displaces the abomasum into a more cranial and transverse position with a greater amount of the abomasum lying to the left of the midline on the abdominal floor. Decreased feed intake reduces the volume of the rumen, and the expanding uterus can displace the rumen dorsally. With calving, the sudden reduction in the volume of the uterus leaves a void in the abdomen that may allow the abomasum to slide more easily to the left under the smaller rumen. Twin pregnancies may increase the risk of LDA by virtue of a more dramatic size change of the uterus in the periparturient period. A phenotypic predisposition in cattle with large abdominal cavities has also been suggested.

Genetics. A number of studies in Europe and in the United States have identified a breed-based predisposition to left displacement in some dairy breeds. Heritability estimates range from 0.11 to 0.50. Incidences of 22.6% and 29.4% were found in a study of cows descending from two bulls. Early explanations for a perceived breed disposition focused on breed differences in milk production capacity. Subsequent studies have not consistently supported the potential for high milk yield as a predisposing factor for abomasal displacement in general, although there was more support for an association with LDAs specifically.

Recent studies have identified a breed difference in the motilin gene and its expression of the peptide hormone motilin. The breed difference corresponds to the breed difference in incidence of LDA. Motilin governs abomasal motility in times between feed intake and would presumably be particularly important in the periparturient period in which feed intake may be dramatically reduced. In addition, a genome-wide association study in German Holsteins, the predominant dairy breed in Germany and one with a high prevalence of left displacements, indicated that genes associated with calcium and insulin-dependent diabetes mellitus were factors in the development of LDA. Levels of local motility inhibitory and stimulatory neuromediators in the abomasal wall may also vary by breed. The levels of the stimulatory neurotransmitter substance P were found to be lower, and the levels of the inhibitory vasoactive inhibitory peptide were significantly higher in the abomasal wall of German Holsteins (high incidence of LDA) compared with the German Fleckvieh (low incidence of LDA). Some studies have indicated that a functional disorder of the enteric nervous system may play a role in altered abomasal motility and the development of a left displacement. Cows with left abomasal displacements have increased neuronal nitric oxide synthase and decreased acetylcholine sensitivity, which may impair normal motility. Conversely, studies of spontaneous contractility of longitudinal and circular muscle fibers have not differed by species.

Nutrition. Nutrition in the dry and transitional periods plays an important role in the development of LDA as well as in the development of a number of associated periparturient disorders. Large amounts of concentrates and low fiber intake in the dry period have been implicated as predisposing factors in multiple studies. Crude fiber concentrations of <16% to 17% have been identified as a predisposing factor for LDA. A negative energy balance commonly occurs during the late gestation period when a decrease in appetite reduces the dry matter intake and energy resources are diverted into increased milk production. Fat is mobilized from adipose tissue as an energy source, resulting in high blood concentrations of nonesterified fatty acids and accumulation of lipid in the liver. Cows with a high-body condition at calving are at greater risk of excessive lipomobilization. One study indicated that nonesterified fatty acid levels in cows that were subsequently diagnosed with LDAs began to diverge from nonaffected cows at 1 week before parturition. Cows with high prepartum nonesterified fatty acid levels of ≥0.5 mEq/L at 0 to 6 days prepartum were 3.6 times more likely to develop an LDA after calving. Increased beta-hydroxybutyrate levels at 0 to 7 days postpartum of >200 µmol/L had an odds ratio of 3.8 times for development of LDA and an odds ratio of 8 for levels ≥1200 µmol/L.

Low postpartum serum calcium levels are often implicated as a predisposing factor for LDA. Although very low levels (<1.2 mmol/L) can reduce abomasal motility, studies do not consistently show a correlation between calcium levels encountered clinically and the occurrence of LDA. Historically, strategies to prevent postpartum hypocalcemia focused on reducing calcium levels in the dry period to prompt the parathyroid gland to secrete parathyroid hormone to prompt bone mobilization of calcium. Limitation of dietary calcium alone has not been shown to be as effective as originally believed, and strategic prepartum supplementation of calcium in feed or systemic administration of vitamin D can help prevent postpartum hypocalcemia. Current strategies are focused on manipulating the dietary cation-anion difference in the transitional diet by reducing potassium levels and increasing anionic salts in the feed to decrease blood pH. The goal is to reduce or prevent metabolic alkalosis, which alters conformation of the parathyroid hormone receptor and reduces the ability of the body to mobilize and retain calcium.

Metabolism. There is a close tie between nutrition and many of the metabolic changes that predispose to abomasal displacement. Prepartum negative energy balance, high blood nonesterified fatty acid levels, high plasma glucose, high plasma insulin, high beta-hydroxybutyrate, and low serum calcium levels are all associated with nutritional management in the dry period as discussed previously. Increased insulin resistance in late pregnancy in cattle contributes to high plasma glucose and insulin levels, both of which can reduce abomasal motility. The impact of lipid mobilization and deposition in the liver can result in elevations in aspartate transaminase. Cows with an elevated aspartate transaminase level in the periparturient period of between 100 and 180 U/L have an increased risk of an LDA.

Other suggested metabolic factors include stress and age. Stress may provide the link between many periparturient conditions such as dystocia, retained placenta, metritis, or ketosis that have been statistically associated with LDAs in some but not all studies. Endotoxemia can reduce gastrointestinal motility and has been proposed to be a predisposing factor, but clinical studies of endotoxemia as a variable have not shown an association. Age is more difficult to confirm as an independent variable. Reports in the 1990s suggested an increased risk of abomasal displacement with age. Others have shown the highest incidence in cows in their second to fourth lactation. However, more recent reports in North America and Europe have found that first-calf heifers were more heavily represented (31% to 58%), suggesting that other factors play a larger role in the development of abomasal displacement than age.

Management and Environment. A number of management practices have been linked to the development of LDA. Exercise and access to pasture are often implicated. Housing at high density in complex systems and overconditioning during the dry period are also commonly identified as predisposing factors. Overconditioning in the dry period increases the risk of negative energy balance as discussed previously under Nutrition. Seasonal changes may play a role in the development of LDA, with an increased incidence reported in cold seasons.

Diagnosis and General Prognosis

Diagnosis. Adult dairy cows with an LDA are typically noticed by the herdsman when their milk production and/or feed consumption is less than expected or they have a sudden drop in milk production and/or feed consumption later in their lactation. Classically, cows with LDAs selectively go off concentrates first, although this may vary with individual animals. Other commonly recognized signs include depression and loose or pasty, scant feces that may be darker in color than normal. The nature of feces is an important indicator of possible concurrent diseases. Although often called *diarrhea*, cows with an LDA alone typically have an increase in fecal fluid content but a reduction in overall fecal volume. When fecal volume and fluidity increase, concurrent intestinal diseases such as Johne's or bovine viral diarrhea should be considered, with the prognosis and plan adjusted accordingly. Dark feces (melena) may occur as a result of abomasal hemorrhage from ulcers, with a similar need for an altered prognosis and plan.

The veterinarian most commonly diagnoses LDA by using simultaneous auscultation and percussion to detect a tympanic ping on the left side of the cow. The ping is usually centered over the last few ribs on the left side on a line from the elbow to the tuber coxae. With extreme distention, the abomasal ping can be detected in the left flank as far caudally as the tuber coxae and as far cranially as the ninth rib. Occasionally, the ping will be located more ventral or cranial than expected. This may occur transiently because of repositioning of structures as gas enters or leaves the abomasum. However, if the abnormal ping location is consistent, the possibility of abomasal adhesions caused by concurrent abomasal ulcers should be considered. In some cases, the ping will disappear completely for a period of time only to recur at a later time. This is commonly called a *floating displaced abomasum*, which suggests the abomasum moves back and forth from displaced to normal position. It is more likely that the ping comes and goes as gas builds and then passes temporarily out of the abomasum while a portion of the abomasum remains to the left of the rumen.

The ping caused by an LDA must be differentiated from other sources of left-sided pings, including ruminal tympany, pneumoperitoneum, and rumen void. By combining information about the ping's location and results from abdominal palpation per rectum, veterinarians can make most diagnoses in adult cattle with a high degree of reliability. It is uncommon for an LDA to distend to a size that can be directly palpated per rectum; however, the rumen is usually smaller with reduced motility and is palpably displaced to the right of the body wall. This often causes a sharp depression of the flank behind the last left rib visible on external examination. This depression commonly is called a *slab-side*. Ruminal tympany causes a ping that is typically more dorsally and caudally placed along the dorsal left-paralumbar fossa than an LDA ping. A distended rumen with a gas cap should be palpable per rectum against the left body wall, and the left-paralumbar fossa will appear full—not sunken—on external examination. The ping associated with pneumoperitoneum is also more dorsally located and may be less resonant than an LDA or ruminal ping, although ping intensity is not a highly reliable method of differentiation. Pneumoperitoneum may produce a ping on either or both sides of the cow, with right-sided pings more common than left. The characteristic "tight" feeling of the collapsed descending colon on one's arm and the readily movable descending colon without the normal abdominal resistance during palpation per rectum should also suggest pneumoperitoneum. It is possible for both LDA and pneumoperitoneal pings to be present at the same time, in which case concurrent left displacement and perforating abomasal ulcers should be suspected. On occasion, a dull ping in the typical location of an LDA can be detected in association with a rapid reduction in rumen size. Sometimes called a *rumen void ping*, this ping is generally not very resonant. Palpation by rectum should confirm the small rumen size (collapsed dorsal sac of the rumen).

On occasion, the veterinarian may also detect a tympanic ping on the right side of the abdomen in cows with a characteristic left-sided LDA ping. In most cases, this represents a transient accumulation of gas in the cecum, ascending colon, or duodenum. This gas may accumulate in these sites from generalized ileus or may represent boluses of gas that have escaped from the displaced abomasum during movement or transportation. In either case, frequent changes in location and size of these right-sided pings help confirm transient gas accumulation as opposed to accumulation related to intestinal obstruction. If the right-sided ping is constant in location and steady or increasing in area, palpation per rectum to check for the presence of a distended viscus is indicated. The characteristic loss of definition of abdominal structures during palpation per rectum would support a diagnosis of pneumoperitoneum.

If a question about the diagnosis of LDA remains, several additional diagnostic steps can be taken. A nasogastric tube can be passed into the rumen. While an assistant blows on the external end of the tube, the left flank immediately caudal to the last rib can be auscultated. The bubbling sound in the rumen will be soft and distant if the abomasum is

displacing the rumen toward midline but loud and close if the rumen is adjacent to the body wall. Decompression of gas from the rumen may allow a better diagnostic evaluation per rectum. Fluid can be collected by stomach tube to evaluate for elevated rumen chloride (normal is less than 30 mEq/L) consistent with abomasal outflow obstruction and ruminal reflux if laboratory resources are available. Alternatively, percutaneous centesis can be used to collect a small amount of fluid from the viscus adjacent to the left flank to evaluate the pH. A 6- to 8-cm or longer, 10- to 14-gauge needle is passed through the body wall into the center of the area defined by a ping. The odor of the gas escaping through the needle may suggest rumen or abomasum, but digestive disturbances can alter contents of either structure enough to make odor alone unreliable. A purulent odor suggests peritonitis with pneumoperitoneum or abscess formation. A 20-cm length of polypropylene tubing with an attached syringe is quickly passed through the needle, and a small amount of fluid is aspirated for evaluation by using standard pH paper. A pH less than 3.5 indicates a displaced abomasum, whereas a pH greater than 5.5 suggests a ping originating from the rumen. This test is known as the *Liptac test*. Although helpful, it should be used only if differentiation cannot be made with standard methods. Some local peritoneal contamination will occur, which increases the risk of infection if exploratory surgery follows. The procedure should be avoided on the right side of the abdomen, where the small intestine can be penetrated and the concentration of pathogenic bacteria in the lumen is more likely to cause peritonitis.

The growing availability of ultrasound yields an additional practical diagnostic tool. Although an LDA can generally be accurately diagnosed based on clinical examination alone, ultrasound can help differentiate between pings due to the abomasum and other sources on the left. Ultrasonographic examinations can be done using a 3.5- to 5-MHz linear or convex transducer in the standing cow. Hair should be clipped over areas in question. Application of alcohol plus or minus a transducer gel will be necessary in most cases for diagnostic images. Ultrasonographic findings consistent with an LDA include the following: 1) gas reverberation artifacts dorsally in the last two intercostal spaces on the left where the displaced abomasum gas cap prevents imaging of the wall of the rumen that normally lies adjacent to the body wall at this level, with hypoechogenic to echogenic ingesta in the abomasum ventrally. The rumen may be visualized above the gas cap and through the echogenic content in the abomasum ventral to the gas cap. 2) The omasum is visible in the 6th to 11th intercostal spaces on the right and immediately ventral to the costal arch. In LDAs, the dorsal and ventral borders of the omasum are more ventral to their location in healthy cattle. 3) Omasal lamina may be visible as thin echogenic straight parallel lines in the 6th to 11th right intercostal spaces compared with healthy controls in which the omasum can be visualized in the same location but in which the lamina were either not visible or only visible at the attachments of the lamina as short echogenic cone-shaped structures. 4) The reticulum may be visualized dorsal to the omasum in the 9th intercostal space on the right. 5) Small intestines may be visible dorsal to the omasum in the 9th intercostal space on the right. 6) Abomasal rugal folds may be visible in the abomasal wall or in the ventral fluid component of the displaced abomasum. These folds are not normally visible in the healthy abomasum and have been proposed to suggest conditions with abomasal reflux.

Assessment of electrolyte and acid-base disturbances should be part of the diagnostic evaluation. In the absence of immediate laboratory access, the degree of electrolyte disturbance can be roughly correlated to the level of dehydration. Decreased Na, Cl, K, and C were found in 88% to 92% of the LDAs. Adult cattle with 4% to 5% dehydration can be expected to have mild metabolic hypochloremic alkalosis with normal to slightly low potassium and/or sodium. These changes generally resolve after restoration of normal abomasal position if the cattle have access to water. Cattle with more severe dehydration can be expected to have more significant disturbances and a laboratory evaluation would be beneficial. In a field setting, cows with 8% to 10% dehydration can be expected to be hypokalemic as well as hyponatremic and hypochloremic. A paradoxical aciduria, detectable with a pH strip, may be present. Hypocalcemia is a common causative or concurrent condition that should be evaluated and addressed. Early signs of hypocalcemia include slow pupillary light response and cool or cold ear tips in comparison to ear base. Muscle fasciculations and weakness suggest advanced hypocalcemia.

In addition to identifying an LDA, the veterinarian must also assess the cow for concurrent conditions and metabolic status. The frequency of concurrent diseases in cows with LDA is high, but documented incidence is not often provided. One study indicated that 61.1% of cows with LDA had some concurrent disease, with conditions of the reproductive system representing up to 76% of the cases. Mastitis, metritis, retained placenta, ketosis, and hypocalcemia are all common postparturient conditions that should be considered. Udder edema may be present in first-calf heifers. The presence of abomasal ulcers is more difficult to confirm, but ulcers are suggested by anemia and a positive fecal occult blood test (bleeding ulcer), cranial right abdominal pain on pressure, pneumoperitoneum, fever of undetermined origin, an elevated peritoneal fluid white blood cell count (>3000 cells/μL) with neutrophilia and degenerative neutrophils and possibly bacteria, or an abnormally located left-sided ping. Other changes associated with LDAs include lower blood cholesterol, total protein and albumin, and higher serum urea levels than nonaffected cows in the same time frame. An elevated serum glucose at delivery has been suggested to be due to a decreased cellular response to insulin in late pregnancy and early lactation. Gamma-glutamyl transpeptidase and total bilirubin are increased as a result of cholestasis. Aspartate transaminase levels were found to be higher in cows with LDA, potentially due to protein breakdown for glucose production. Elevated hemoglobin, total leukocyte and neutrophil counts, total protein plus aspartate transaminase, and urea have also been identified in cows with LDA compared with controls.

Prognosis (general). The prognosis for return to function varies slightly with the treatment approach chosen (see discussion for each technique) and the nature of concurrent conditions. Rolling alone caries the poorest long-term prognosis. Although rolling eliminates the ping in most cases and may transiently correct the abomasal position, up to 70% have redisplaced by 6 weeks after rolling. The prognosis for return to function ranges from 77% to 91% after closed surgical procedures (blind tack, tack and roll) and 80% to 100% after conventional surgical procedures. A large study of cattle presented to 17 North American teaching hospitals for treatment of an LDA showed an overall hospital fatality rate of 5.6%. Additional losses may be expected after initial treatment. In one randomized treatment study, 6 of 37 (15.2%) cows treated by a closed technique and 12 of 35 (34.3%) cows treated by conventional surgery were lost from the herd through death or culling within 120 days of the procedure. A longer term study of LDAs in German dairy cattle treated surgically showed that approximately 50% were culled from the herds within 1 year of surgery. The overall percentage of cows lost to the herd (dead or culled)

treated by open surgical procedures in one study was 38%, compared with a general herd attrition rate for similar herds of 18.7%.

Pretreatment prognostic factors that can be used to predict outcome in individual cows with LDA are limited. L-lactate, which is a promising prognostic tool in cows with right-sided abomasal pings (RDA, RVA), has not been shown to be predictive in cows with LDA. Morbidity and mortality are more related to concurrent diseases than either the LDA or the treatment method. Cows with an LDA have a delayed return to breeding and a loss of total milk production of 368 to 755 kg for that lactation. The prognosis for cows with concurrent perforating ulcers is particularly poor, with a reported survival to discharge rate of 38% and retention in the herd 1 year after surgery of only 14%. One study of cows treated for LDA demonstrated that there was a 43-fold greater odds of culling for "miscellaneous reasons." A drop in milk production can be expected in lactating cows diagnosed with an LDA, with recovery to expected production levels within 120 days of surgical (conventional or closed) treatment. The milk loss (after an adjustment for decreased feed cost) was estimated in one case-control study to be 10% more for a closed procedure than for conventional surgery. Losses from delayed conception, loss of genetic potential, and other consequences of the LDA and concurrent diseases are more difficult to factor into a formula but may be important considerations in the decision to treat or not treat an individual cow. Finally, the amount of potential income from slaughter should be considered. The cost of treating LDAs by toggle pin was 65% of omentopexy cost in a case-control study that considered the cost of treatment, milk loss, and livestock loss (replacement cost and slaughter value based on percent of treated animals lost to the herd within 120 days).

Treatment

General considerations. Effective management of a cow with an LDA requires a number of decisions, the first being whether to treat the individual cow at all. This decision should be based on the cost of treatment, anticipated economic losses from the LDA and concurrent conditions, prognosis for return to production, expected future income from production, immediate slaughter value, and—perhaps of greatest impact—the owner's interest in treating the specific animal in question. Use of decision analysis can help weigh the variable economic factors, although the owner may ultimately make his or her decision based on factors that do not fit directly into an objective formula.

Several studies have provided useful information for predicting treatment costs, prognosis, and expected economic gains and losses in general terms. A decision-tree cost analysis of treatment options for LDA in the late 1980s in the USA that included cost of treatment, subsequent milk production, cost of feed, and cost of treatment showed an expected monetary value of $1661 for open surgical techniques, a slightly lower values of $1636 for closed surgical procedures (blind tack), an expected monetary value of $764 for rolling alone, and an expected economic value of $480 for selling the cow. Sale was recommended if an LDA recurred regardless of the technique. This analysis did not separate the costs of treatment for concurrent diseases, or toggle-pin or laparoscopic techniques. Without travel, examination, or concurrent disease-treatment expenses, the cost of a minimally invasive closed procedure for treatment was estimated to be half that of a conventional open procedure.

A variety of methods have been used to correct and stabilize abomasal displacements. Selection of a specific approach should take into account the likelihood the process will do the following: 1) effectively return the abomasum to its normal position; 2) stabilize the abomasum in a functional position; 3) allow management of concurrent pathology in the abdomen; 4) minimize additional risk to the patient; 5) be possible with the available restraint options; and 6) be economically reasonable for the owner. Although each technique has unique features, approaches can be grouped into three main categories: medical management, minimally invasive closed procedures, and conventional open surgical procedures.

Medical management and supportive care. The goals of medical management include promotion of abomasal motility, correction of fluid, electrolyte and acid-base disturbances, and treatment of concurrent disorders. The ultimate goal is to speed return to production and minimize economic losses. Medical therapies can be a valuable adjunct to surgery; however, the likelihood of effectively resolving an LDA with medical management alone is very low and cannot be recommended at this time as a reliable approach. Withholding feed for 48 hours, feeding high-fiber diets, forced exercise, and truck rides have been suggested treatments but are generally acknowledged to have little long-term effect. A transient reduction or loss of the characteristic LDA ping after transportation is a phenomenon well recognized by food animal practitioners at referral centers. The rapid return of the ping (generally within 6-8 hours) suggests that transportation helps expel gas from the abomasum but does not restore normal abomasal position or function.

Medical management tools that can be important parts of supportive care include fluid therapy, abomasal motility–stimulating agents, and treatments specific for concurrent diseases. The typical fluid disturbances in adult cattle with LDAs are dehydration with hypochloremic metabolic alkalosis and often hypokalemia and hyponatremia. In the absence of laboratory results, the magnitude of the hypokalemia is generally directly related to the severity of dehydration. Adult cattle with an LDA and clinically mild (<6%) dehydration without other metabolic disturbances do not necessarily require systemic fluid therapy if surgical correction of the displacement is planned within a few hours. These cows can generally self-correct their fluid imbalances through oral intake after surgery if adequate water is available. Provision of two water sources is recommended for 48 to 72 hours after surgery: plain water as well as water supplemented with electrolytes (including potassium) and dextrose. Most cattle will select the electrolyte solution as needed; however, plain water should always be available to avoid accidentally exacerbating dehydration in those few cattle that will not drink electrolyte solution. Supplementing water or water plus electrolyte solution by stomach tube after correcting the displacement is also an option if access to water sources for spontaneous intake is unreliable.

Preoperative or postoperative IV fluid therapy is encouraged for moderately dehydrated adult cattle and strongly recommended, if not mandatory, for severely dehydrated animals. Administration of 20 to 40 L of isotonic saline with 20 to 40 mEq/L of KCl given IV over 4 to 6 hours is ideal but is generally only practical when the cow is brought to a clinic or referral site. Hypertonic saline (1 to 2 L) is a more practical initial approach in a field setting, assuming that surgical correction of the displacement is planned within several hours and that oral supplementation can be provided after surgery. Because of its rapid rate of administration, potassium should not be added to hypertonic saline. Oral supplementation with a 24-hour KCl dose of 0.4 g/kg of body weight after surgery, in a single dose or split into two doses every 12 hours, is an effective way to address moderate hypokalemia. Additional magnesium supplementation may be necessary for cows that do not rapidly resume full feed intake.

The most effective way to stimulate abomasal motility is to restore the normal abomasal position. Ensuring that the abomasum remains in position until all gas is cleared and normal motility patterns have returned is also an important step to ensuring that displacement does not recur. These two steps are best achieved through a minimally invasive or open surgical approach. However, medical management can facilitate return of normal motility patterns and help prevent gas buildup. Correction of low calcium and potassium levels are also important steps in supporting normal motility. Potassium supplementation has been discussed. Systemic administration is the most direct way to restore calcium levels in the face of at least temporarily reduced abomasal motility. Intravenous administration is the most direct and rapid way to restore levels. Calcium solutions (0.5- to 2-L 50% calcium dextrose or calcium gluconate) can be given IV alone, but cardiac monitoring is important because rapid administration can result in potentially fatal bradycardia. In the absence of ionized calcium levels, the amount of calcium administered should be based on the magnitude of clinical signs. Cool ear tips and/or slow pupillary response in the absence of skeletal muscle weakness or fasciculation can usually be managed with 0.5 to 1 L of IV calcium solution. Muscle weakness or fasciculations may require larger volumes. Recumbency and/or cardiac arrhythmias can indicate more extreme calcium deficiencies but also requires more caution in the rate of calcium administration. Calcium borogluconate can be administered subcutaneously with minimal risk of tissue damage and reduces the risk of toxicity, but the subcutaneous route results in slower and less reliable absorption.

Several prokinetic agents have been used as a part of supportive care postoperatively to encourage abomasal motility. Agents that have been tried include metoclopramide, bethanechol, neostigmine, and erythromycin and other macrolide antibiotics. Most studies included multiple therapeutic steps, and the efficacy of individual drugs specifically on abomasal motility is difficult to verify. Erythromycin and several other macrolide antibiotics have been shown to specifically enhance propulsive motility of the abomasum in calves and in cattle. A preoperative erythromycin dose of 10 mg/kg restored normal abomasal motility patterns after surgical correction of LDA. The mechanism of action for macrolides is believed to be through their ability to bind to motilin receptor sites and stimulate the rate of abomasal emptying during periods between meals. Acid-base disturbances can be exacerbated if magnesium-based intestinal stimulant use is continued in an uncorrected displacement.

Intravenous dextrose (1 to 2 L of 50% dextrose or a calcium/dextrose solution) is the preferred initial treatment for cattle with moderate to severe ketosis. Return to full feed consumption after surgery is an important goal for control of ketosis and for recovery of milk production. Oral propylene glycol (300 mL orally sid or bid for 4-5 days) can increase ruminal alkalosis and decrease appetite. Therefore it is only recommended in postoperative cattle with mild ketosis that are eating and have good rumen motility. More aggressive therapy such as corticosteroids (10-20 mg dexamethasone once), protomine zinc insulin (200 U subcutaneously every 48 hours while receiving intravenous 5% dextrose), or continuous IV 5% dextrose infusion may be indicated for cows with nonresponsive ketosis after surgery. Administration of 500 mg of recombinant bovine somatotropin after surgical correction of LDA may improve recovery from ketosis after surgery.

Whether they are causally related or incidental, the veterinarian must recognize that concurrent diseases are very commonly present and must be identified and addressed for successful case management of cows with an LDA. A large multiinstitute study identified concurrent diseases in 53.6% of cattle with LDAs; ketosis and uterine disease were most commonly identified. Thirteen percent of cows with concurrent disease had more than one disorder. Other studies report that as many as 64% of cases have concurrent disease, with one study reporting that 44.1% of cases had multiple concurrent diseases. In addition to ketosis, metritis, and retained placenta, other concurrent conditions commonly reported are mastitis, hypocalcemia, fatty liver, lameness, and abomasal ulcers.

Left Abomasal Displacement (LDA): Closed Procedures

Closed procedures include rolling, blind tack, and toggle pin. All three procedures rely on the concept that gas trapped in the displaced abomasum will carry the abomasum to the highest available space in the abdomen when a cow is on its back. This position approximates the abomasum's normal position on or slightly to the right of ventral midline. Repositioning requires that the abomasum be free to move, which will not occur if the abomasum is adhered in an abnormal position or lacks sufficient gas to float it back to its normal position during the procedure. These procedures share many similar advantages and disadvantages.

All three closed procedures share advantages compared with open surgical procedures, including a short procedure time (<15 minutes in most cases), minimal invasion of the peritoneal cavity, and very few equipment and supply requirements. The short procedure time lessens the risks associated with dorsal recumbency and can be performed in most cows without withholding feed and water. Dorsal recumbency may also increase drainage of the uterus in cows with concurrent metritis. The absence of an incision into the peritoneal cavity can reduce the risk of complications related to peritonitis and incisional healing. The minimal equipment required and short procedure time result in lower costs for abomasal stabilization than for conventional surgical approaches. As a consequence, closed procedures may be more economical than open procedures in cattle with limited long-term value in the herd or with medical problems that temporarily preclude more involved surgical procedures.

The primary disadvantage of the closed approaches is the veterinarian's inability to confirm return of the abomasum to a functional position at the time of the procedure. These approaches cannot be used for prophylactic stabilization of the abomasum in the absence of gas, because the abomasum would not be adjacent to the body wall and available for fixation. Dorsal recumbency alone may align an RDA in an anatomically correct position but will not correct an abomasal volvulus. Because of the difficulty of differentiating between RDA and RVA without surgical exploration, these approaches should not be considered for treatment of cows with right-sided abomasal pings. Although the time required in dorsal recumbency is short, it is not without risk. In a study of arterial oxygen levels of cows without supplemental oxygen support, values dropped from a baseline standing mean of 85.9 ± 2.06 mm Hg in the standing cow to a mean of 64.7 ± 2.92 mm Hg within 15 minutes and 61.5 ± 2.29 mm Hg at 30 minutes. Even a limited period of dorsal recumbency carries significant risk in animals with preexisting respiratory compromise or abdominal distention, and an alternative standing approach should be considered in these cases. Sufficient personnel to safely cast and position the cow must be available, although judicious use of tranquilizers and experience reduces the number of people needed. Evaluating and treating concurrent abdominal pathology are not possible with these approaches.

Rolling and closed techniques with suture or toggle pins have a few different disadvantages. Rolling has the disadvantages of a high recurrence rate (50-70%) and lack of stabilization. Abomasal volvulus has been reported as a complication of rolling to correct an LDA. Toggle pin and blind tack techniques can result in penetration of other gas-filled intestinal structures that float to the ventral midline, resulting in obstruction and/or peritonitis. The omentum can also be caught in the suture/tack. Because these closed techniques have a high statistical success rate in a herd, an occasional failure can be accepted as financially justifiable. The risk to individual animals prohibits using minimally invasive techniques other than laparoscopy-assisted procedures in very valuable cattle, except possibly rolling for temporary relief of displacement.

Rolling. Rolling relies on the gas in the displaced abomasum to float it to its normal location when the cow is placed in dorsal recumbency. It does not allow the veterinarian to confirm complete correction of abomasal position and the abomasum is not stabilized in position. Because of the limited security of this procedure, it is only recommended for short-term relief of symptoms in cows that do not warrant or cannot tolerate another procedure at that time. Rolling is contraindicated in cows with marked respiratory compromise, in cows without a ping at the time of the procedure, and in cattle with concurrent abdominal disease. An alternative procedure that allows more secure stabilization is justified for animals with long-term value in the herd.

Preparation. Several preparatory steps can improve the success and safety of the procedure in adult cows. Preoperative administration of calcium (IV) to cows with signs of hypocalcemia will help improve abomasal motility and can decrease the risk of musculoskeletal injury during recovery. A single preoperative dose of prophylactic antibiotics may be indicated if needle decompression is planned. Preoperatively clipping the right cranioventral abdomen from xiphoid to umbilicus between the midline and the right mammary vein also reduces the amount of contamination if needle decompression is planned. Placing ropes on the front and back legs on the side that will be down initially (typically right) helps control the casting process and allows quick control of all feet as the cow is placed in dorsal recumbency. Sedation is not required for most cows; however, a rapid-acting sedative such as xylazine HCl (0.05 to 0.1 mg/kg IV) administered immediately before casting facilitates the process of dropping and stabilizing the cow on its back. Xylazine HCl use should be avoided during the last trimester of pregnancy because of its potential stimulatory effect on uterine myometrium. It is not recommended in the presence of abdominal distention because of its tendency to promote ruminal distention.

Procedure. The cow should be cast into right lateral recumbency. If ropes were not preplaced on the front and back legs, they can be placed at this time. The cow is then rolled into dorsal recumbency and the front and hind feet hobbled together to help control movement. Alternatively, the process can be done under sedation without ropes by placing a person on either side of the withers to stabilize the cow on her back.

Once the cow is in dorsal recumbency, the veterinarian should confirm the location of the abomasum by simultaneous auscultation and percussion of the cranioventral abdomen. The cow should be maintained on its back until the ping is no longer detectable, thus indicating that most or all of the gas has been cleared from the abomasum. Rocking the cow gently in a 60- to 70-degree arc while it is in dorsal recumbency may help evacuate gas and return the abomasum to its normal position. The veterinarian can speed gas clearance by placing a large-gauge (14- or 16-gauge), 6- to 12-cm needle through the ventral body wall into the center of the area of the ping until gas flow has ceased. The needle should be rapidly removed as soon as gas flow ceases to minimize tissue trauma and peritoneal contamination. Suction, if available, accelerates the process and may allow more complete decompression. Local infusion of an antibiotic through the needle during removal is not recommended, although it is anecdotally described. If decompression is planned, a single prophylactic dose of antibiotic before the procedure would be a more effective method of controlling infection.

After decompression, the cow should be carefully and slowly rolled onto her left side and into sternal recumbency. Once in a sternal position, the cow should be allowed to stand when ready. Pushing a cow to stand while it is hypoxic and disoriented from dorsal recumbency may increase the risk of incoordination and injury.

Posttreatment care. Examination per rectum after recovery is not a routine procedure but is an advisable precaution for cows in the last trimester of pregnancy to identify early uterine torsion. It may also be valuable in detecting mesenteric or uterine volvulus secondary to rolling. Examination per rectum is mandatory in any adult cow that demonstrates signs of abdominal pain after recovery. Any concurrent periparturient disorders should be treated. The owner should be made aware of the risk of recurrence, and the cow should be monitored for signs consistent with the recurrence of abomasal displacement.

Prognosis and complications. Long-term studies of rolling alone as a treatment indicate that, despite apparent initial improvement in a high percentage of cows, 50% to 70% of cows redevelop an LDA, often within several weeks. Therefore rolling is recommended only as a temporary means of relief for adult cattle that do not warrant a more aggressive approach. Although they are the primary complications of rolling, uterine torsion and mesenteric volvulus have been reported in rare cases.

Blind Tack/Toggle Pin. The blind tack suture procedure was described by Hull in 1972. Sterner and Grymer first described the toggle pin (Figure 14-68) technique in 1982. Like the rolling procedure, the blind tack and toggle pin techniques

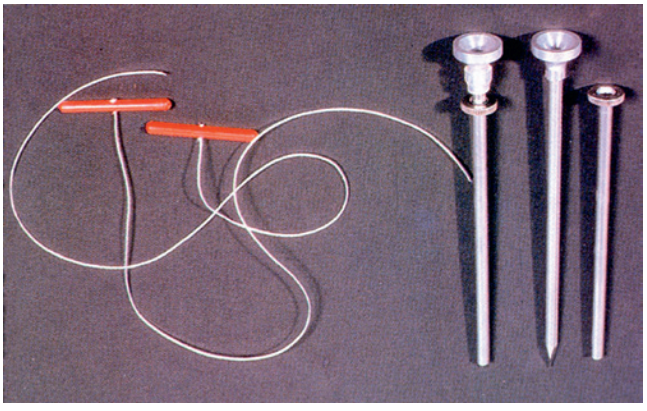


Figure 14-68 Pictures of toggle pin and attached suture material and, from right to left, cannula, trocar, and assembled cannula and trocar.

rely upon the gas in a displaced abomasum to carry the abomasum to a normal position when the cow is placed in dorsal recumbency. However, these approaches add a step, to stabilize the abomasum once it has returned to its normal position. Although this increases the long-term success of these procedures over rolling alone, complications are more severe if complete repositioning does not occur. The primary advantages of the toggle pin technique over a blind tack are the ability to confirm penetration of the abomasum before fixation and to remove most of the gas from the abomasum.

The toggle pin technique shares many of the limitations described for the blind tack, including contraindications for cows with marked respiratory compromise, for cows without a current ping, and for cows with concurrent abdominal disease. The presence of other gas-filled structures in the abdomen would be another contraindication because these structures may also rise to the highest position in the ventral abdomen and be mistakenly identified and "pexied" as the abomasum once the cow is on its back. Neither technique can be used to stabilize the abomasum prophylactically in an animal without an existing displacement.

Preparation. Preoperative considerations are similar to those described for rolling, with a few additional recommended steps. Clipping the right cranioventral abdomen from umbilicus to xiphoid before casting, although not absolutely necessary, decreases the risk of infection, facilitates identification of the appropriate location, and minimizes the time the cow must spend in dorsal recumbency. Identifying the milk well and milk vein locations on the right with a marker before casting the cow may also be helpful because the vein is less distended when the cow is on her back.

The cow should be cast and positioned in dorsal recumbency (see Rolling). Tying the front and hind limbs in an extended position increases safety for the veterinarian. Hay bales can be used to support the shoulders if a ditch or gutter is not available. Use of local anesthesia is recommended; however, it must be applied quickly to minimize time and risk of premature abomasal decompression.

Procedures. It is important to work quickly once the abomasum returns to a functional position before the gas is cleared from the abomasum. As soon as the cow is restrained in dorsal recumbency, the position of the abomasum must be confirmed by locating a ping in the right cranioventral abdomen, and the area should be quickly scrubbed. *If a distinct ping cannot be identified in the appropriate location, the procedure should be aborted without placing any sutures or pins.* By following this simple guideline, accidental tacking of structures other than the abomasum can be avoided in most cases.

For a blind tack, a large, 9- to 20-cm, curved, hand-held needle (originally an upholstery needle) should be placed in the center of a long (30-cm) strand of No. 2 to No. 4 nonabsorbable suture material. The needle is pushed through the body wall into the abomasal lumen and back out through the body wall at a site in the center of the ping area between the midline and milk vein and several centimeters caudal to the xiphoid. The doubled suture is tied and auscultation and percussion repeated to identify the remaining area of ping. If the area is large enough, a second suture is placed 4 to 6 cm cranial or caudal to the first within the area that still pings. Once the suture or sutures have been placed and tied, the cow is rolled slowly onto her left side and then into sternal recumbency. The cow is allowed to stand when ready.

Placement of toggle pins begins by pushing a 4-mm (12 French) cannula and trocar (Figure 14-69) into the abomasum through the body wall in the area of ping. Placement of the first pin at the most cranial aspect of the ping has been suggested to facilitate penetration of the abomasum. The trocar is removed, and entry into the abomasal lumen is confirmed by the abomasal gas odor passing through the cannula. If the veterinarian is in doubt, polyethylene tubing passed through the cannula can be used to aspirate a small amount of fluid from the penetrated lumen for evaluation with a wide-range pH paper. A fluid pH of 2 to 3 would confirm penetration of the abomasum. In practice, the time necessary to collect fluid must be weighed against the risk of losing contact with the abomasum as gas escapes. If confirmation by fluid pH is performed, gas escaping from the cannula should be minimized until the bar is placed. Once the position has been confirmed, a 3-cm-long 10 French (3.3-mm diameter) polypropylene toggle pin with a centrally attached 30-cm polyamide suture should be pushed through the cannula with the trocar into the abomasal lumen. The cannula is then removed, the bar is pulled firmly against the abomasal wall, and a hemostat is placed on the suture near its exit from the skin. If gas is still present, a second pin should be placed 5 to 10 cm caudal (or cranial if that is where the ping remains) to the first. Once the second pin is pushed through the cannula, the cannula should be left in place until all gas has escaped from the abomasum. The cannula is then removed; the second pin is pulled firmly against the abomasal wall; and the two sutures are tied together, leaving room for 1 to 2 fingers under the suture. Tighter placement increases the risk that the bars necrose through the abomasal wall. If the ping disappears before the second pin is placed, the sutures attached to the first pin can be sutured to the skin or around a stent (rolled gauze, a button, or other object). Once the pins have been placed, the cow can be rolled slowly onto its left side and then into sternal recumbency.

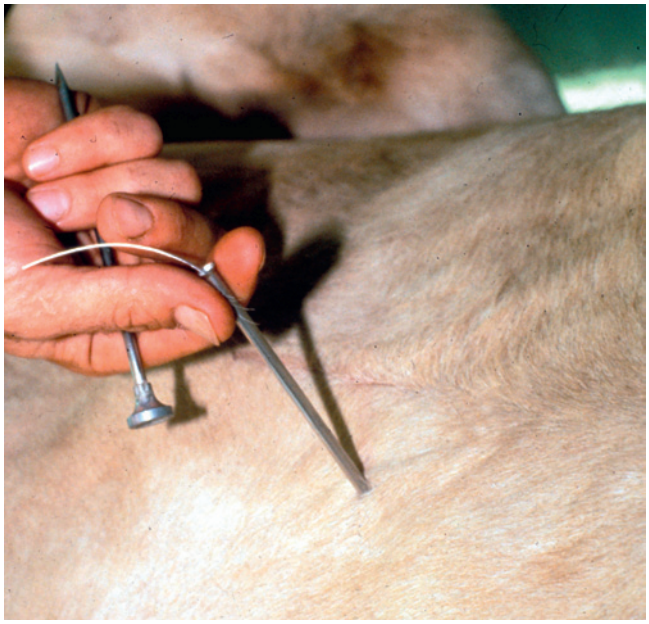


Figure 14-69 Use of toggle pin in a cow with left displacement of the abomasum. With the cow in dorsal recumbency, the trocar is placed at the intended pexy site.

Postoperative care. Concurrent diseases should be treated accordingly. If antibiotic prophylaxis was administered before surgery, there is no need to continue after surgery unless indicated for treatment of other medical problems.

The cow should be closely monitored during the first week after surgery for signs of restored abomasal function (appetite, milk production). In some cases of left abomasal displacement, the abomasum only partially repositions when the cow is placed in dorsal recumbency, thus leaving its long axis perpendicular to the cow's midline. This may still produce a ping in the right-paramedian area when the cow is on her back. If the abomasum is tacked in this position, function will be mildly to moderately impaired. Incomplete repositioning also increases the risk of accidentally catching the greater omentum with the suture or toggle pin, thereby fixing the abomasum in an abnormal position. If significant improvement in clinical signs is not evident, the sutures or toggle pins should be released by cutting the sutures as close to the skin as possible within 48 hours after surgery and allowing the suture ends or pins to slide into the abomasal lumen. An open procedure should be considered at this point if the cow is to remain in the herd.

One of the more serious and avoidable complications of the blind tack and toggle pin techniques is abomasal fistulation along the suture tract (Figure 14-70). This complication can be avoided by releasing the sutures at the skin surface after a stable adhesion has formed but before the track for a fistula develops. A stable fibrous adhesion should be present by 10 to 14 days after suture placement. Sutures should be cut as close to the skin as possible 2 to 3 weeks after placement. The portions remaining in the abdomen will either slide back into the abomasum and be passed through the intestinal tract or be incorporated into the fibrous adhesion. Delaying release of the sutures or pins for more than 3 weeks after surgery increases the risk of fistulation.

Prognosis and complications. An initial success rate of 77% to 93% has been reported for blind tacks. The reported initial success rates for cows treated with toggle pins vary from 80% to 88%. The reports generally refer to short-term survival and do not usually take into account the percentage of cows (4%-7%) for which a planned blind procedure could not be performed in the absence of a ping. Toggle pin stabilization of left abomasal displacement compared favorably with right-paramedian abomasopexy in postoperative feed intake, milk production, and survival in the herd in one randomized study. More cows treated by toggle pin stabilization remained in the herd 120 days after treatment (31/37) than those treated by standing right pyloroomentopexy (23/35). When comparing the economic value of toggle pin versus open pyloroomentopexy at 120 days after repair, the cost of toggle pin (including cost for the procedure, milk loss, and livestock losses) was 63% of that for pyloroomentopexy.

Although the blind tacks and toggle pin procedures have high success rates that are comparable with those for open techniques, potential complications can be severe. Reported problems include redisplacement (caused by failure to catch the abomasum or suture pullout), abomasal rupture at the suture site (Figure 14-71), local or diffuse peritonitis (caused by leakage along the suture line, laceration of a viscus during needle or pin placement, or suture pullout), cellulitis, pexy of structures other than the abomasum (Figure 14-72*A* and *B*), partial or complete abomasal obstruction (caused by pexy of the abomasum without full return to a normal position, placement of pexy sutures too close to the pylorus, or pexy of omentum that results in a forced displacement), fistulation, and thrombophlebitis of the subcutaneous vein. Despite the purported severity of complications, controlled studies indicate failures tend to be most commonly due to factors unrelated to the surgical technique. In the original report of the blind tack procedure, 5 of the 40 treated animals were considered failures. Four of the failures were related to concurrent diseases, and the fifth was a complication of casting the animal for recumbency. In one study of 96 cows scheduled for treatment by toggle pin, 6 cows died within 1 to 11 days of treatment, and 6 procedures failed. Seven of the 12 deaths/failures were directly related to the surgical procedure. Four procedures were cancelled in the absence of a detectable ping in dorsal recumbency, and three bar sutures were pulled out, thus resulting in one animal with fatal peritonitis and two redisplacements corrected in subsequent procedures. Of the 5 remaining deaths/failures, 3 were unrelated to the procedure, and 2 were lost to follow-up. In a second study, 13 of 31 cows treated with toggle pins died or were culled by 60 days of lactation after treatment. Of the 13 losses, only one case, an obstruction of the pylorus by misplacement of the caudal pin, was attributable to the procedure itself. All others were lost because of concurrent or subsequent diseases or poor production.



Figure 14-70 Abomasal fistula and infection 3 months after toggle application.

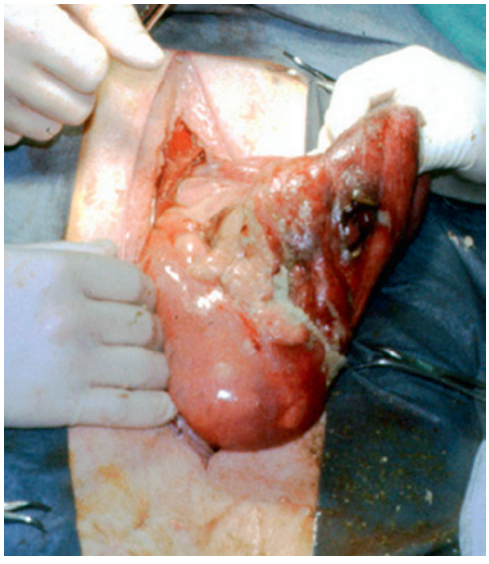


Figure 14-71 Lacerated abomasum after a blind tack procedure (as seen through a ventral right-paramedian incision).

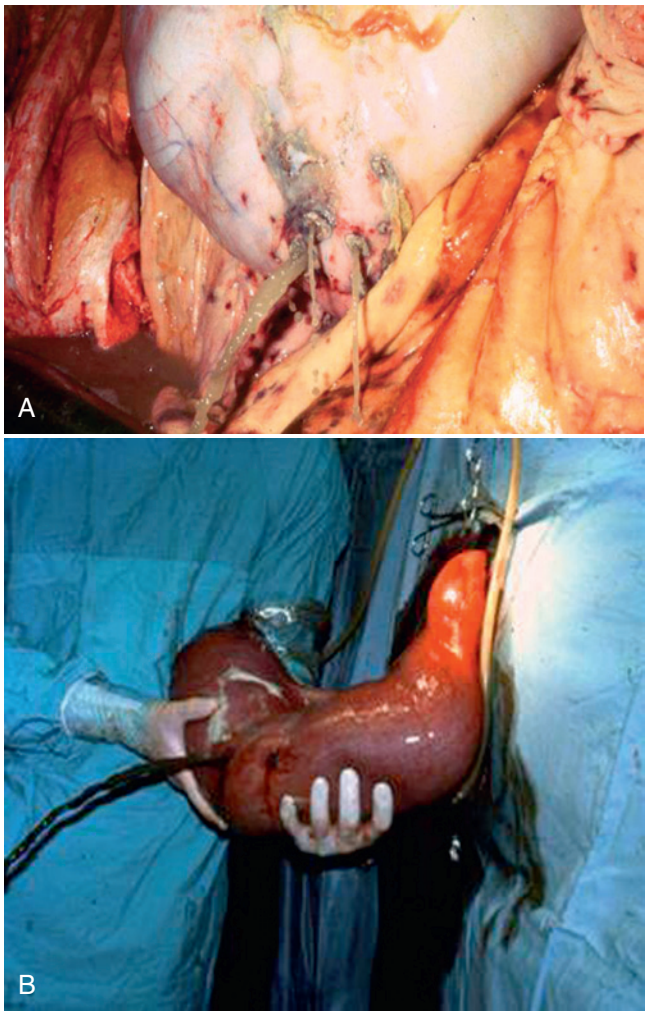


Figure 14-72 *A*, Inadvertent perforation of the rumen during toggle placement. *B*, Inadvertent perforation of the cecum during toggle pin placement was apparent when viewed during a right-paralumbar fossa exploratory celiotomy.

Left Abomasal Displacement: Open Surgical Procedures

Procedures that involve a surgical approach to the abdomen share diagnostic and therapeutic advantages over closed procedures by allowing direct visualization and/or manual examination of the abomasum and other structures in the abdomen, but they share the disadvantages of cost and risks associated with abdominal surgery. These procedures differ from each other by the cow's position during surgery, location of the approach incision, quality of access to the abomasum and other structures in the abdomen, and structures used to stabilize the abomasal position. The commonly used open procedures that meet the goals of treatment for LDAs include right-paralumbar fossa omentopexy, right-paralumbar fossa pyloropexy, right-paramedian abomasopexy, and left-paralumbar fossa abomasopexy. Other techniques described in the literature—including rumenopexy, pyloromyotomy, left-paralumbar fossa omentopexy, and right-paralumbar fossa abomasopexy—have significant disadvantages over the four described procedures and have largely fallen out of use in favor of the other more reliable techniques.

The open procedures share a similar risk of peritoneal and/or incisional infection. In otherwise healthy cattle with good technique used, all open procedures would be considered clean, and prophylactic antibiotics would not be warranted. However, a high percentage of cows with an LDA either have a concurrent infectious process (mastitis, metritis) or a concurrent condition that may decrease the host response to surgical contaminants (ketosis, hypocalcemia, dehydration). Cows with concurrent abomasal ulcers would also have the potential for pathogenic bacterial colonization of the damaged mucosa, and this could increase the risk of peritoneal or systemic infection. Limitations in restraint and the surgeon's ability to control the surgery site in a field setting also increase the risk of surgical contamination. If any of these risk factors exist, a single, broad-spectrum, preoperative, prophylactic dose of antibiotics given intramuscularly (1 hour) or IV (15 minutes) before surgery would be indicated. Preoperative calcium supplementation is particularly important if a recumbent approach is planned or if the cow is at risk of going down during a standing approach. Fluid therapy should be initiated before surgery in moderately and severely dehydrated cattle.

Right-Paralumbar Fossa (Flank) Omentopexy. The standing right-paralumbar fossa (flank) approach is probably the most versatile approach to reposition and stabilization of the many types of abomasal displacements. As a standing procedure, this approach is safer than recumbent procedures in cows with respiratory disease, with increased abdominal pressure caused by late-term pregnancy or ruminal distention, or with musculoskeletal problems that might make rising after surgery difficult. Minimal restraint is required for this approach, and the small number of people needed for restraint and positioning make this approach very popular. The right-paralumbar fossa approach allows access to more abdominal structures for diagnostic and therapeutic procedures than any other approach in adult dairy cattle and should be considered when evaluation of other abdominal structures is needed. The status of the postpartum uterus can be evaluated, and to a limited degree purulent material can be drained by intraabdominal uterine elevation and massage. The combination of access and relatively low stress on the cow make this a common choice for prophylactic stabilization of the abomasum in cows at high risk for displacement.

Although the majority of the abomasum can be palpated in its normal position from this approach, only the most distal pyloric region can be visualized at the level of the incision by placing caudal traction on the greater omentum. Access to the abomasum is even more limited from the right-flank approach while the abomasum is displaced to the left. Therefore this approach is not indicated when direct access to the abomasal fundus or body is needed. Correction of left displacement from this approach requires the abomasum to be movable with space for the abomasum to slide ventrally under the rumen. Therefore this is not a viable approach if focal adhesions caused by ulcer perforation are holding the abomasum in the left displaced position or if peritonitis from any source has resulted in accumulation of fibrin or fibrous tissue in the cranioventral abdomen. This approach is also not appropriate if the cow is too weak or lame to remain standing for the time needed for surgery.

Preparation. The cow should be restrained in a head gait with an immobile wall or gait on its left side and with surgical access to the flank and paralumbar fossa on its right side. A chute or stocks with a head gait provide adequate restraint and exposure as long as there is direct access to the right-paralumbar fossa dorsal to the stifle. The right flank should be clipped and prepared for aseptic surgery. A right-paravertebral or inverted-L block is recommended for

analgesia. A line block can also be used but may increase incisional swelling, add to difficulty in closure, and potentially add to incisional complications. If the cow is in danger of lying down during surgery due to weakness or hypocalcemia, leg ropes can be placed on the left front and hind limbs before surgery. This will allow a nonsterile assistant to help reposition the cow without disturbing the sterile field. The cow's head should be tied with the head turned slightly up and to the right during the procedure to increase the likelihood that, if the cow goes down, the incision will stay on the top side and minimize contamination of the surgical field. Sedation increases the risk of recumbency and is not recommended unless the cow is intractable and a recumbent approach is not possible.

Approach. A 15- to 20-cm vertical (or up to 20-degree craniodorsal to caudoventral) incision should be made through the body wall in the cranial right-paralumbar fossa. The incision starts at 8- to 10-cm ventral to the transverse processes of the second or third lumbar vertebra and extends ventrally. The location of the ventral end of the incision is critical for proper placement of the omentopexy and should be placed 3 to 4 cm caudal to the caudal curve of the last rib. In large cows or bulls, the incision can be made 3 to 4 cm caudal and parallel to the last rib. Unless specifically required for certain manipulations, the incision should not extend ventral to the caudal curve of the last ribs. This minimizes the likelihood of the small intestine exiting through the incision. To allow room for the omentopexy and incisional closure, at least a 2-cm-wide band of all three muscle layers should be left between the incision and the last rib. This is generally not a challenge for the external abdominal oblique or transversus abdominis muscle. However, the fiber direction of the internal abdominal oblique can carry the incision too far cranially as the surgeon moves from the dorsal to the ventral aspect of the incision. This can be avoided by angling the incision in this layer from craniodorsal to caudoventral to cross perpendicular to the fiber direction.

When the abomasum is in its normal position, the descending duodenum will be one of the first structures encountered deep to the peritoneum crossing the dorsal aspect of the incision in a standing right-paralumbar fossa approach. With a left displacement, the descending duodenum will be pulled ventrally and appear at the ventral aspect of the incision. Care should be taken to avoid accidental injury to the duodenum during the approach. Once the peritoneum has been incised, the location of the abomasum in a left displaced position should be confirmed by first reaching caudally with the left arm around the omental sling to the caudal dorsal sac of the rumen on the left side of the abdomen. The dorsal sac of the rumen is followed as far cranially as possible to palpate the dorsal aspect of the abomasum between the cranial aspect of the rumen and the left body wall. Before attempting to replace the abomasum, the craniventral abdomen between the greater omentum and ventral midline should be palpated to confirm freedom from adhesions. Adhesions can indicate the presence of abomasal ulcers, traumatic reticuloperitonitis, or other sources of peritoneal contamination. Regardless of their source, they can prevent relocation of the abomasum, and an alternative approach should be considered. The area of the umbilicus should be palpated specifically to check for an umbilical vein remnant running from the umbilicus to the visceral surface of the liver on the right. If present, this fibrous, cordlike remnant can interfere with correction of the displacement and should be sharply transected as close to the umbilicus and its insertion into the liver as possible. Once the path for replacement is clear, the process of relocation can begin. Either before or after the abomasum is repositioned a quick but systematic exploration of the rest of the abdomen should be performed to identify other lesions.

Abomasal repositioning. Before attempting to reposition the abomasum, decompression of the gas in the abomasum is recommended to facilitate manipulation and minimize tension and omental tearing. A large-gauge (14- to 10-gauge) needle securely attached to a 40-cm or longer piece of sterile tubing should be placed in a guarded position in the left hand and carried caudally around the omental sling and to the left, over the dorsal rumen sac, to the dorsal bulge of the abomasum. The needle tip should be repositioned from its guarded position so it can be pushed at a fairly shallow angle into the lumen at the dorsal-most aspect of the abomasum. The free end of the tubing should be external to the cow and directed away from the sterile field in case fluid is evacuated as well as gas. The left hand should keep the needle in the abomasum and apply mild ventral pressure until just before the abomasum falls out of reach. The tubing should be occluded to prevent reflux of contents into the peritoneal cavity by folding the tube with the right hand, and the tubing and needle should be withdrawn in one smooth motion out of the abdomen and placed away from the sterile fields. Inserting the needle at an angle offsets the holes in the serosal and mucosal surfaces and minimizes leakage when the needle is withdrawn. Although the bacterial count in the abomasum is normally low, the low pH of the fluid can initiate peritoneal inflammation and increase the risk of peritoneal infection, even with a low number of organisms.

Two common techniques are used to move an abomasum from the left side via a right paralumbar fossa approach. In some cases the surgeon can reach around the omental sling and rumen with the left arm, place the left hand on the dorsal aspect of the abomasum, and physically push the viscus ventrally under the rumen. In the author's experience this is only possible for surgeons with very long arms in small cows with minimal rumen fill. In most cases it is more feasible to pull the abomasum under the rumen by grasping and placing traction on the omentum. To perform this technique, the surgeon should push the left hand with the palm facing down between the omentum and ventral body wall under the rumen and as far as possible toward the left elbow. This will generally place the hand ventral to the pyloroduodenal juncture or the thick greater omentum adjacent to the pylorus. The hand is turned over with the palm up and the hand open. The open hand will be filled with either the thick greater omentum or the pylorus. The pylorus may be identified by its relative firmness associated with the thick torus pyloricus muscle. These are the most stable structures that can be reached from this approach and can tolerate the most tension. Once a handful of thick greater omentum or pylorus is grasped, steady traction is applied to the right, with care taken to keep the fingers together to minimize the concentration of pressure and decrease the risk of tearing fragile omentum. By turning the palm ventrally again and flexing the wrist while pulling, the dorsal surface of the wrist elevates the rumen, which may help ease the path for the abomasum. If the surgeon can feel the tissue tearing in his or her hand at any point, traction should be stopped, the tissue released, and an attempt made to grasp more solid tissue, or preferably the pylorus, by repeating the reaching process again. If the omentum continues to tear and the abomasum is not replaced after several attempts, the possibility of abomasal adhesions should be considered, and the procedure should be aborted in favor of an alternative approach. Persistent traction on an adhered abomasum carries a high risk of disrupting a fibrinous or fibrous seal over a perforating ulcer and causing extensive peritoneal contamination. Minor tears in the omentum carry minimal risk, but

full-thickness tears adjacent to the greater curvature of the abomasum can damage the vessels and nerves in the greater omentum that supply the abomasum, thus leading to significant hemorrhage and possible neurovascular injury as well as limiting or eliminating the use of the omentum for a pexy.

Once the abomasum has moved to the right side of the rumen, it is important to ensure that the normal position has been fully restored and no additional pathology is present. The ventral tension on the descending duodenum should be decreased, and it should move more dorsally in the incision. The surgeon should be able to identify the pylorus and confirm the absence of twists by placing caudodorsal tension on the greater omentum and working hand over hand from its attachment on the ventral aspect of the descending duodenum in a cranioventral direction until the pylorus is visible (usually) or palpable (always) at the cranioventral aspect of the incision (Figure 14-73). The omentum can be torn if mishandled, especially in overconditioned or underconditioned cattle. Damage usually occurs when pressure is concentrated in a small area, such as at the fingertip, so fingers should not be spread apart while placing traction on the omentum. Using a moistened and spread gauze or small laparotomy sponge in each hand is recommended if the omentum appears particularly fragile. Once the pylorus has been identified, the caudodorsal tension on the greater omentum should be maintained with the right hand while the left hand is passed cranioventrally along the greater curvature or parietal surface of the abomasum to the reticulum. This allows the surgeon to palpate the abomasum for thickenings or adhesions suggestive of ulcers and to confirm that the reticulum is free of adhesions. The omasum should be palpated dorsal to the lesser curvature of the abomasum and to the right against the visceral surface of the liver. If the omasum is positioned medial to the abomasum, it should be lifted into its normal position by reaching cranially, medial, and ventral to the abomasum and pushing up and to the right on the omasum with the palm of the left hand.

Once the abomasum has been repositioned, the surgeon has three options for stabilization: 1) omentopexy alone, 2) pyloropexy alone, or 3) omentopexy and pyloropexy.

Omentopexy. The keys to a stable omentopexy are the following: 1) choosing a site as close as possible to the normal position of the pyloroduodenal juncture without interfering with duodenal function; 2) distributing the pexy over as wide an area of omentum as possible; 3) incorporating peritoneum in the pexy; and 4) using a suture that lasts long enough for a firm fibrous adhesion to form and that does not promote infection. A variety of suture techniques have been used to pexy the greater omentum to the body wall. Most are effective if placed in an appropriate location, although they vary in ease of placement and impact on incisional closure. The one described in this text meets all of the requirements described previously and is easily placed.

A 6- to 8-cm vertical fold of thick greater omentum located no more than 3 to 4 cm caudal to the pyloroduodenal juncture is identified. The cranial part of the duodenum should be avoided. This part of the intestine is covered by a thin layer of omentum (Figure 14-74) and might be obscured in fat cows. If an assistant is not available to hold the selected site on the greater omentum, the fold can be grasped with two Lahey thyroid clamps or penetrating towel clamps placed in a vertical plane 15 cm apart. This facilitates incorporation of the fold of omentum in the closure of the peritoneum and transverse abdominal muscle. However, care must be taken to avoid using the clamps for traction as they can easily tear through the omentum and prevent a stable pexy. An appendage of the omentum, commonly called the *sow's ear,* has been cited as a landmark for the pexy, but this feature is highly variable in development and proximity to the pylorus and is not recommended as the primary target for pexy location. If the paralumbar fossa incision was placed appropriately, inclusion of the targeted section of the omentum in the pexy and incision will allow the pylorus to fall with only slight tension into a functional position cranioventral to the incision and just inside the ninth to tenth intercostal space. If the incision is too dorsal for this to occur, it should be extended ventrally. If it is too caudal, the surgeon will have to make a choice between choosing a more caudal site on the omentum and allowing more room for the abomasum to swing or pulling the desired site more caudally and increasing the tension on the omentum. Placement of the pexy in the omentum either too far caudal or dorsal to the pylorus and fatty omentum is considered the primary reason for dilation and redisplacement and should be avoided.

The omentum is stabilized by incorporating a 1.5-cm fold of omentum with three horizontal mattress sutures that pass through all three muscle layers and the peritoneum 2 cm

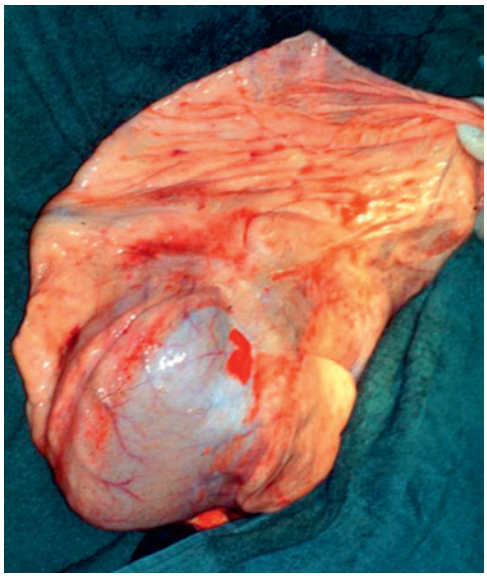


Figure 14-73 Pylorus elevated to incision on right-paralumbar fossa.

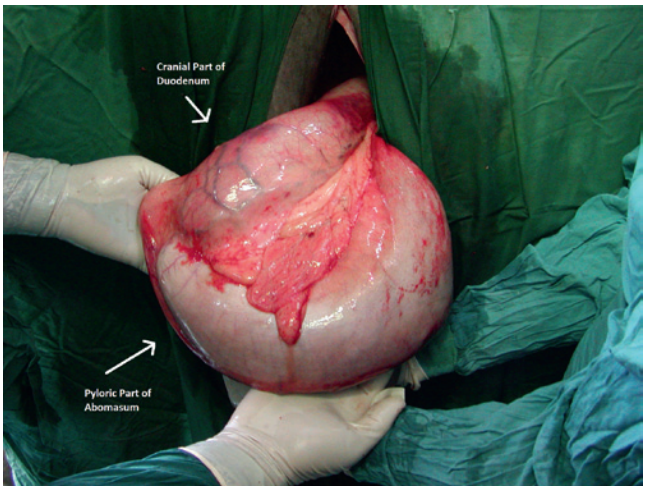


Figure 14-74 View from a right-paralumbar fossa incision of the pyloric part of the abomasum and the cranial part of the duodenum.

cranial to the incision, from cranial to caudal and then caudal to cranial through the omental fold, and back through the peritoneum and all three muscle layers 2 cm cranial to the incision (Figure 14-75). Inclusion of the peritoneum enhances the quality of the adhesion and should be an intentional part of the pexy and the first layer of closure. Particular attention should be paid to the placement of the mattress sutures through the internal abdominal oblique muscle, which can slip cranially and be missed, making incisional closure difficult. The insertion and exit of each mattress suture should be at least 2 cm apart to provide a broad area of tension on the omentum. The first mattress suture should be placed at the most ventral aspect of the incision and tied firmly, checking to be sure that the omentum is held snugly against the peritoneum. Each subsequent suture is placed dorsal and as close as possible to the last suture to avoid gaps between sutures. The first layer of incisional closure should begin ventrally and include the transversus abdominis muscle and peritoneum as well as a small bite of omentum. This continuous layer closes any gaps between the three mattress sutures and should also be considered to be part of the omentopexy. If it is difficult to include omentum in the most dorsal part of the incision it can be excluded. Air should be evacuated from the peritoneal cavity before the first layer of closure is completed to minimize postoperative pneumoperitoneum. After placing the first throw of the knot at the dorsal end of the incision but before pulling the throw down, the tips of a hemostat or Mayo scissors are placed between the last two bites of the first incision line and spread. Then, while the instrument blades are spread to maintain an opening to the peritoneal cavity, the surgeon (and scrubbed assistant if available) compresses the right flank to expel air. Once the sound of air escaping has stopped, the instrument is removed and the first throw is pulled tight, and then pressure on the abdomen is released. Alternatively, if available, gas suction applied through a blunt teat cannula placed through the dorsal aspect of the incision after the first layer is closed will reduce the amount of air in the peritoneum. Postoperative pneumoperitoneum adds confusion during postoperative evaluation for pings and can also delay return to full feed.

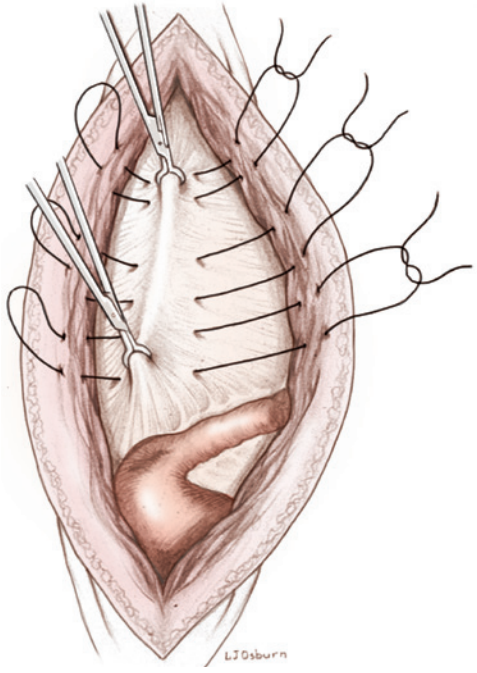


Figure 14-75 Line diagram of one way to perform an omentopexy.

A large-gauge (No. 2 or No. 3) suture is preferred for the three horizontal mattress sutures and the first layer of incisional closure to reduce the risk that sutures will pull through the omentum or peritoneum/transversus muscle layers. Monofilament nonabsorbable sutures are optimum for lasting adhesions. Slowly absorbed sutures may be an acceptable alternative, but the long-term quality of adhesions has not been documented. Braided and coated nonabsorbable materials do form strong adhesions but increase the risk of infection and are not recommended if other risk factors for infection such as peritonitis, inflammation, or remote infection are present. No. 2 chromic catgut was recommended at one time because of its initial inflammatory effect, which was thought to promote the formation of adhesions. However, chromic gut is rapidly absorbed and produces less stable long-term adhesions than nonabsorbable materials. Other common absorbable materials do not maintain their integrity long enough to stimulate stable adhesions and are also not recommended.

The remainder of the incision can be closed in 2 or 3 layers with an absorbable material for the muscle layers and a nonabsorbable material for the skin.

Prognosis and complications. The prognosis for successful treatment of LDA with omentopexy is good, with reports of 86% to 90% of treated cattle returning to the herd, and as high as a 98.5% short-term cure rate. A higher success rate of 93.8% for omentopexy was reported in a study that combined 411 LDAs and 43 right-sided displacements. As for other open and minimally invasive techniques, early-treatment failures are more commonly a result of concurrent diseases rather than the displacement or method used for treatment. Cows treated for LDA by omentopexy compared favorably to those treated by abomasopexy at 1-, 3-, and 6-month follow-ups with respect to milk production, reproductive performance, surgical complications, and length of time retained in the herd, although there was a trend ($P \leq 0.1$) for better milk production at the 1-month follow-up in cows treated by abomasopexy.

The most commonly reported complications are recurrence of dilation and displacement to the left or right, incisional infection, and peritonitis. A redisplacement rate of 1.8% to 4.2% has been cited in studies of LDAs. A rate of 5% was cited in a larger study that included 411 LDAs and 43 right-sided displacements. A group of 25 (78%) out of 32 cattle operated on a second time for recurrence of abomasal displacement initially were treated by omentopexy, and 18 out of the 25 cattle were originally treated for LDA. The recorded reasons for omentopexy failure included omental tearing, stretching, and suture pullout. The risk of omental breakdown leading to redisplacement is thought to be increased by faulty technique (most commonly related to placing the pexy too far caudal or dorsal in the omentum relative to the pylorus or to placement of the incision too far caudal or dorsal to the recommended position) and in cows with damaged, very thin, or extremely fat omentum. Subjectively, redisplacement may be more common when omentopexy is performed in cows in their last trimester of pregnancy because of the altered visceral positions of late pregnancy and changes in position during and immediately after parturition.

If a left-sided ping that is not consistent with pneumoperitoneum develops after surgery, it is likely that the pexy has failed and an LDA has recurred. Dilation and displacement to the right around a persistent but stretched omentopexy are also possible, as are right-sided displacement or volvulus with complete loss of the pexy. However, one study

of repeat surgeries found that 78% of redisplacements, regardless of the method of fixation, occurred on the same side as the original displacement. Dilation on the right in the face of an existing pexy may occur with ileus from persistent hypocalcemia and, if the cow is otherwise stable and can be closely monitored, IV calcium may resolve the problem. However, reexploration is indicated in other cases of left- or right-sided pings if the cow is to remain in the herd. A right-paramedian approach for abomasopexy is the author's preferred method for stabilization in the case of redisplacement after a failed omentopexy. In those cases it is not necessary to release any remaining omentopexy from the right-flank approach to be able to perform an abomasopexy. Occasionally an incisional infection will develop into a large abscess and produce a right-sided ping that must be differentiated from an RDA or other viscus.

Pyloropexy with or without omentopexy. A right paralumbar fossa pyloropexy may be performed alone or used in conjunction with an omentopexy to stabilize the abomasum. The pyloropexy is a more secure, direct fixation method; however, one should be aware that the risk of penetration of the lumen may be slightly greater than with a right-paramedian abomasopexy because the mucosa in the pyloric area is more adherent to the submucosal area.

Preparation. The preparation, approach, and correction of LDA are the same as those described for standing right flank omentopexy.

Pyloropexy. Several methods can be used to perform a pyloropexy. Methods differ by the location of suture placement in the abomasum or pylorus and in the incision or body wall. When a pyloropexy is performed without omentopexy, sutures placed in the pyloric antrum may be directly incorporated in the incisional closure. The pylorus is identified as described previously. The site of the pyloropexy should be at least 5 cm orad to the pylorus to prevent secondary stenosis. After slipping the mucosa away from the seromuscular layer, a penetrating towel clamp or Lahey thyroid forceps are placed 5 cm orad to the pylorus in the seromuscular layer of the pyloric antrum. A second clamp is placed 10 cm orad to the first. With these two clamps, the portion of pylorus to be used in the pexy is placed in the ventral aspect of the incision. A suture is placed to reappose the tranversus abdominal muscle and peritoneum. The next bite of this continuous suture line incorporates the portion of the abomasum identified by the clamps. Before each bite is placed into the abomasum, the mucosa is "slipped" away from the seromuscular layer to prevent inadvertent penetration of the lumen and its potentially disastrous consequences.

Pyloropexy with omentopexy. When pyloropexy is combined with omentopexy some modifications of the omentopexy or pyloropexy is needed. A common form of pyloropexy involves placement of one or two sutures through all muscle layers and the peritoneum cranioventral to the incision and in a cruciate pattern through the thick torus pyloricus muscle or the pyloric antrum. Sutures are tied subcutaneously. The omentum caudal to the pylorus can then be included in the incisional closure as described for right flank omentopexy. Other modifications include placement of horizontal mattress sutures through the omentum and peritoneum and also muscle layers and peritoneum caudal to the incision with or without inclusion of the omentum in the incisional closure.

Prognosis and complications. Reports that describe the technique and outcome of right-flank pyloropexy, with or without omentopexy, are limited, although the procedure is fairly common in certain areas of North America. In one randomized study that compared a modified pyloropexy with toggle pin fixation for treatment of LDAs, 23 of 35 (65.7%) cows in the pyloropexy group remained in the herd 120 days after surgery, compared with 29 of 37 (78.3%) treated by toggle pin. Anecdotal reports suggest that using a pyloropexy decreases the risk of redisplacement compared with omentopexy alone; however, controlled comparisons are lacking. Potential complications include peritonitis (localized or diffuse), redisplacement, and physical or functional interference with motility at the pyloroduodenal juncture.

Right-paramedian abomasopexy. The right-paramedian approach provides the most direct access to the greatest surface area of the abomasum, and because the abomasal wall is attached directly to the ventral body wall, an abomasopexy theoretically allows a more secure stabilization of the abomasum than an omentopexy and can better prevent dilation and displacement of the abomasal body than either omentopexy or pyloropexy. The tendency of the abomasum to return to normal position once the cow is in dorsal recumbency reduces the need for abomasal manipulation and decreases the risk of iatrogenic omental or serosal trauma. The proximity of the abomasum to the incision makes this approach possible for the smallest surgeon and largest cow. It is the approach most likely to allow safe correction of a left displacement with concurrent adhesions. The right-paramedian abomasopexy is usually the preferred procedure to stabilize a failed omentopexy or pyloropexy. Although available personnel and facilities will occasionally make dorsal recumbency difficult to safely achieve or maintain, experience and judicious use of tranquilizers make this approach viable in most settings. The paramedian incision scar is not apparent in the standing cow, and owners who have cosmetic concerns may prefer this approach. Finally, an added benefit of this technique (for the cow but not necessarily the adjacent surgeon) is spontaneous drainage of purulent fluid from the uterus in cows with metritis.

The need for dorsal recumbency does add to the requirements for restraint and may not be appropriate if help is unavailable or if facilities or equipment for restraint in this position are limited. Dorsal recumbency also places an added strain on the cow's cardiopulmonary system and would be contraindicated in cows that will not safely tolerate this position, including those with pneumonia, hypotension, a distended rumen, a heavily gravid uterus, or major musculoskeletal problems that may be exacerbated during casting or recovery. Injury during recovery is a possibility that can be minimized by picking a site with good footing, allowing the cow to take its time to stand after returning to sternal recumbency, and judicious use of hobbles in cows with signs of hypocalcemia or preexisting musculoskeletal disorders. This approach also provides very limited access to other structures in the abdomen of adult cattle and is not indicated if a more complete abdominal exploration is needed. The presence of periparturient edema that extends cranial to the umbilicus will interfere with delineation of tissue layers and make closure more difficult; therefore the right-paramedian approach should be avoided when ventral edema is extensive unless other options present more significant disadvantages. In some freestall housing conditions, the amount of fecal contamination may make an adequate clip and preparation extremely difficult to achieve. The procedure does require the surgeon to kneel and may be physically challenging for individuals with knee or back problems.

Preparation. The procedure can be performed without withholding food or water in cows that have been anorexic. However, a fasting period (24 to 36 hours) may be

considered if the cow's rumen is distended or a complicated procedure is anticipated (i.e., suspected ulcers, previous attempt at fixation, etc.). Withholding food will exacerbate any existing ketosis, and supplementation with IV dextrose may be necessary. Prophylactic antibiotics should be considered before surgery. If possible, clipping the cranioventral abdomen before casting the cow will decrease the time in dorsal recumbency and decrease respiratory stress. The right-paramedian area should be examined for scars that might indicate previous surgery. Large vessels in this area can make hemorrhage a problem.

The cow must be positioned and restrained in dorsal recumbency (Figure 14-76). In a field setting, this can be done by casting the cow and rolling it with its left side against a wall, fence line, or other stable structure or by rolling the cow into a ditch or gutter padded with bedding that is deep enough to limit lateral movement. Hay bales can be used to limit rolling because the withers are usually not adequate alone. With either option, the front and hind limbs should be tied in an extended position. A sedative such as xylazine HCl (0.05 to 0.1 mg/kg IV), acepromazine (0.025 to 0.075 mg/kg IV), or butorphanol tartrate (0.0025 to 0.005 mg/kg IV or IM) can be administered to help cast the cow and minimize struggling. Xylazine is the most commonly used sedative. Sedation is not mandatory unless the individual cow in question is fractious or the facilities available for restraint are limited. The benefits of improved restraint must be weighed against the undesirable tendency of xylazine to produce ruminal atony with distention and stimulate uterine contractions. Xylazine is not recommended for use in the last trimester of pregnancy in cattle because of its uterine-stimulatory effects. However, it is useful in cattle that are difficult to handle. Analgesia can be achieved with an L block or line block. The L block is preferred because it minimizes swelling at the actual site of the incision. The L should extend from ventral midline 1 to 2 cm caudal to the xiphoid process, laterally to the right 5 to 8 cm, and then continued caudally parallel to the ventral midline and medial to the milk well and milk vein.

Procedure. A 15- to 20-cm incision should be made parallel and 3 to 4 cm to the right of the midline, extending caudally from a point 4 to 5 cm caudal to the xiphoid. The incision must be long enough to allow insertion of the surgeon's arm to the proximal humerus but not so long that it causes unnecessary hemorrhage or additional time in closure. In this location, the incision will be continued through six distinct layers: the skin, subcutaneous fascia (including the caudal deep pectoral muscles in the cranial third of the incision), thick external fascia of the rectus sheath, rectus abdominis muscle (which can usually be separated rather than incised), thinner internal fascia of the rectus sheath, and peritoneum. A relatively large branch of the superficial epigastric vein often crosses the caudal half of this incision in the subcutaneous layer and should be ligated before transection if possible.

A quick but thorough exploration of the abdomen is strongly recommended before proceeding with abomasal repositioning and stabilization. This step can identify additional problems as well as adhesions or other situations that might interfere with abomasal repositioning. Adhesions should only be disturbed as necessary to restore the abomasum to its normal position.

Abomasal repositioning. Once exploration is complete, the surgeon can concentrate on identifying the abomasal regions and related structures. If the abomasum has returned to its normal position, the serosal surface of the abomasum or its attached greater omentum will be the first structures observed deep in the peritoneum. The greater omentum attaches along the greater curvature of the abomasum and continues to the left of midline to completely cover the ventral sac of the rumen. The serosal surface of the abomasum can be followed caudally and dorsally along the right body wall as it narrows approaching the pylorus (Figure 14-77). The pylorus can be identified by the attachment of omentum on both sides and the palpable firmness of the torus pyloricus muscle. The pylorus is a common site for focal lymphosarcoma and should be carefully evaluated for enlargement or irregularities. Fat necrosis can also occur in the omentum surrounding the pylorus and interfere with abomasal outflow. In either case, masses in this region should be biopsied. If either lymphosarcoma or fat necrosis is present, the prognosis is poor, although it is theoretically possible to provide temporary relief by bypassing the pylorus with an abomasoduodenostomy (descending duodenum) via a subsequent right-flank or right-paracostal approach. After evaluation of the pylorus, the greater curvature of the abomasum should be followed cranially along the insertion of the greater omentum and reticuloabomasal ligament directly to the distinctively honeycombed reticulum positioned against the diaphragm (Figure 14-78). When following the greater curvature of the abomasum to the reticulum,



Figure 14-76 Right-paramedian abomasopexy completed in an adult dairy cow in dorsal recumbency.

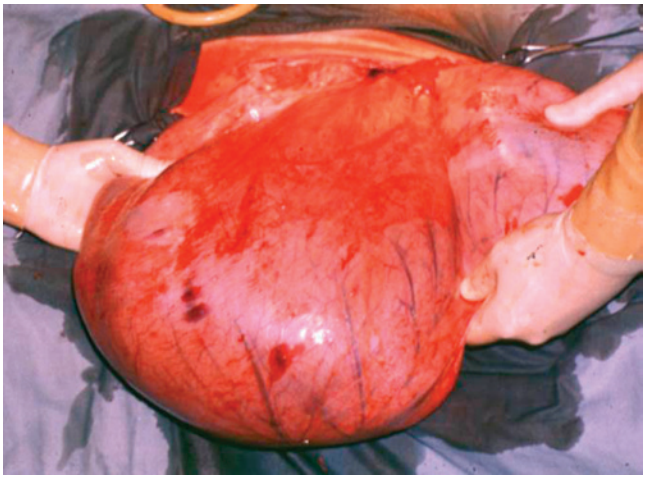


Figure 14-77 Abomasum exteriorized through right-paramedian celiotomy in a heifer.

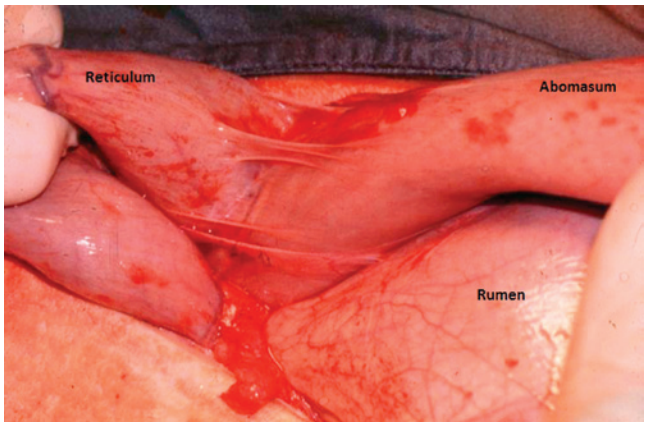


Figure 14-78 View through a cranial right-paramedian celiotomy. The reticulum, rumen, and abomasum are identified.

the parietal serosal surface of the abomasum should be visually and manually examined for scarring or thickening that might suggest previous or impending penetrating ulcers, focal bleeding ulcers, or lymphosarcoma. The location of the omasum dorsal to the body of the abomasum against the right body wall and the visceral surface of the liver should also be confirmed by palpation.

To find the abomasum, if it is not immediately obvious at the incision, the surgeon palpates cranially and then left and right along the diaphragm and body wall, while he or she checks for the smooth serosal surface of the abomasum and adhesions to the body wall that might be interfering with relocation of the abomasum. If the abomasum is still not identified, one returns to the reticulum and follows any connected structure to the left or right. Alternatively, an arm can be swept to the left and right and used to sweep any mobile structure to the midline. Finally, the location of the greater omentum is confirmed by beginning on the left side of the rumen and following it cranially and to the right to the next serosal surface. The greater omentum may be fragile at this level, and care should be taken not to tear it. Complete repositioning must be confirmed before suture placement by identifying the pylorus, the insertion of the greater omentum on the greater curvature of the abomasum, and the ligament between the abomasum and reticulum.

Adhesions associated with an LDA are commonly a result of abomasal ulcers. Many focal adhesions can be broken down with careful manual pressure. Manipulation of adhesions is painful, and analgesia will not be provided by standard local nerve blocks. Topical lidocaine applied with a lidocaine-soaked gauze sponge may decrease pain in some cases, but application to the specific areas needed is often difficult, and manual lysis is often performed without additional analgesia. If manual lysis is possible, the ulcer site should be pulled to the incision and oversewn. If manual lysis is not considered possible without risking abomasal penetration and the site is close enough to place a curved intestinal clamp across the ulcer site, the adhesion can be separated with Mayo scissors as close to the body wall as possible. The ulcer and clamp can then be drawn to the celiotomy incision to allow oversew of the ulcer. If the site is not accessible for safe lysis and oversew, one should consider leaving the site undisturbed and culling the cow. Transection of a fibrous abomasal adhesion can be associated with significant morbidity from leakage and disruption of walled off contamination. If the farmer chooses to pursue surgery to "free" the abomasum, it should be done carefully. The goal is to dissect the weaker adhesions so only a fibrous core remains to hold the abomasum in place. Then the fibrous core is transected at the body wall; this procedure is done blindly with a large scissors with a long handle that are kept as close to the body wall as possible. As soon as the abomasum is released it is brought to the incision and any perforation is oversewn.

Adhesions localized around the cranial abdomen in the area of the reticulum may be associated with TRP. It may be possible to allow repositioning of the abomasum without transecting the adhesions. If possible, the adhesions and reticulum should be palpated to identify any inciting foreign body. If the foreign body has partially penetrated the reticulum, it is rarely possible to extract it through the adhesions without causing extensive peritoneal contamination. A small incision in the reticular wall can be used, if necessary, to facilitate foreign-body removal.

Abomasopexy. Once the abomasum has been identified and all landmarks confirmed, the site for pexy should be identified. The optimum site for pexy is a 10- to 12-cm section on the serosal surface, 2 to 4 cm to the right of the insertion of the greater omentum and extending caudally from a site 5 to 8 cm caudal to the reticuloabomasal ligament. To locate the desired site, caudal tension is placed on the abomasum near its juncture with the greater omentum until the connection to the reticulum, often identified by the thin reticuloabomasal ligament, can be visualized or palpated. The site can be marked by placing towel clamps through the seromuscular layer of the abomasum at the cranial and caudal ends of the planned suture line.

Partial or total decompression of gas from the abomasum can facilitate manipulation, palpation, and suture placement if the abomasum is tautly distended. A 14- to 16-gauge needle securely attached to a section of sterile tubing should be inserted at a shallow angle at the most dorsal site on the serosal surface of the abomasum, with the free end of the tubing held away from all sterile surfaces. Offsetting the serosal and mucosal penetration sites reduces the likelihood of fluid leakage into the peritoneal cavity once the needle is removed. Application of suction can speed the rate of decompression but is generally not necessary for an LDA.

The standard suture pattern for an abomasopexy is a simple continuous pattern initiated at the caudal aspect of the incision through the internal layer of the rectus sheath and peritoneum. Inclusion of the peritoneum is specifically indicated in this approach to enhance the stability of the adhesion at the incision. As the pattern is continued cranially the seromuscular layer of the abomasum should be incorporated in at least six subsequent bites with the peritoneum and internal fascia. Care should be taken to avoid penetrating the mucosa by pinching the abomasal wall with each bite and feeling the mucosa slip out of the fingers before suture placement in the abomasum. Towel clamps preplaced in the seromuscular layer to mark the site of the pexy can also help separate the seromuscular layer. Although the caudal clamp must be removed after the first bite in the abomasum, the cranial clamp can be used to help elevate and depress the abomasum to facilitate suture placement. A No. 1– to No. 3–gauge nonabsorbable nonreactive suture material is recommended for the first layer of closure to establish the most permanent adhesion. Monofilament such as nylon or polypropylene is preferable. Polyamide is frequently used even though it contains multiple strands because of its low cost. Slowly absorbed materials such as polydioxanone may also be acceptable but are economically less practical. As for omentopexy, more rapidly absorbed materials do not persist long enough to consistently cause a stable long-term adhesion and are not recommended. Braided and coated nonabsorbable materials will cause very stable adhesions in the healthy cow but carry an increased risk of infection or

fistulation and are not recommended in the presence of peritoneal inflammation or remote infection. Particular care should be taken to avoid penetration of the lumen if a multifilament suture is used.

The remainder of the incision should be closed in 3 to 5 layers. Closure of the rectus abdominis muscle adds little strength to the incision but does close dead space and may facilitate closure of the next layer. A No. 1– to No. 2–gauge absorbable suture in a continuous pattern is recommended for this layer. The external fascial layer is considered to be the most critical strength-holding layer in this incision, and particular attention should be paid to its closure. As a layer that is primarily dense connective tissue, slow return of maximum tensile strength can be expected. For this reason, a nonreactive nonabsorbable suture material may be most appropriate for this layer. However, high-tensile strength, absorbable materials such as polyglactin 910 are also commonly used. Choice of a suture pattern should reflect the quality of the tissue, tension on the incision, stability of the cow, and technical skill of the surgeon. A continuous pattern helps allay tension and is definitely indicated when time is critical. Horizontal mattress patterns may be indicated when wound tension is high to help avoid suture pullout between the fibers of the external fascia, which are oriented perpendicular to the incision. The choice may be personal preference for remaining layers. A separate subcutaneous layer, including any cutaneous muscle involved in the cranial aspect of the incision, should be added if the gap between fascia and skin is wide. Absorbable suture (No. 0 or No. 1) is adequate for this layer. A nonabsorbable material is typically used for skin, with suture removal indicated 10 to 14 days after surgery.

A modification of the right-paramedian abomasopexy uses three horizontal mattress sutures through the abomasal wall and the peritoneum and transversus abdominis muscle. These three sutures are placed lateral to the incision, and the incision is closed without inclusion of the abomasum. The modification was proposed to decrease the risk of fistulation because the abomasopexy is not part of the incision. This technique is more time consuming and therefore not used routinely. At present, there is no objective information available to indicate whether this modified procedure is more or less successful than the more commonly used procedure described earlier.

Prognosis and complications. Reported initial success rates for cows treated by right-paramedian abomasopexy range from 83.5% to 95%. Right-paramedian abomasopexy is often considered the most stable fixation method for treating LDAs, although controlled comparisons with other treatment options are limited. Repeat surgeries for correction of abomasal redisplacement were more common after omentopexies than abomasopexies in one study. Another study that compared 48 cows treated by abomasopexy and 52 treated by omentopexy in a randomized trial of LDAs found similar results for incisional complications, reproductive performance, and loss from the herd in follow-up at 1, 3, 6, and 12 months after surgery. Milk production was also similar, although a trend for better milk production at 1 month after surgery was noted for the right-paramedian abomasopexy group.

Recognized complications after right-paramedian abomasopexy include incisional hemorrhage, dehiscence, herniation or fistulation, redisplacement, and, rarely, intestinal or uterine volvulus associated with shifting of viscera during recovery from dorsal recumbency. Incisional hemorrhage is a common risk that results from the high vascularity of the ventral abdomen of lactating cattle. While in dorsal recumbency, vessels are under less pressure and ligatures that appear adequate during closure may not maintain hemostasis as pressure increases in the standing cow. Although incisional hemorrhage can be significant, it can be controlled by a pressure wrap or a temporary stent and is rarely life threatening. Acute dehiscence generally reflects technical failure (torn sutures, torn external rectus fascia, poor suture placement), whereas delayed dehiscence is more commonly associated with incisional infection (potentially caused by contamination from penetration of the abomasal lumen, ulcer-related inflammation, or surgical contamination). Herniation involves loss of integrity of one or more incisional layers deep in the skin and occurs days to weeks after surgery. Fistulation refers to the development of a patent track between the abomasal lumen and skin surface and typically takes weeks to develop. Fistulation is most commonly attributed to placement of sutures, particularly multifilament nonabsorbable sutures, completely into the abomasal lumen. Leakage of abomasal fluid along the suture lines begins the development of a tract that progresses gradually toward the skin surface. Left untreated, the fistula enlarges and the mucosal leaves of the abomasum herniate through the fistula (Figure 14-79). These abomasal leaves become ulcerated, and blood loss can result in severe anemia. Body wall hernias without fistulas or signs of intestinal compromise can be left without treatment if economics warrants a more conservative approach. However, dehiscence and fistulation must be treated surgically if the cow is to be kept in the herd. Because of the loss of fluid, electrolytes, and blood, the veterinarian should evaluate the blood gas and electrolyte status and perform a packed cell volume and total serum or plasma protein determination before beginning surgical repair of an abomasal fistula. The surgical approach for treating incisional herniation, dehiscence, and fistulation is similar and is described later under Mechanical Obstructions (herniation, dehiscence) and under ulcers and fistulation. In addition to local incision-related complications, one should remember the rare complications associated with placing a cow in dorsal recumbency—uterine torsion and small intestinal volvulus. The uncommon complication of uterine torsion is most likely to occur when the uterine mass is greatest and is therefore a greater risk in the last trimester of pregnancy. Intestinal volvulus is also a rare complication and appears to be a spontaneous event that would be difficult to predict or prevent, but cows with ileus and distended small intestine may be more at risk.



Figure 14-79 Cow with postabomasopexy fistula with herniation of abomasal leaves. Note edge of fistula and the herniated swollen abomasal leaves contaminated with bedding material.

Redisplacement after right-paramedian abomasopexy is uncommon and generally reflects improper technique, including use of absorbable suture material with premature absorption, suturing of the greater omentum rather than the seromuscular layer, incomplete penetration of the seromuscular layer, or placement of too few sutures leading to suture pullout. A repeat surgery that uses the same right-paramedian approach is typically the preferred approach to correct a redisplacement after abomasopexy because it allows good access to release any remaining sutures and provides greater stabilization.

Left-Paralumbar Fossa (Flank) Abomasopexy. The left-flank abomasopexy provides the surgeon with some access to the greater curvature and parietal surface of the abomasum when it is in a left-displaced position (Figure 14-80). The procedure provides the safety of a standing approach and in cows with adhesions secondary to ulcers and LDA may provide limited access to the greater curvature of the abomasum to permit adhesion lysis. This approach has been cited as the safest method of stabilization for left displacements in cows in the last trimester of pregnancy, although accurate repositioning can be challenging and requires experience. It allows correction during performance of a left-paralumbar fossa/flank exploratory celiotomy if the clinician has misidentified an LDA as ruminal bloat. This is more likely to occur in cases of chronic LDA in yearling heifers. Although the need is uncommon, this approach is the only one that allows safe treatment of an LDA and a C-section in one surgical episode. It is possible to evaluate a postpartum uterus and, to a limited extent, to facilitate drainage of purulent fluid by manual elevation and massage using the standing left-flank approach.

The left-flank approach provides poor access to intestinal structures distal to the abomasum and is not indicated if evaluation and possible manipulation of intestinal structures are necessary. Adequate access to the abomasum for suture placement depends on a fairly dorsal displacement of the abomasum on the left; therefore this approach should not be considered if the ping is absent, relatively low (below midabdomen), or cranial (cranial to the tenth rib) on the left side at the time of surgery. *This approach is not indicated for right displacements or volvulus.* Placement of the pexy sutures in the right-paramedian area from the left flank approach requires a fairly long reach. Although access can be improved by extending the flank incision further ventrally, an alternative fixation method may be preferable for surgeons with very short arms or in very large cows with deep abdominal cavities. A distended rumen will also increase the difficulty of suture placement and may be reason to consider another approach. Unlike other stabilization procedures, this approach requires a capable assistant to help with suture placement and stabilization to ensure both efficiency and asepsis. An untrained herdsman or other assistant can be prepared to perform these tasks, although the assistance of a trained technician is preferable.



Figure 14-80 Standing left-flank celiotomy to correct a left displacement of the abomasum. A continuous pattern is placed through the seromuscular layers of the parietal surface of the abomasum 2 to 3 cm from the attachment of the greater omentum and a hands breadth from the reticulo-abomasal junction.

Preparation. Preparation is similar to that for a standing right flank omentopexy, with appropriate substitutions for the left-side approach. Prophylactic antibiotics should be considered if risk factors for infection are present. In addition, steps to prepare the assistant to aid in the procedure and to ensure correct and safe placement of the pexy sutures should be taken before starting the surgery. If the assistant is knowledgeable about the relevant anatomy, minimal preparation is necessary. Otherwise, several steps should be taken to prepare the assistant, including explaining his or her role and placing a mark at the target sites for suture placement and marks to indicate hazards including the right milk well and milk vein. A local block of the target area for needle placement in the ventral body wall can be performed, but it is difficult to accurately identify the sites, and multiple needlesticks to place the block can result in more apparent discomfort than quickly pushing the two needles through the body wall during surgery.

Approach. A 15- to 20-cm vertical incision should be made in the left flank 2 to 4 cm caudal to the last rib. The ventral aspect of the standard incision should be at the level of the caudoventral curve of the costochondral arch but can be extended more ventrally if the ping is relatively low, the cow large, or the surgeon's arms short.

The parietal surface of the greater curvature of the abomasum should be visible at the cranioventral aspect of the incision. The abomasal serosal surface faces the left body wall. The greater omentum attaches along the dorsal and caudal border of the visible abomasum (see Figure 14-80) and continues medially between the abomasum and the rumen, which is pushed to the right by the distended abomasum.

Stabilization. A straight needle should be threaded on each end of a 1- to 2-m length of No. 2 monofilament nonabsorbable suture. Suture with swaged curved needles at both ends may also be used. One needle should be used to take 5 to 8 bites in a continuous pattern through the seromuscular layers of the parietal surface of the abomasum 2 to 3 cm away from but parallel to the attachment of the greater omentum and as far cranially on the abomasum as possible. The bites should be placed at the center of the suture segment, and two long ends of suture are left. The needle attached to the most cranial aspect of the suture line in the abomasum should be guarded in the right hand and carried ventrally along the left body wall to a site 3 to 4 cm to the right of the midline and 4 to 5 cm caudal to the sternum. The assistant can use the end of a syringe case pressed up against a premarked site to help the surgeon identify the appropriate site for needle placement. Once the surgeon reaches the desired site, he or she should push the needle quickly through the ventral body wall, where the assistant

should grasp the needle with a hemostat, pull it completely through the ventral body wall, clamp it with a hemostat, and maintain moderate ventral tension. It may be necessary to swing the side gait out to allow the assistant access to the ventral abdomen to reach the needles and place ties. The surgeon can protect his or her assistant from being kicked by firmly locking his or her right hip in front of the left stifle. Alternatively, another assistant may be needed for a tail jack during the passage of needles through the body wall. After successful placement of the cranial suture, the procedure should be repeated with the needle on the caudal end of the suture, taking care to avoid crossing sutures or perforating omentum or other viscera that can be present on the ventral body wall.

Once both suture ends have been passed through the ventral body wall and stabilized with hemostats by the assistant, the surgeon can decompress the gas from the abomasum with a 10- to 14-gauge needle with attached tubing. The surgeon should then manually push the abomasum to the ventral body wall as the assistant maintains tension on the sutures. The assistant, if skilled in tying surgical knots, should place the first throw on the knot while the surgeon confirms that the abomasum is pulled firmly to the ventral body wall without any entrapped tissue (Figure 14-81). The assistant can then complete the knot. If the assistant is not skilled in tying surgical knots, he or she should make a simple throw on a knot and clamp the throw with a hemostat. The surgeon can complete the knot after closing the incision.

Closure of the incision is routine. If prophylactic antibiotics were administered before surgery, no postoperative antibiotics are indicated. To avoid fistulation, exposed suture must be cut and allowed to retract into the abdomen once a stable adhesion has been allowed to form but before the process of fistulation has begun—optimally between 14 and 21 days after surgery.

Prognosis and complications. Less information is available on the success rate of the left-flank abomasopexy than for other techniques. The most commonly recognized complications of this technique are accidental damage to the milk vein, entrapment of omentum or small intestine between the abomasum and the ventral body wall, and improper positioning of the abomasum leading to partial outflow obstruction. Structures, particularly omentum, can be easily caught by the needle as the surgeon passes it blindly from the incision to the ventral body wall or trapped between the abomasum and ventral body wall between the two sutures as the abomasum is pulled down. Structures may also be trapped between the abomasum and ventral body wall if the abomasum is allowed to slip back away from the ventral body wall before it is tied. Redisplacement can occur if the sutures break, are placed in the omentum rather than the seromuscular layer, or pull through the abomasal wall. The risk of suture breakage increases when a clamp is used to stabilize the suture ventral to the abdomen in an area that will be involved in the knot. An inadequate number of bites in the abomasal wall or failure to pull the abomasum snugly to the ventral body wall increases the risk of suture pullout. Suture pullout can also result in localized or generalized peritonitis. Abomasal fistulation is of particular risk if multifilament nonabsorbable sutures are used to penetrate the mucosa. Proper technique and release of sutures 2 to 3 weeks after surgery can minimize the risk of these complications. In the author's experience, this technique has one of the steepest learning curves.

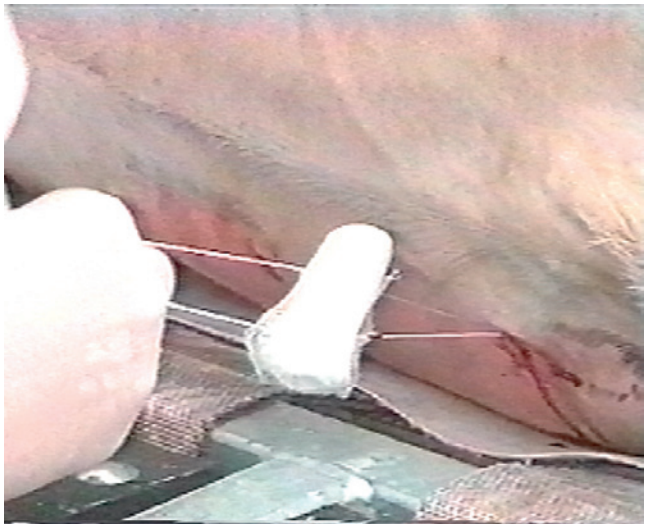


Figure 14-81 Sutures delivered just caudal to the xiphoid and tied by nonsterile assistant.

LAPAROSCOPIC ABOMASOPEXY

Jean-Philippe Roy and Marjolaine Rousseau

Several laparoscopic abomasopexy (LA) techniques have been described in the literature. These minimally invasive techniques were developed to decrease complication rates related to conventional laparotomy and blind roll-and-tack or toggle pin techniques used to treat abomasal displacement disorders. LA techniques can be divided into laparoscopy-assisted toggle pin procedures (two-step LA, one-step LA on a standing or recumbent patient) and ventral LA. This chapter will focus on the two-step LA technique that was first described in 1998 by Janowitz and the one-step LA technique as described by Christiansen and Barisani in 2004. Other LA techniques will be briefly described as well.

LAPAROSCOPE-ASSISTED TOGGLE PIN PROCEDURES

These procedures share advantages of the blind toggle pin technique such as the speed of completion, minimal invasiveness, and ability to remove most of the gas from the abomasum but under visual guidance. It allows precise insertion of the toggle pin in the larger curvature of the abomasum. Accidental misplacement has commonly been reported with blind toggle pinning that can unfortunately be fatal for the patient. Another advantage is the limited administration of prophylactic antimicrobials with LA techniques, which limits the milk loss associated with milk withdrawal periods. In fact, 80% of LDA cases treated by the two-step LA technique do not require antimicrobial therapy. Nonetheless, antimicrobials may still be required to treat a concomitant infection, such as a metritis.

Shared drawbacks are the risks associated with dorsal recumbency and the need for assistance to lay down the cow during or at the beginning of the procedure, except for the one-step LA on a standing patient. Cost of the equipment (Figure 14-82) is also significant. However, the equipment can also be used for diagnostic laparoscopy (see Chapter 6). Laparoscopic instruments required for these procedures are marketed (Set-Lab-231 or Set-Lab-232[9] or Karl Storz

[9]Dr. Fritz, GmbH, Tuttlingen-Möhringen, Germany; Swissvet Veterinary Products, LLC, Knoxville, TN, USA.



Figure 14-82 Equipment needed to perform a two-step laparoscopic abomasopexy. (From the top to the bottom): 1) grasping forceps; 2) 8-mm 0° forward-viewing laparoscope; 3) battery-powered light-emitting diode light source; 4) 8-mm trocar-cannula unit; 5) 5.5-mm trocar-cannula unit; 6) No. 11 Bard-Parker scalpel blade and scalpel handle; 7) specially designed 33-cm-long, 5-mm-diameter trocar-laparoscopic cannula unit with the push rod.

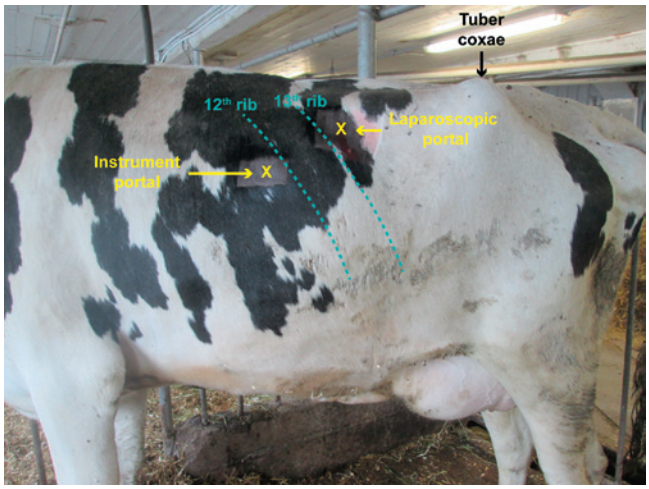


Figure 14-83 Instrument and laparoscopic portal sites for the first step of the two-step laparoscopic abomasopexy technique.

Abomasopexy Set[10]) for bovine practitioners and can be easily used in field settings. A safety toggle pin is used in these techniques, which is a stronger version of the traditional toggle pin used in the blind toggle pin technique. It has two strands of 90-cm-long suture thread attached to a 6-cm-long metallic rod. The learning curve for this technique is quite fast. It is expected that the surgeon will acquire a good level of confidence after performing approximately ten procedures.

Two-Step Technique

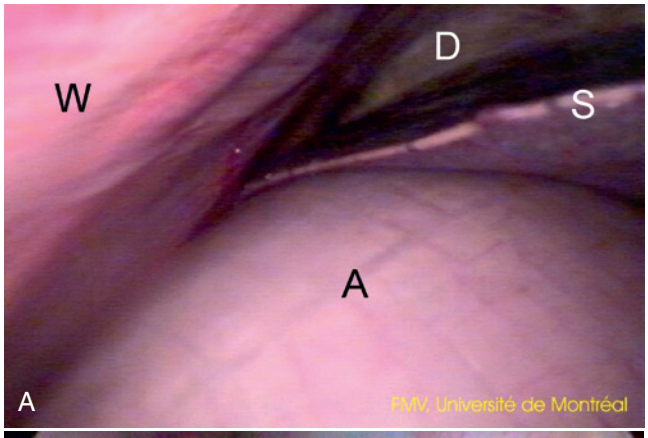
The two-step LA is currently the most commonly used LA technique and was developed by Janowitz. It is mainly indicated for treatment of LDA and can be used to treat RDA or to prophylactically secure a nondisplaced abomasum but is contraindicated for abomasal volvulus. This technique consists of placing a toggle pin into the abomasal lumen and deflating the abomasum via a left-flank standing laparoscopy. The toggle pin thread is then retrieved by laparoscopy via the right-paramedian area on a dorsally recumbent cow. Using this technique, it is possible to visually confirm the diagnosis of LDA. It allows the surgeon to detect abomasal ulcers located at the greater curvature and adhesions between the abomasum and the left body wall or the rumen. In those cases, a different surgical approach may be more appropriate.

The first step of the procedure is performed on a standing patient. The cow is restrained within a large and bedded box stall with her head tied to a solid fence or post. To correct an LDA, two portals in the left flank are needed. The laparoscopic portal is located in the left paralumbar fossa approximately 5 to 8 cm caudoventrally from the angle formed cranially by the last rib and dorsally by the transverse processes of lumbar vertebrae. The instrument portal is located in the 11th or 12th intercostal space depending on the position of the displaced abomasum. This instrument portal should be located dorsally to the abomasum (based on the auscultated ping) to allow easy introduction of laparoscopic instruments into the abdominal cavity. Two 10-cm^2 areas centered over the proposed sites of portals are shaved or clipped and aseptically prepared using 70% isopropyl alcohol and gauzes (Figure 14-83). Local infiltration of the proposed sites of portals is then performed using a volume of 10 mL of 2% lidocaine per site. A vertical 0.5- to 1-cm skin incision is performed at each site using a No. 11 scalpel blade. To create a pneumoperitoneum, a 12-cm-long 5.5-mm-diameter pyramidal trocar and an automatic valve laparoscopic cannula of similar size, with its valve in an open position, are introduced through the laparoscopic portal skin incision in a craniolateral direction aiming toward the right shoulder. The trocar is removed and intraabdominal location of the laparoscopic cannula is confirmed by audible entry of air into the abdomen through its open valve. Removing the silicone sealing cap of the cannula can facilitate passive entry of ambient air and obtain appropriate pneumoperitoneum until distention of the paralumbar fossa. The cannula should be freely movable without any restriction in any direction. Following creation of the pneunoperitoneum, the 5.5-mm cannula is removed and replaced within the same incision by a 12-cm-long, 8-mm-diameter trocar-cannula unit, which will allow introduction of the laparoscope. The trocar is removed and a 46-cm-long, 8-mm-diameter, 0° forward-viewing rigid laparoscope connected to a portable battery-powered light-emitting diode light source is then introduced in the 8-mm cannula to inspect the abdominal cavity under direct observation (Figure 14-84). The displaced abomasum is located between the abdominal wall laterally and the rumen medially. The spleen can be seen dorsally and the diaphragm cranially to the displaced abomasum (Figure 14-85*A*). It is important at this stage to perform a thorough visual examination of the abomasum because findings such as adhesions or ulcers could diminish the prognosis or jeopardize the completion of the surgical procedure. A specially designed 33-cm-long, 5-mm-diameter trocar-laparoscopic cannula unit is then inserted through the instrument portal into the abdomen under laparoscopic control. This long trocar-cannula unit is used to puncture the most dorsal aspect of the greater curvature of the abomasum lateral to the insertion of the greater omentum (Figure 14-86). The insertion of the greater omentum is recognized by the

[10]Karl Storz Veterinary Endoscopy America, Inc., Goleta, CA, USA.



Figure 14-84 Laparoscope insertion into the laparoscopic portal to examine the abdominal cavity and confirm the displaced abomasum. (Courtesy of Dr. Pierre-Alexandre Morin.)



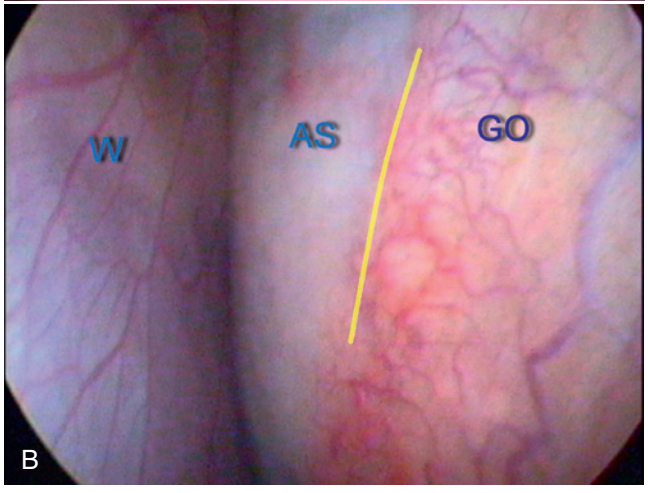


Figure 14-85 *A*, Laparoscopic image of the left-displaced abomasum (A), left abdominal wall (W), spleen (S), and diaphragm (D) during standing left-flank laparoscopy. *B*, Same laparoscopic view in a different cow. The attachment of the greater omentum (GO) on the abomasal serosa (AS) is clearly seen (*yellow line*). W, left abdominal wall.



Figure 14-86 A long specialized trocar-cannula unit is used to puncture the greater curvature of the abomasum and decompress it under laparoscopic guidance during the first part of the two-step laparoscopic abomasopexy technique.



Figure 14-87 Laparoscopic image taken at the end of the first part of the two-step laparoscopic abomasopexy technique showing that the abomasum has been completely decompressed and that the toggle-pin thread has been pushed and let free into the abdominal cavity.

presence of several serosal blood vessels and a more pink coloration compared with the abomasal serosa (Figure 14-85*B*). Once introduced into the lumen of the abomasum, the long trocar is removed from its cannula, care being taken to avoid removing the tip of the cannula from the abomasal lumen. The toggle pin is rapidly introduced within the long cannula, and its rod is pushed down into the abomasal lumen with a 35-cm-long laparoscopic push rod, keeping the tip of the toggle pin thread outside of the cannula. With the tip of the cannula still located in the abomasum, the laparoscopic push rod is removed from the cannula, and the abomasum is passively decompressed until it disappears under the rumen. Once the long cannula gets dislodged from the abomasum, the toggle pin thread is pushed into the abdomen using the laparoscopic push rod under direct laparoscopic control (Figure 14-87). All laparoscopic instruments are removed and the skin incisions can be left to heal by second intention or apposed using a U.S. Pharmacopeia No. 2 resorbable suture material. It is important to note that the pneumoperitoneum is left intact and is not aspirated at the end of the first step. Laparoscopic instruments are kept over

a surgical table drape in between the two steps of the procedure.

The second part of the procedure, commonly called the *second step*, is performed with the cow placed in dorsal recumbency, which is achieved by casting her with cables alone or in combination with xylazine sedation. In Europe, a specially designed tilt-table is frequently used to perform this surgery on the farm, achieving rapid dorsal recumbency with perfect positioning of the animal. If xylazine is used, a dose of 20 to 40 mg IV is usually administered (0.05 mg/kg IV). When laying the cow down, it is important to first position the cow in right-lateral recumbency before positioning her into dorsal recumbency. This will prevent the abomasum from remaining under the rumen and allow proper examination of the abomasum. If a tilt-table is unavailable, the limbs of the cow should be securely tied to a secure location. Two ventral portals in the right-paramedian area are needed. The instrument portal, which is used to retrieve the toggle pin thread, is located 10 cm cranial and lateral to the umbilicus. The location of the laparoscopic portal is variable, based on surgeon preference, but is usually located 15 to 20 cm cranially to the instrument portal to establish triangulation for appropriate laparoscopic inspection and instrument manipulation in the ventral abdomen (Figure 14-88). These surgical sites are aseptically prepared, as previously described for the first step. A 0.5- to 1-cm skin incision is performed at each site. It is important to pay attention and avoid large subcutaneous cranial epigastric vessels that tend to be collapsed in a dorsally recumbent patient. Local infiltration of anesthetics is usually not performed if the cow is well sedated. The 12-cm-long, 8-mm-diameter trocar-cannula unit is inserted in the laparoscopic portal. The trocar is removed and the laparoscope is introduced into the cannula. A complete examination of the ventral abdomen is then performed to assess any abnormalities (peritonitis, adhesions, fatty liver) and to locate the thread of the previously placed toggle pin (Figure 14-89). The 12-cm-long (5.5-mm-diameter) trocar-cannula unit in inserted in the instrument portal under direct laparoscopic control. The trocar is removed and a 46-cm-long, 5-mm-diameter laparoscopic grasping forceps is introduced through the cannula and used to grasp and exteriorize the thread of the toggle pin through the cannula. The thread is temporally secured using a hemostatic forceps. A slight tension should be applied on the thread under laparoscopic control to confirm appropriate toggle pin location within the abomasum. The laparoscope is removed. While maintaining the toggle pin thread outside of the abdominal cavity, the pneumoperitoneum is reduced by applying external pressure to the ventral abdomen and removing the silicone-sealing cap of both cannulas. Laparoscopic cannulas are then removed. Laparoscopic portal skin incision is apposed or left to heal by second intention. The cow is then slowly moved from dorsal recumbency to right lateral recumbency to tie the suture. The two strands of the toggle pin thread are separated, threaded on a sharp needle, and stitched through a 5-cm roll of conforming gauze (Kling). The suture is then tied without excessive tension over the roll of gauze, which acts as a stent that allows some space for postoperative edema or inflammation to develop. Before tying the suture, it is crucial to identify both preset dyed markers on the thread located 5 and 10 cm away from the toggle pin rod. While slowly pulling on the thread, the surgeon identifies first the marker located 10 cm away from the toggle pin rod and then the marker located 5 cm away from the toggle pin rod. The toggle pin thread is tied when this last marker is seen because the marker indicates that the abomasum has been pulled adjacent to the abdominal wall (Figure 14-90). The cow is rolled into sternal recumbency and allowed to stand. Reversal of the sedation may be required. When standing, tension on the toggle pin thread is evaluated again and corrected as needed.

A modified two-step LA can be used to treat an RDA or prophylactically fix a nondisplaced abomasum. Because it is difficult to clinically differentiate RDA from abomasal volvulus and LA techniques are not recommended for treatment of abomasal volvulus, selection of potential RDA cases for LA becomes crucial. Diagnosis of RDA and abomasal volvulus is traditionally made during laparotomy. In the authors' practice, abomasal volvulus is more commonly diagnosed than RDA and standing right-flank laparotomy is the most commonly selected approach. Nevertheless, according to the authors, case selection criteria for treatment of a potential RDA by LA include normal body temperature, heart rate, respiratory rate, hydration status, and quantity of fecal

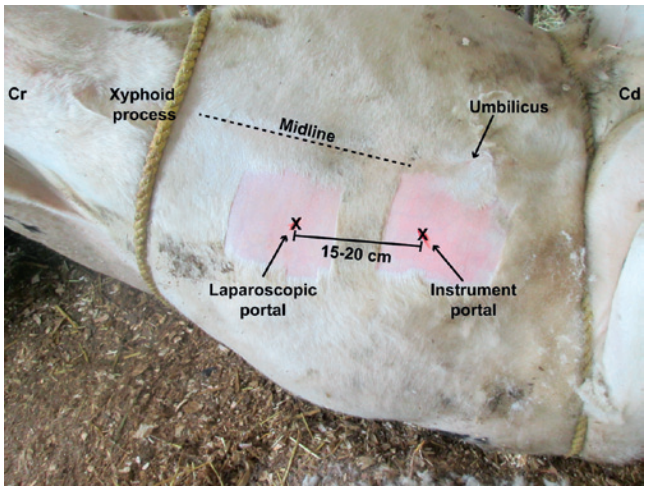


Figure 14-88 Instrument and laparoscopic portal sites for the second step of the two-step laparoscopic abomasopexy technique.



Figure 14-89 Laparoscopic examination of the abdominal cavity to locate the toggle-pin thread in a dorsally recumbent cow during the second part of the two-step laparoscopic abomasopexy technique.

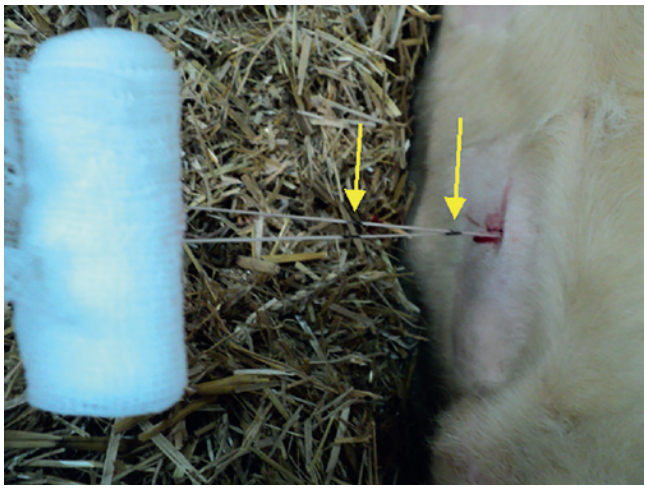


Figure 14-90 With the cow in right-lateral recumbency, preset dyed markers located 5 and 10 cm away from the toggle pin rod are identified on the thread (*yellow arrows*) before tying the thread over a roll of gauze. (Courtesy of Dr. Pierre-Alexandre Morin.)

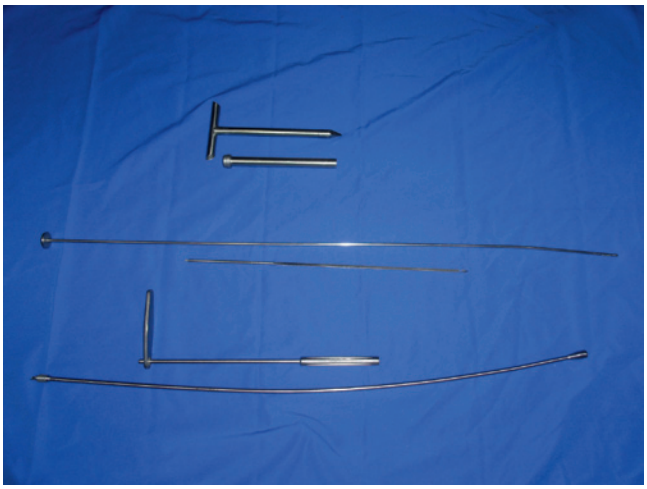


Figure 14-91 From top to bottom: 1) 13-mm trocar-cannula unit required to introduced the Spieker tool into the abdominal cavity for the one-step laparoscopic abomasopexy technique on a standing patient; 2) eyed lancet of the Spieker tool; 3) outer part of the specialized 1-m-long Spieker tool. Please note that the instruments have been disassembled for the picture. After assembly of the eyed lancet, it is introduced into the outer part of the Spieker tool.

output. The mucous membranes must be pink with a capillary refill time <2 sec. Simultaneous abdominal percussion and auscultation must reveal a right-sided ping with concurrent positive succussion mainly localized to the abdomen beneath the right costal arch without involvement of the right paralumbar fossa. Furthermore, upon preoperative transrectal examination, the abomasum must not be palpable and a pneumoabdomen must not be found in order to choose LA for treatment of an RDA. When available, L-lactatemia should be measured. Any cow with an elevated L-lactatemia (>2 mmol/L) should not be treated by LA. The modified two-step LA procedure consists in creating a pneumoperitoneum through a left paralumbar fossa portal, as described previously for the first part of the two-step LA technique. Because the abomasum is not present in the left abdomen in the case of an RDA, no instrument portal is required into the left flank. The cow is then placed in dorsal recumbency, and a laparoscopic portal is created, as described previously for the second part of the two-step LA technique. In the case of an RDA, exploration of the ventral abdomen reveals a distended abomasum not covered ventrally by the greater omentum. However, presence of the greater omentum covering a dilated abomasum should warn the surgeon because it indicates an abomasal volvulus. In this case the laparoscopic procedure should be aborted, and further surgical treatment by laparotomy should be undertaken. The instrument portal is created, as described for the second part of the two-step LA technique. The 12-cm-long, 5.5-mm-diameter trocar-cannula unit is introduced under laparoscopic guidance. The trocar is replaced by the specialized 33-cm-long, 5-mm-diameter trocar-cannula unit, which is then used to puncture the greater curvature of the abomasum approximately midway between the reticuloabomasal ligament and the pylorus near the insertion of the greater omentum. The toggle pin is then inserted into the abomasal lumen using the cannula and laparoscopic push rod. The abomasum is passively decompressed. All instruments of the instrument portal are removed, leaving the toggle pin thread exteriorized. As described previously, the abdomen is passively deflated. The laparoscopic portal is sutured. The cow is placed in right lateral recumbency, and the toggle pin thread is tied over a roll of gauze.

One-Step Standing Technique

The one-step LA is also one of the most commonly used LA techniques. Compared with the two-step LA technique, the one-step LA technique offers the advantage of being a simpler and quicker procedure performed entirely on a standing cow. It is only indicated for LDA. In addition to a specialized 1-m Spieker tool and a larger trocar-cannula unit for the instrument portal (Figure 14-91), the material required for this procedure is identical to that for the two-step LA technique, except the laparoscopic grasping forceps is not needed. Like the two-step LA technique, it is possible to visually confirm the diagnosis of LDA and detect the presence of an abomasal ulcer located at the greater curvature and adhesions between the abomasum and the left body wall or the rumen. Using this technique, it is impossible to explore the ventral abdomen and right-paramedian body wall for the presence of adhesions. Another major drawback of the technique is the risk of transfixing the greater omentum or puncturing the abomasum or other viscera during transfixation of the toggle pin thread through the ventral body wall with the Spieker tool.

The one-step standing LA technique begins by preparing the same surgical sites and performing a standing left-flank laparoscopic approach, as described previously for the two-step LA technique. A 14-cm-long, 13-mm-diameter pyramidal trocar-cannula unit is introduced in the instrument portal under laparoscopic guidance. The trocar is replaced by the 33-cm-long, 5-mm-diameter trocar-cannula unit required to puncture the abomasum and introduce the toggle pin, as described previously for the two-step LA technique. The abomasum is then passively deflated, and the 5-mm cannula is withdrawn, leaving the toggle pin thread outside the abdominal cavity. The thread is tied to the eyed lancet of a specialized 1-m-long Spieker tool. The lancet is then retracted into the inner tube of the Spieker before introducing this tool into the abdominal cavity through the 13-mm cannula. The surgeon needs to carefully guide the Spieker against the abdominal wall ventrally toward the right-paramedian region (Figure 14-92). It is very important to keep constant contact between the tip of the Spieker and



Figure 14-92 Picture of the one-step laparoscopic abomasopexy technique being performed on a standing Holstein cow. The Spieker tool has been introduced into a portal created in the eleventh intercostal space. With direct viewing of the left abdominal cavity, the surgeon is driving the Spieker tool ventrally and ensuring that the tip of the Spieker tool stays adjacent to the abdominal wall until reaching the right-paramedian area to avoid concomitant transfixation of the greater omentum or other viscera. (Courtesy of Dr. Denis Harvey.)



Figure 14-93 The suture ends are threaded through a roll of gauze and they are tightened without excessive tension. (Courtesy of Dr. Denis Harvey.)

the abdominal wall to avoid the omentum or another viscera getting caught between the Spieker and the abdominal wall. When the right-paramedian region is reached and confirmed visually or by external palpation by an assistant, the lancet is pushed through the abdominal wall outside the abdomen. An assistant is asked to secure the thread outside the cow using hemostatic forceps. Finally, all laparoscopic instruments are removed, and skin incisions are either apposed or left open to heal by second intention. The toggle pin thread is attached to a roll of gauze as described previously for the two-step LA technique (Figure 14-93). It is sometimes difficult to reach the right-paramedian region. In this circumstance, the Spieker may be aimed at the midline or left-paramedian area. Surprisingly, no adverse effect has been reported so far, but long-term data are needed to determine whether the outcome is similar compared with suture placement in the right-paramedian area. More recently, Nessmann et al. proposed using a more ventral instrument portal located at the level of the costochondral joints in the last intercostal space to allow the end of the Spieker tool to reach the right-paramedian region more easily.

One-Step Recumbent Technique

The one-step LA performed on a dorsally recumbent cow is an alternative LA technique to correct LDA. This technique has been developed by Newman and Anderson in hospital settings but can easily be performed on farms. It can be accomplished using the same laparoscopic instruments as the one utilized for the two-step LA technique, except that the laparoscopic grasping forceps is unnecessary and a portable device to pump room air is required to establish a pneumoperitoneum to create a working optical cavity. This technique requires fewer portals and less surgical time (average, 22 minutes) than the two-step LA. Although its use has been reported only for correction of LDA, it could theoretically be used to prophylactically pexy a nondisplaced abomasum. Using this technique, diagnosis of LDA cannot be confirmed because dorsal recumbency induces a reduction of the displacement. Furthermore, ventral exploration of the abdomen cannot detect the presence of adhesions between the abomasum and the rumen or left body wall.

As previously described for the second part of the two-step LA technique, the cow is placed in dorsal recumbency. A large area of the right-paramedian region is clipped and aseptically prepared. Infiltration of 2% lidocaine HCl is administered at the proposed portal sites. Two portals in the right-paramedian area are needed. The laparoscopic portal is made 20 cm caudal to the xiphoid process and 5 cm lateral to the ventral midline (see Figure 14-88). The instrument portal is made 10 cm caudal to the the xiphoid process and 5 cm lateral to midline. A 0.5- to 1-cm skin incision is carefully performed at each portal site using a No. 11 scalpel blade, avoiding the large subcutaneous cranial epigastric vessels. Laparoscopy begins by introducing a 12-cm-long, 8-mm-diameter trocar-cannula unit at the laparoscopic portal. The trocar is replaced by the laparoscope connected to a light source, endoscopic camera, and monitor. Carbon dioxide is insufflated into the abdominal cavity to create a pneumoperitoneum (up to 15 mm Hg). In a field setting, a portable battery-powered air pump is used instead of an automatic insufflator to create an adequate pneumoperitoneum, and a portable light source and direct observation technique are used instead of an endoscopic light source and a monitor. Abdominal exploration through this right-paramedian approach allows examination of the abomasum, ventral body wall, and diaphragm. After the abomasum is identified, the 12-cm-long, 5.5-mm-diameter trocar-cannula unit is introduced through the instrument portal under laparoscopic guidance. The trocar is replaced by the specialized 33-cm-long, 5-mm-diameter trocar-cannula unit, which is then used to puncture the greater curvature of the abomasum approximately midway between the reticuloabomasal ligament and the pylorus near the insertion of the greater omentum. The toggle pin is then inserted into the abomasal lumen using the cannula and laparoscopic push rod. The push rod is removed. Leaving the long, specialized cannula in the abomasal lumen passively decompresses the abomasum. All instruments of the instrument portal are removed. The toggle pin thread is slowly pulled until its dyed preset marker is seen and then tied over a roll of conforming gauze. Finally, the laparoscope is removed from its cannula. The abdomen is deflated by applying an external pressure to the abdominal wall. The cannula is removed and the skin of

the laparoscopic portal is apposed in a simple interrupted cruciate suture pattern.

Postoperative Care

Postoperative recommendations are similar among all laparoscopy-assisted toggle pin procedures. No prophylactic antimicrobials are administered unless required to treat a concomitant infection. Supportive therapy such as IV dextrose solution or oral propylene glycol should be administered as necessary. After surgery, the cow can return to its normal diet and activity level. Postoperative recommendations include twice-daily monitoring of rectal temperature for 3 days. Curative antimicrobial therapy (procaine penicillin G, 21,000 IU/kg IM bid for 3 days) is recommended if the rectal temperature is >39.5°C [102.2°F] for more than 24 hours. The toggle pin thread is cut level with the skin 30 days after surgery.

VENTRAL LAPAROSCOPIC ABOMASOPEXY

The ventral LA represents another minimally invasive treatment option for LDA and RDA in which intracorporeal and extracorporeal suturing techniques are used to pexy the abomasum to the right-paramedian abdominal wall in a dorsally recumbent patient. It can be used to prophylactically pexy a nondisplaced abomasum. In fact, the technique was first described in healthy dry cows with nondisplaced abomasums. This technique should not be used to treat abomasal volvulus. This technique has been developed in a hospital setting with a high success rate. Advantages include excellent cosmetic outcome, no suture (toggle pin thread) removal needed, and a potentially longer area of fibrous adhesions between the abomasum and peritoneum (compared with laparoscopic-guided toggle pin procedures). It is technically a more difficult procedure to execute than laparoscopic-guided toggle procedures and requires two surgeons, which limit its use in the field.

As described by Babkine and Desrochers, the cow is first sedated and positioned in dorsal recumbency. The right hind limb is tied in slight caudal extension, and all other limbs are tied in a straight position. The ventral abdomen is clipped and aseptically prepared from the xiphoid process to 10 cm caudal to the umbilicus and 20 cm on either side of midline. Local infiltration of 2% lidocaine is performed at the three required portal sites. The laparoscopic portal is located 1 to 3 cm craniolateral to the left aspect of the umbilicus. Instrument portal 1 (grasping forceps) is located 3 cm caudal to the xiphoid process and 7 cm to the right of midline. Instrument portal 2 (needle holder) is located 3 cm cranial and 5 cm to the right of the umbilicus. A 12-cm line block of the abdominal wall of the right-paramedian area is also performed at the proposed site of abomasopexy, which is located 3 to 5 cm to the right of midline and centered between the xiphoid process and the umbilicus. The surgical site is then aseptically draped (Figure 14-94).

Both surgeons stand side by side next to the right aspect of the cow (Figure 14-95). The main surgeon stands to the right of the second surgeon. The main surgeon makes laparoscopic approaches, inserts instruments, and manipulates the needle driver and laparoscope, and the second surgeon manipulates the grasping forceps and suture needles out of the abdominal wall. First, a 1-cm skin incision is performed at the laparoscopic portal and extended into the body wall. An 8-mm trocar-cannula unit is inserted through the incision in a cranial direction at a 45° angle. Intraabdominal location of the cannula is confirmed by inserting a 42-cm-long, 8-mm-diameter rigid forward-viewing 0° laparoscope, previously hooked to a video-endoscopic system (light source, video camera, and monitor), into the cannula to observe intraabdominal content. A pneumoperitoneum is created by insufflation of filtered ambient air through the laparoscopic cannula using an automatic insufflator until a proper optical cavity is obtained. The ventral abdomen is explored and the abomasum is identified. If the abomasal wall remained against the ventral peritoneum after abdominal insufflation, the abomasum is deflated using a 30-cm-long, 16-gauge spinal needle attached to a sterile flexible tube and suction device. The needle is inserted under laparoscopic guidance (Figure 14-96). A full-thickness abdominal wall incision is made under laparoscopic guidance at instrument portal 1, and a 10-mm trocar-cannula unit is introduced through this incision. A 10-mm 2 × 3 teeth laparoscopic grasping forceps is inserted through the cannula at instrument portal 1 (see Figure 14-94). This grasping forceps is used to grasp and hold the pexy site of the abomasum, which is located over the greater curvature 2 to 3 cm from

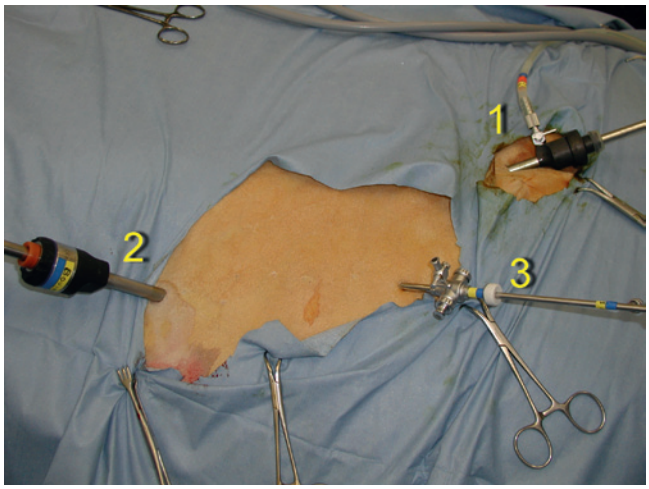


Figure 14-94 The three instrument portals: 1) laparoscope; 2) grasping forceps holding the abomasum; 3) needle driver. (Courtesy of Dr. André Desrochers, Université de Montréal.)



Figure 14-95 Standard positions of the surgeons performing a ventral laparoscopic abomasopexy. The head of the animal is to the left. (Courtesy of Dr. André Desrochers.)

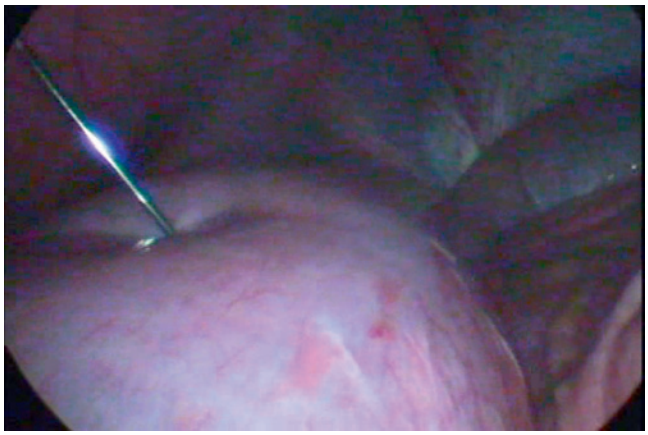


Figure 14-96 The distended abomasum is decompressed with a 30-cm laparoscopic needle inserted through the grasping forceps port. (Courtesy of Dr. André Desrochers.)

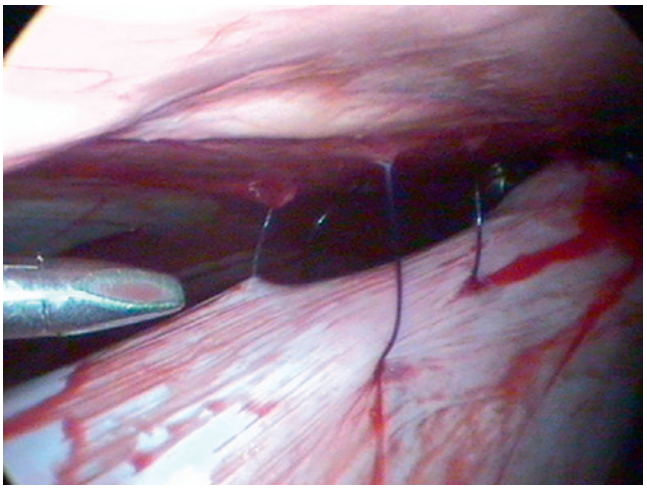


Figure 14-98 The abomasum is gently pulled toward the ventral abdominal wall to verify the final apposition. (Courtesy of Dr. André Desrochers.)

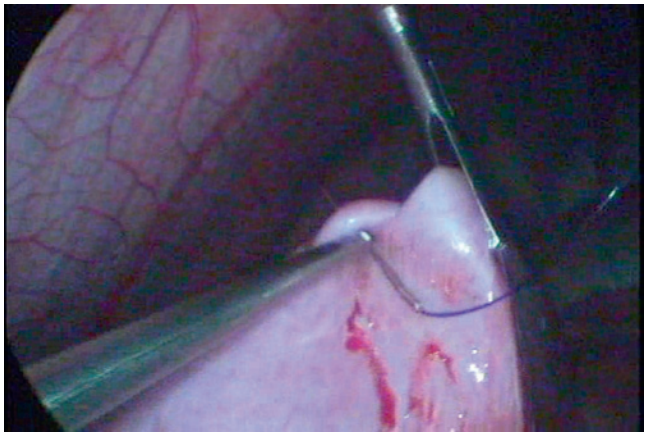


Figure 14-97 With the forceps holding the abomasum, the suture is threaded through the abomasal wall. (Courtesy of Dr. André Desrochers.)



Figure 14-99 The three stay sutures are ready to be tightened. (Courtesy of Dr. André Desrochers.)

the insertion of the greater omentum and halfway between the reticuloabomasal ligament and the pylorus (Figure 14-97). Using a similar technique as for instrument portal 1, a 5.5-mm trocar-cannula unit is inserted through instrument portal 2, and a laparoscopic needle driver is introduced through this cannula. Then, four 1-cm skin incisions are made 2.5 cm apart and perpendicular to the midline over the proposed site of abomasopexy (see previous discussion). A 40-mm-long No. 2 polydioxanone suture swaged on a half-circle reverse-cutting needle is used to perform the abomasopexy in a simple interrupted suture pattern (Figure 14-98). The needle is straightened to facilitate intraperitoneal and extraabdominal handling. The needle is introduced through the abdominal wall at one extremity of the most cranial 1-cm right-paramedian skin incision and is then grasped within the abdominal cavity, by the laparoscopic needle holder. A 2-cm-long seromuscular bite of abomasum is grasped with the suture needle perpendicularly to the long axis of the greater curvature at the proposed site of pexy. Next, the needle is reintroduced back through the abdominal wall at the opposite extremity of the same 1-cm skin incision. The two ends of the suture are temporarily secured to the outside of the abdomen with hemostatic forceps (Figure 14-99). Three other interrupted sutures are performed using the same technique. Although moderately pulling on the suture, examination of the pexy site ensures correct positioning of the sutures. Cannula valves are opened to passively reduce pneumoperitoneum, and tension is applied to the sutures to pull the abomasum adjacent to the peritoneum. Laparoscopic instruments are removed and all portal and surgical sites are closed with an interrupted cruciate suture pattern using No. 2 polydioxanone. No prophylactic antimicrobials are administered unless required to treat a concomitant infection. After surgery, the cow can return to its normal diet and activity level. No skin suture removal is required.

COMPLICATIONS

Intraoperative complications during laparoscopic-guided toggle pin procedures are rare and generally do not cause adverse effects. During a left-flank standing laparoscopic

approach, potential complications include accidental trocarization of the abomasum or rumen, inadvertent retroperitoneal insufflation, difficulty in introducing air into the abdominal cavity (9.2%), and slow decompression of the abomasum (6.6%). Difficulty in localizing the toggle pin thread during the second part of the two-step LA technique has been reported in 6.6% of cases. Reported intraoperative complications during the one-step standing LA technique include difficulty in penetrating the skin with the lancet and breakage of the toggle pin thread by the distal edges of the Spieker tool. In the later situation, the LA needs to be completed by performing a right-paramedian laparoscopic approach in a dorsally recumbent cow, as described for the second step of the two-step LA technique. Presence of ventral abdominal adhesions can preclude completion of LA techniques. In this case a laparotomy technique is chosen to pursue treatment of the displaced abomasum. Presence of edema of the ventral abdomen, as often found during early lactation of a primiparous cow, can make ventral laparoscopic approaches technically more challenging. Accidental perforation of the external leaf of the greater omentum and insufflation of the omental bursa have also been reported with ventral laparoscopic approaches. Insufflation of the omental bursa can be avoided by withdrawing the tip of the cannula from the greater omentum.

Postoperative complications following two-step LA techniques occur in 11.6% and include swelling of the surgical sites (12.5%), cellulitis at the abomasopexy site (5-7.9%), moderate localized peritonitis (3.3%), and relapses. Using the two-step LA technique, the same lactation and subsequent lactation relapses occur in 0.9-3.3% and 0.7-1.5% of treated cases, respectively. Freick et al. reported a relapse rate of 2.7% within 3 weeks postoperatively, 3.9% during the same lactation, and 12.2% in the subsequent lactation after one-step standing LA technique. Causes of LDA relapses within 3 weeks postoperatively are due to accidental breakage of the toggle pin thread or intentional toggle pin thread removal due to postoperative pain. One of the most catastrophic and difficult postoperative complications to treat following one-step LA technique is inadvertent fixation of another viscera by the toggle pin thread. Signs of abdominal pain following the one-step LA technique warrant immediate cutting of the toggle pin thread level with the skin. Exploratory laparotomy is warranted if a treated cow shows continued signs of gastrointestinal obstruction during the early postoperative period. Incisional complications following the ventral LA technique are usually mild and transient and include subcutaneous hematoma formation, periportal swelling, and subcutaneous emphysema. No adverse effect was noted on the cosmetic outcome of the ventral LA technique. So far, only a limited number of cases treated by the one-step recumbent LA have been reported in the literature, which precludes determination of a relapse rate. No relapses have been reported following the ventral LA technique.

EXPECTED OUTCOME

Few studies have compared the two-step LA technique to the omentopexy for correction of LDA. One study was conducted in hospital settings in Germany whereas the other was conducted in field conditions in Canada. In both studies, success of correction was not different between the two surgical treatments. Seegers et al. have demonstrated a more rapid increase in milk yield and feed intake during the first 5 days postsurgery in the LA group compared with the omentopexy group. The mean duration of the procedure was shorter in the LA group (27 vs. 38 min). In one out of 60 LA cases, the surgery could not be completed because of adhesions. Few surgical site infections were observed in both groups, and two relapses occurred in the LA group but none in the omentopexy group. Roy et al. reported that surgical success rate, appetite, and milk yield (assessed by phone follow-up 7 and 60 days after surgery) were not different between groups. Only 1 out of 152 LA cases relapsed and another surgical approach was used in 6 LA cases because the surgeon was unable to complete the procedure for different reasons such as presence of adherences. Antimicrobial therapy was avoided in 80% of the cases in the LA group. Finally, LA was significantly faster than omentopexy (36 vs. 75 min.). Veterinary students were involved in the procedures performed in this last study, which may explain the difference in duration compared with the Seegers et al. study. It has been hypothesized that the faster recovery observed in the LA cases compared with omentopexy is due to a greater and faster abomasal emptying rate after correction of LDA. The more anatomic pexy site of the abomasum in LA may be the reason for this observation. In another study, it was demonstrated that the inflammatory peritonitis resulting from LA is not more severe than that following omentopexy. On the other hand, muscular damages were lesser after LA than after omentopexy. To the authors' knowledge, other LA techniques have not been compared with any other surgical techniques such as paramedian abomasopexy.

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ABOMASAL DISPLACEMENT (RDA) AND VOLVULUS (RVA) TO THE RIGHT: GENERAL CONSIDERATIONS

DEFINITION AND INCIDENCE

When the abomasum dilates on the right side of the cow, it has the potential to float dorsally with a relatively flat (Figure 14-100) or folded (Figure 14-101) lesser omentum (RDA) or to twist on the lesser omentum that supports it, creating an abomasal volvulus (RVA; Figure 14-102). Historical descriptions of the RVA referred to it as an abomasal *torsion*. However, the omental attachments prevent the abomasum from twisting around its own luminal axis as would be required for a torsion, and the term *volvulus* more accurately describes the condition.

The direction and amount of twist necessary to be considered a volvulus have been much discussed and are a source of much confusion. It is most accurate to describe the process as a volvulus of the abomasum and attached structures around an axis through the center of the lesser omentum on which they are suspended. A volvulus can only occur around the center axis in the lesser omentum in a clockwise or counterclockwise direction relative to the fixed points along the dorsal border of the lesser omentum. The vast majority of cases of abomasal volvulus occur in a counterclockwise direction. In most cases, the duodenum becomes trapped ventrally between the cranial aspect of the abomasum and the omasum, and aside from some medial and ventral displacement, the omasum is relatively uninvolved. In some cases the cranial duodenum is actually entrapped ventrally between the omasum and reticulum. In these cases the omasum is clearly displaced medial to the abomasum, and the reticulum is pulled caudally, craniomedial to the abomasal body. In either case, the weight of fluid in the abomasal body and fundus is sufficient to prevent the duodenum from sliding free caudal to the abomasum.

The amount of twist necessary to be a volvulus is also a common topic for debate. Technically, any degree of rotation around the lesser omentum could be called a volvulus. The real question is not the number of degrees of rotation but whether the positional change will produce complete luminal obstruction and irreversible neurovascular damage if left uncorrected. Once the change in position has progressed to the point at which the abomasum cannot fall back into its normal position even after excessive gas has been relieved, it may be presumed to be at risk of permanent damage. From the surgeon's perspective, this allows a functional definition

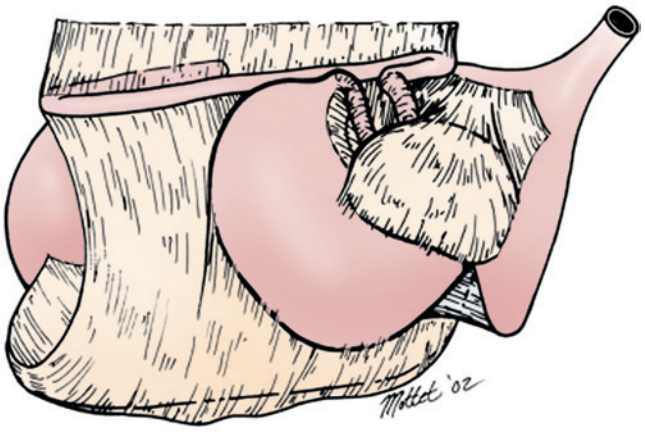


Figure 14-100 As gas accumulated in the abomasum, the pyloric antrum may begin to move dorsally.

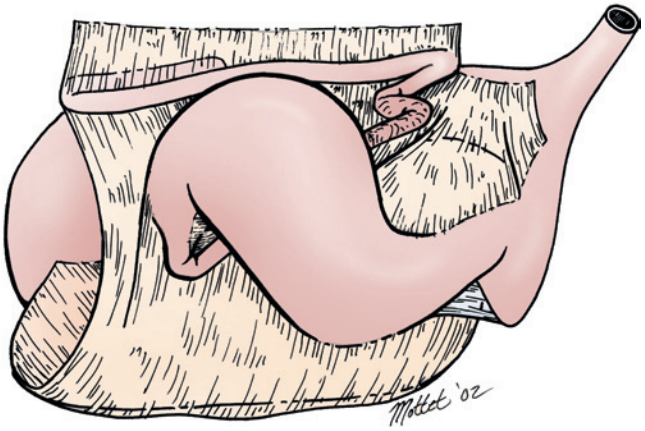


Figure 14-101 As gas accumulates in the abomasum, the abomasal body may float dorsally along the right body wall.

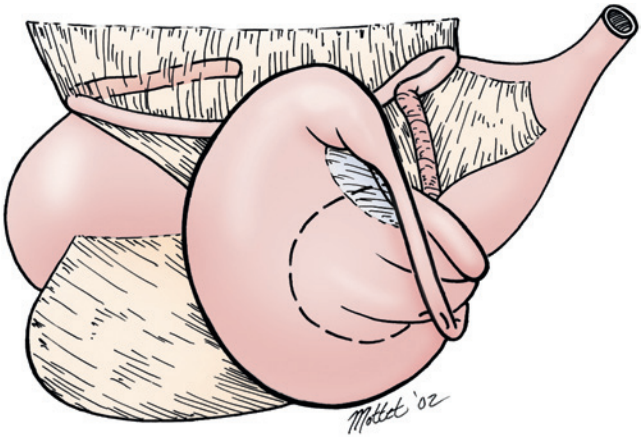


Figure 14-102 As the abomasum and attached structures rotate in a counterclockwise direction around an axis through the center of the lesser omentum, the cranial duodenum becomes trapped by the distended abomasal body, either between the abomasal fundus and omasum or more cranially between the omasum and reticulum.

based on the ability or inability of the surgeon to correct the displacement after gas decompression by placing caudodorsal traction on the greater omentum from a point ventral to the descending duodenum. If the displacement cannot be corrected by traction (barring adhesions), then the rotation has been sufficient to entrap the duodenum, complete outflow obstruction has occurred, neurovascular compromise is probable, and, if left uncorrected, progressive rotation and death are essentially ensured.

An accurate comparison of the incidence of RDA to RVA is hampered by the overlap of clinical parameters in affected animals, making accurate presurgical differentiation of the two conditions impossible. The variations in definition and application of diagnostic criteria used during surgery also make the differentiation difficult. In a review of case records at a single institution using a uniform set of surgical/postmortem criteria, 280 cases of RVA and 123 cases of RDA were identified, suggesting a ratio of approximately 2 to 1. The tendency to refer more compromised cases and the potential for an RDA to progress to an RVA during the time between on-farm diagnosis and arrival at a referral institution may result in a higher ratio of RVA to RDA in this study that used referral centers than would be expected on the farm.

Displacements to the right (including both RDAs and RVAs) are far less common in dairy cows than those to the left. In a comparison with RVAs only, left displacements were found to be seven times more common in a large North American multiinstitute study. As with LDAs, right-sided disorders (RDAs and RVAs) are more commonly identified in dairy cows than in dairy bulls, beef cattle, or calves of any breed. Abomasal volvulus specifically was found to be more common in dairy than in beef cattle (adjusted odds ratio of 36.4) and more common in female than male cattle (adjusted odds ratio of 3.3).

PREDISPOSING FACTORS

Although less information on predisposing factors for RDAs and RVAs is available, the etiopathogenesis is considered similar to an LDA. Factors that alter abomasal motility and lead to gas accumulation also presumably predispose to displacement to the right. Reports of RVA, as those of LDA, show that cases are more likely in the first 2 weeks after parturition (28.3% of cases), although cases are generally more evenly distributed across the rest of the lactation period. In several studies, both abomasal volvulus and LDA developed most commonly between 4 and 7 years of age, although volvulus was relatively more common than LDA in cattle less than 1 year of age. Recent trends for LDAs to occur in first calf heifers have not been reported in cases of RDA/RVA. The normal position of the abomasum on or slightly to the right of the midline (as well as the normal weight and position of the rumen) presumably makes displacement to the right the easier path outside of the periparturient period. Concurrent diseases (such as ketosis, uterine diseases, mastitis, and pneumonia) are also found commonly in cattle with abomasal volvulus. Perforating ulcers with adhesions are less common in cows with RDAs than in those with LDAs. Two of 21 cases of concurrent abomasal displacement and perforating ulcers involved right-sided displacements. In contrast to LDAs, abomasal volvulus has been reported to occur most commonly in January. Although the incidence of RDA/RVA is much lower than for LDA, several researchers indicate that both LDA and the right displacements are highly genetically correlated and are associated with the same genes.

DIAGNOSIS

Cows with either an RDA or RVA typically present with signs very similar to those described for LDAs (i.e., partial or complete anorexia, decreased milk production, and decreased fecal output with altered consistency [fluid or pasty]). However, in the case of an RVA, the progression of signs may be very rapid, and a subset of affected cows will first present with signs of severe depression, anorexia, and dehydration.

The presence of a tympanic area (ping) centered over the 10th to the 13th ribs and on a line from elbow to tuber coxae is the primary diagnostic sign of an RDA or RVA. This ping must be differentiated from other sources of right-sided pings that include cecal dilation/torsion, gas accumulation in the duodenum, spiral colon, ascending colon or small intestine, or right-flank abscess. An abomasal ping can generally be differentiated from pings associated with other structures by combining information about ping location, size, and pitch. The cecum, colon, and small intestine are limited in their mobility by their mesenteric attachments to the dorsal body wall whereas the abomasum and ascending duodenum are limited by more cranial attachments at the duodenal sigmoid flexure and the reticular connection to the diaphragm. Cecal, colonic, and small intestinal pings will be centered on a point in the paralumbar fossa, more caudal than that for the abomasum or duodenum. The cecum is the only structure that has the potential to dilate to a size comparable to the abomasum and is the primary differential for single-pitched pings greater than 10 cm in diameter. In addition to differentiation by location of the ping, the cecum is usually palpable by examination per rectum whereas the abomasum rarely distends far enough caudally to be palpable and, if it does, it is attainable by fingertips only. Small intestinal pings are typically a collection of small-diameter pings of variable pitch. Spiral colon pings also tend to involve multiple areas that vary in pitch. The cranial and descending sections of the duodenum can accumulate gas and may ping at or dorsal to the location for an abomasal ping, although the maximum diameter of a ping the duodenum can produce is about 10 cm.

Ultrasound provides another tool to aid in diagnosis of RDA/RVA. The last four intercostal spaces on the right and the area immediately caudal to the last rib on the right should be evaluated from ventral to dorsal with a 5- to 3.5-MHz linear or sector probe. With either RDA or RVA, the liver may be displaced medially from its normal position against the right body wall, and the abomasum can be visualized in the normal location of the liver. However, medial displacement of the liver is generally considered to be associated with abomasal volvulus. Small intestines are less commonly visible in the 9th to 12th intercostal spaces (RDA) and the 9th to 11th intercostal spaces (RVA), and large intestines are imaged less commonly in the 11th and 12th intercostal spaces and in the cranial flank. With right displacement, the abomasum may be situated dorsal to the omasum, and parts of the greater omentum may be visible between the omasum and right body wall. The dorsal margin of the liver may be more dorsal to its location in healthy cows. Small intestine cannot be visualized in the 8th to 10th intercostal spaces. In both RDA and RVA, the dorsal and ventral borders of the omasum are ventral to their normal location. Images may support a diagnosis of RVA versus RDA if the abomasum appears medial to or wrapped around the omasum; however, these findings are not consistent enough to rely upon.

Preoperative differentiation with any degree of reliability between RDA and RVA is difficult in an individual animal. Although severe electrolyte disturbances are more typical of abomasal volvulus, the size of the ping and degree of most fluid imbalances overlap, with both conditions associated

with dehydration and a hypochloremic, hypokalemic, hyponatremic metabolic alkalosis. Prolonged RDAs can produce severe fluid and electrolyte disturbances, whereas early RVAs may have relatively mild disturbances. Some disturbances tend to follow a progression that reflects the severity of disease, but overlap is possible. In a study that included RDAs and RVAs, the following parameters on average reflected the progression of disease: decreasing body temperature, increasing heart rate, hyponatremia, and anion gap. In severe cases of volvulus, tissue ischemia and necrosis can produce a metabolic acidosis that superimposes on the metabolic alkalosis common to abomasal outflow obstructions. As a result, the blood pH, chloride, and potassium values may return toward normal in the most severe cases of volvulus, even in the face of a very high anion gap. Normal or close to normal values in the face of a severely compromised cow with an abomasal ping should be viewed with caution. Definitive diagnosis can only be made by exploratory or postmortem. The difficulty of differentiating between RDA and RVA preoperatively, the potential risk that an RDA will progress to an RVA at any given time, and the difference in prognosis should a volvulus develop are all reasons to support surgical exploration within several hours after identifying any right-sided abomasal ping.

PROGNOSIS

Negative outcomes for RDA have been reported to range from 8.7% to 15%. Negative outcomes for RVA range from 26.3% to 65%. One study that followed cows with RDA and RVA for a year after surgical treatment showed that 97% of cows with RDA and 84% of cows with RVA were discharged from the hospital. Survival rates for RDAs remained fairly stable at 6 months after surgery (94%) and fell slightly to 88.5% at 12 months after surgery. For cows with RVA, the survival rate fell to 74% at 6 months after surgery and 66% at 12 months after surgery. RVAs that involve the omasum appear to have a poorer prognosis than those that do not, with a 6-month survival rate of 0% to 40% when the omasum was involved versus 64% to 75% when the omasum was not involved.

Given the difference in prognosis it would be helpful to be able to differentiate between an RDA and an RVA and better identify the prognosis of the individual animal as early in the process of assessment as possible to allow the farmer to decide if the cost of treatment is economically viable. Unfortunately, differentiation between RDA and RVA based on physical examination parameters alone is highly unreliable. A few clinical variables have been investigated as possible prognostic tools, including heart rate and hydration status. Over half of all cows with RDA/RVA with a heart rate over 100 bpm will not survive long term as opposed to 12% to 25% of cows with a heart rate of less than 100 bpm. A number of biochemical parameters have been tested as prognostic factors including preoperative L-lactate concentrations, and lactate combined with chloride levels and heart rate. The predictive power of models with lactate, chloride, and heart rate was superior (0.360) to those using lactate and chloride (0.34), lactate alone (0.219), or heart rate alone (0.124). The availability of portable L-lactate clinical analyzers makes lactate a more convenient prognostic tool in a field setting. Lactate values less than 2 mmol/l carry a good prognosis, whereas those greater than or equal to 6 mmol/L are highly suggestive of a volvulus and carry a poor prognosis

Intraoperative indicators of prognosis have been proposed, but most lack quantitative verification. Suggested factors include abomasal size, fluid volume (based on amount drained) or the subjective ratio of fluid to gas in the abomasum, presence of omental attachment damage, presence of hemorrhage along the greater or lesser omentum (along vascular routes), intraluminal gas pressure, and abomasal wall perfusion. Studies have shown that intraoperative abomasal intraluminal pressures were correlated with survival after RVA, with the median intraluminal pressure of 20.6 mm Hg in nonsurvivors versus 11.0 mm Hg in survivors. A cutoff value of 16 mm Hg was suggested to differentiate between productive survivors (<16 mm Hg) and those that fail to return to production (>16 mm Hg). Further studies showed an inverse relationship between abomasal intraluminal gas pressure with abomasal wall perfusion based on abomasal oxygen saturation in RVA and a direct relationship with plasma L-lactate concentration.

TREATMENT

General Treatment Considerations

Treatment options must take into account the possibility of either an RDA or RVA and the risk of rapid and potentially uncorrectable deterioration if treatment is delayed. If treatment is to be pursued, surgical intervention for definitive diagnosis and position correction is essential. Two different approaches allow correction and stabilization of an RDA or RVA in adult cattle. The standing right-flank omentopexy plus or minus pyloropexy is the most universally effective approach for adult cows with right-sided pings consistent with RDA or RVA and provides optimal access for abomasal evaluation, decompression, and position correction with minimal stress on the cow. Some information suggests that adult cows with RDA or RVA treated by right-paramedian abomasopexy may have better in-hospital survival than those treated by right-flank omentopexy. The right-paramedian abomasopexy can also be used if a cow cannot stand for the right-flank approach. One should avoid right-paramedian abomasopexy in very sick animals with ruminal distention because of the risk of regurgitation and the added stress of compromising ventilation with the animal in dorsal recumbency.

Some evidence suggests that, regardless of approach, redisplacement is more common after surgical correction of displacements to the right than after surgical correction of LDAs. Redisplacement is more likely to occur on the same side as the original displacement. Medical management of fluid and electrolyte disturbances in conjunction with surgery is a critical part of management. Electrolyte and acid-base disturbances are, in most cases, those described for LDA. However, the dehydration and hyponatremic, hypokalemic, hypochloremic metabolic alkalosis may be more extreme, particularly with RVA. In prolonged or extreme cases of RVA, the abomasal wall may become necrotic and the presence of necrotic tissue and lactic acidosis may override the typical metabolic alkalosis, resulting in normalization of blood pH and secondary increases in potassium, sodium, and chloride. Therefore the presence of mild changes in acid-base and electrolyte levels in a cow with severe dehydration and an abomasal ping on the right is a negative prognostic indicator, and euthanasia should be considered. Lactate levels over 6 mmol/L also support the presence of tissue damage.

Medical Management and Supportive Care

Regardless of the approach selected, thorough preoperative evaluation is necessary to identify concurrent conditions that might affect the approach selection or interfere with the success of surgery. Specific evaluation for conditions that may have predisposed to altered abomasal motility—such as hypocalcemia, endotoxemia, and ketosis—is indicated. Correction of hypocalcemia, ketosis, and other fluid imbalances is initiated before surgery, if possible. Fluid therapy is similar to that described for LDAs earlier, although disturbances may be greater and more aggressive therapy is frequently

needed. Studies comparing preoperative small-volume resuscitation hypertonic saline versus isotonic saline suggests that hypertonic saline provides improved hemodynamics and perfusion; however, intravenous support with isotonic fluids may be necessary after surgical correction if abomasal motility is slow to return or if the cow is unwilling to drink. Preoperative prophylactic antibiotics are indicated due to the risk of ischemic injury. Preoperative erythromycin (10 mg/kg) has been shown to improve postoperative abomasal motility for cows with RVA in one study and may be considered as a part of supportive care.

ABOMASAL DISPLACEMENTS TO THE RIGHT (RDA AND RVA): SPECIFIC PROCEDURES

Right-Flank Omentopexy/Pyloropexy

Preparation

The preparation and approach for a right-flank omentopexy are as described previously for LDA. In addition to the standard surgical equipment and a 10- to 14-gauge needle with attached tubing needed for an LDA, a 3- to 6-cm-diameter sterile stomach tube should be available in case fluid decompression of the abomasum is necessary.

Procedure

A standing right-flank approach is performed, as previously described for the LDA. The distended abomasum will be the first structure encountered after the peritoneum is incised, and care must be taken to avoid accidental incision during the approach.

The first step in correcting the displacement is to determine whether the abomasum is simply dilated and/or displaced or if a volvulus has occurred. First locate the greater omentum ventral to the descending duodenum, and place caudal tension on the omentum by walking hand over hand along the omentum in a cranioventral direction. If the abomasum is dilated and displaced dorsally without volvulus it will usually be possible to follow the omentum directly to a site of attachment on the greater curvature of the pylorus or abomasum. Occasionally the displaced abomasum will be too distended to allow the surgeon to follow the greater omentum all of the way from the descending duodenum to its attachment to the pylorus without decompression. Inability to follow the omentum to the abomasum or pylorus after decompression indicates the presence of a volvulus. Additional findings that suggest the presence of a volvulus include large amounts of fluid in the abomasum, medial displacement of the omasum, and caudal displacement of the reticulum medial to the abomasum. In a counterclockwise volvulus around the axis of the lesser omentum, the omentum will be pulled from the ventral descending duodenum into a taut narrow band as it passes cranioventrally (medial to the abomasum), and then ventral to the twist between the abomasoomasal (see Figure 14-102) or omasoreticular juncture, cranial to the distended abomasal body. In the case of a clockwise volvulus, the omentum would be pulled cranially, then lateral dorsal to the twist between the abomasum and omasum. The direction of the volvulus can be determined in many cases by placing the left hand palm down on top of the omentum with fingers in two folds of the omentum and following the omentum forward. If it is a counterclockwise volvulus, the hand will be forced to turn clockwise, with thumb down. The reverse would occur with a clockwise volvulus. The direction the hand is forced to turn is the direction that the abomasum must be pushed to correct the volvulus.

Reducing the size of the abomasum is occasionally necessary to differentiate between an RDA and RVA and almost always to allow safe repositioning. In most cases of RDA and RVA, the abomasum is primarily distended with gas and can be decompressed with a needle and attached tubing as described for LDA. However, if there is a large amount of fluid in the abomasum, it should be removed before all the gas is removed. If gas is removed first, the abomasum will fall ventrally, making access for fluid removal difficult and greatly increasing the potential for peritoneal contamination. Fluid should be removed by first placing a 4- to 7-cm-diameter circular purse-string suture in the exposed serosal surface of the abomasum at a location as far dorsal to the ventral aspect of the paralumbar fossa incision as possible (Figure 14-103). A high–tensile strength, low–tissue drag suture material, such as polydioxanone, is indicated. After the first throw of the purse-string suture is placed, a stab incision is made in the center of the purse-string pattern. A 3- to 6-cm-diameter sterile stomach tube is quickly inserted through the stab incision into the abomasum, and the purse-string suture is tightened to minimize leakage. The surgeon or assistant should keep his or her left arm ventral to the abomasum to help maintain elevation of the site during drainage. Fluid should be siphoned from the abomasum until flow ceases or the site of tube insertion begins to fall ventral to the incision. When this occurs, the tube should be kinked to reduce backflow and removed from the abomasum while the purse string is tightened. Gross debris should be removed from the area of the purse string. The purse string is then tied and the site of the purse string is oversewn with an absorbable suture material. If gas distention still prevents repositioning, gas decompression should be performed with needle and tubing.

Once an RDA or RVA has been decompressed, the surgeon should attempt to expose the pylorus by placing caudodorsal tension on the greater omentum. If the abomasum was displaced without a volvulus, the greater omentum can be followed to the pylorus. If the pylorus cannot be exteriorized at the incision by this process, an RVA is confirmed and manual correction will be necessary. The goal is to push the abomasal body in the correct direction to free the cranial duodenum and pylorus. The direction the dilated abomasal body should be moved is indicated by the direction the surgeon's hand turns during the omentum examination, the same as a volvulus. If in doubt, the surgeon should assume the counterclockwise volvulus occurred. To correct a counterclockwise volvulus, the surgeon should place the

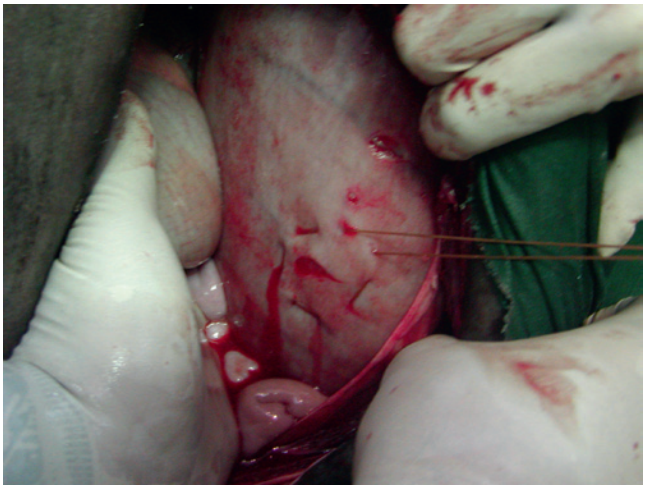


Figure 14-103 Purse string placed in abomasum. A stomach tube will be placed to drain fluid from the abomasum.

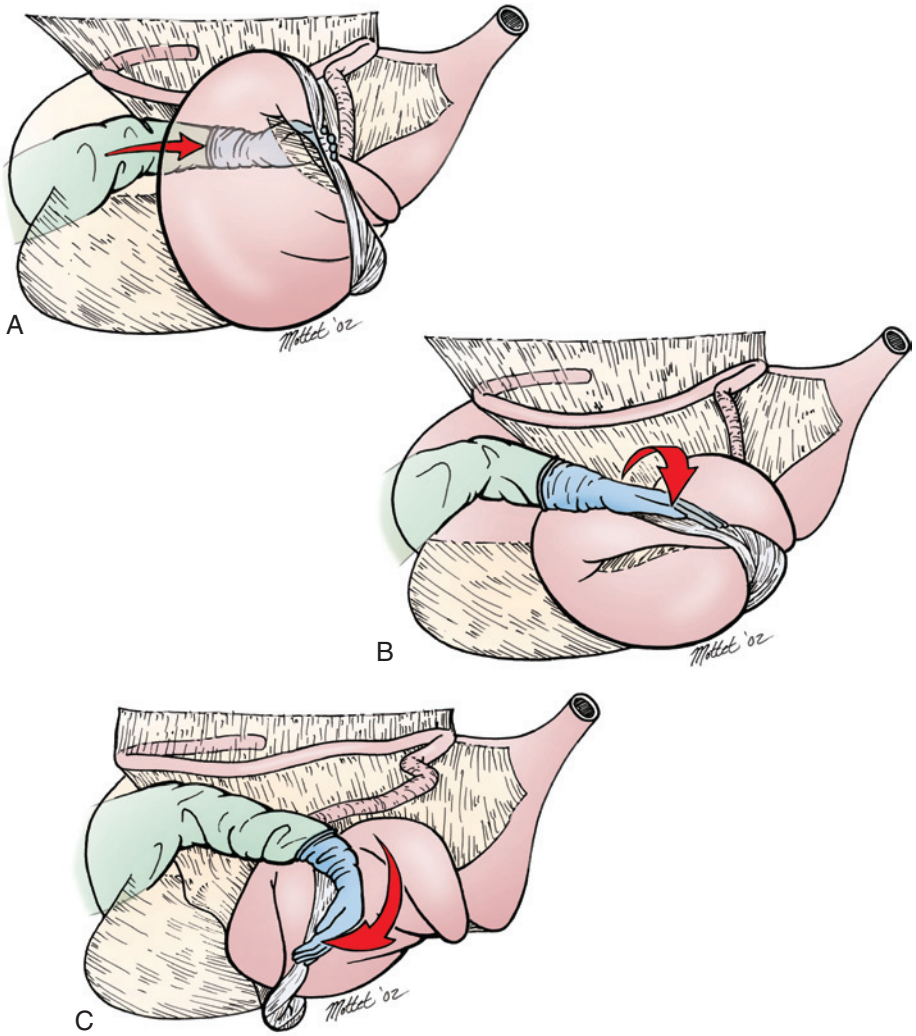


Figure 14-104 Correction of a counterclockwise abomasal volvulus by abomasal manipulation from a right-paralumbar fossa approach. A counterclockwise abomasal volvulus can be corrected by placing the left forearm medial to the distended abomasal body (*A*) and rocking the distended body laterally, ventrally (*B*), and finally caudally (*C*) to free the duodenum from its site of entrapment ventral to the abomasoomasal juncture. Once freed, the greater omentum can be traced from the descending duodenum to the pylorus.

left arm medial to the abomasal body as far cranially as possible and dorsal to the path of the greater omentum (Figure 14-104*A*). Keeping all fingers together with the palm facing laterally against the dilated abomasal body, the palm and heel of the left hand should be used to rock the dorsal aspect of the abomasal body in a large loop, first laterally and then ventrally and caudally (Figure 14-104*B* and *C*). A long, sweeping motion is usually most effective. Several tries may be necessary. This method works well for the more common volvulus in which the pylorus and duodenum pass between the abomasum and omasum but may not be effective when the duodenum is entrapped cranial to the omasum. If no progress has been made after 3 to 4 tries, a change to the second approach is indicated. In this approach, the left hand is placed medial and ventral to the abomasum and ventral to the omasum, which will have been drawn medially by the volvulus. In a volvulus, the omasum tends to accumulate more fluid than usual, but its thick walls still make it distinguishable by palpation. With the left hand and arm placed medial to the abomasum and ventral to the omasum, the omasum should be lifted dorsally and laterally toward the liver (Figure 14-105). This typically frees the duodenum and allows exposure of the pylorus when tension is placed on the greater omentum. After repositioning the omasum, the abomasal body can be rocked laterally, then ventrally and caudally, to return it to normal position.

Clockwise volvulus is relatively uncommon, and descriptions of correction procedures are also limited; however, the principles of correction are similar to those used to correct a counterclockwise volvulus. After fluid and/or gas decompression have been completed, the surgeon should attempt to expose the pylorus by placing caudodorsal tension on the greater omentum. If unsuccessful, the surgeon should place his or her left or right arm between the dorsal aspect of the abomasal body and right body wall. The palm should face the abomasum while cupping the cranial aspect of the abomasal body. With the palm and forearm, the dorsal aspect of the body should be rocked medially and then ventrally and laterally.

After the abomasum has been decompressed (RDA), the duodenum has been freed (RVA), and the pylorus exteriorized by traction on the greater omentum, the remaining

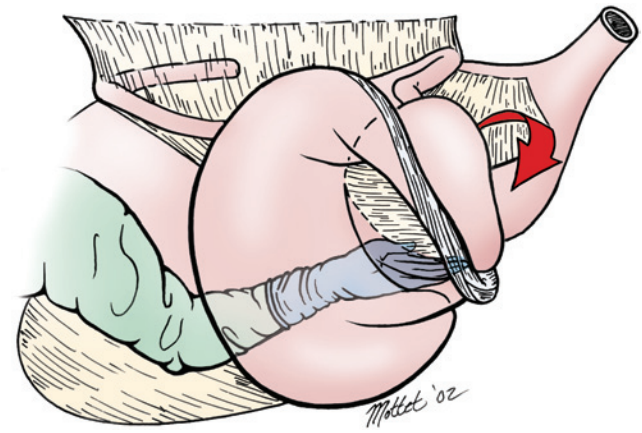


Figure 14-105 Correction of counterclockwise abomasal volvulus by omasal manipulation from a right-paralumbar fossa approach. As a second method for correcting a counterclockwise abomasal volvulus, the surgeon can place his or her left forearm ventral to the omasum in its position medial to the abomasum and then lift the omasum dorsally and then laterally. This method is particularly valuable for correcting a volvulus that results in entrapment of the cranial duodenum between the omasum and reticulum but can also be a valuable tool in management of the more common form of volvulus (Figure 14-102). This method may be combined with abomasal manipulation as described in Figure 14-104.

landmarks should be checked as described previously for LDA. The pylorus, greater omentum, parietal abomasal surface, reticulum, and omasum should each be identified and evaluated for correct location and freedom from lesions. The greater omentum should be carefully inspected for any tears that may have occurred as a result of the volvulus or from efforts to reposition the abomasum. Incomplete tears through one of the two serosal surfaces can and should be left without closure. Full-thickness tears should be closed with an absorbable material to protect the vasculature to the greater curvature and prevent entrapment of small intestine in the rent. Once all landmarks have been identified and evaluated, an omentopexy/pyloropexy can be performed as described previously for an LDA. In some cases the omentum has been so severely traumatized that an omentopexy is not advised; therefore pyloropexy is performed. If the omentum is not healthy enough for omentopexy and a pyloropexy is not an option, a right-paramedian abomasopexy could be performed on the following day after fluid and electrolyte disturbances have been addressed. Incisional closure is as described previously for LDA.

Prognosis and Complications

Abomasal motility disturbance is one of the most common complications following surgical correction of RDAs/RVAs, occurring in 14% to 21% of RDAs/RVAs. It has a high case mortality rate (80% to 89%) and frequently leads to delayed (median, 5 days after surgery) death or euthanasia. Increased abomasal intraluminal gas pressures and abomasal volume have been associated with decreased abomasal perfusion and decreased survival in RVAs. In a study of vagal syndrome such as motility disturbances after surgical management of RDA/RVA, the most common finding was abomasal wall damage, including edema, ulcers, and necrosis. Necrosis of the omasum was also present in some cases. Septic peritonitis was also a common finding. Thrombosis or hemorrhage of major abomasal vessels was noted in less than 25% of cases necropsied but were only associated with abomasal wall necrosis, suggesting that necrosis is more associated with direct wall damage from extensive and/or prolonged distention. Gross lesions of vagal nerves (focally extensive hemorrhage and edema) were observed in 5 cases (38.5%); however, the branches that were affected did not correlate well with the location of abomasal dysfunction. Duodenal outflow obstruction can occur after omentopexy if omentopexy or pyloropexy sutures are poorly placed and perforate the duodenum or create a kink in the outflow route. Duodenal obstruction should be considered in cows that show clinical deterioration within a day or two after a right flank omentopexy or pyloropexy.

Use of prokinetic agents including neostigmine, bethanechol, metoclopramide, and macrolide antibiotics have been suggested as ancillary treatments to enhance abomasal motility after surgical correction of abomasal volvulus. Erythromycin at a single preoperative dose of 10 mg/kg has been shown to increase abomasal emptying rate and milk yield in the immediate postoperative period after surgical correction of RVA. Other agents that have potential ameliorative effects on perfusion/reperfusion injuries, such as steroids and vitamin C, have also been suggested as adjunctive therapy. Aside from erythromycin, efficacy of these agents following RDA/RVA has not been demonstrated.

Right-Paramedian Abomasopexy

A right-paramedian approach is not recommended as the first option for a right-sided abomasal ping. However, it may be the only option in a cow that is down or that is unlikely to stand for the time needed to do a standing right-flank omentopexy. The preparation and approach are as described earlier for an LDA. When a cow or bull is positioned in dorsal recumbency, the unsupported ventral body wall caudal to the rib cage collapses dorsally, and viscera are more difficult to distinguish and manipulate. In addition, the relationship of structures is less familiar to most veterinarians from this approach. Nonetheless, identification of key landmarks is critical for successful diagnosis and correction of abomasal displacement disorders to the right. Decompression is usually mandatory to allow accurate evaluation and repositioning.

If the abomasum is displaced without a volvulus, it will often return to its normal position once the cow is placed in dorsal recumbency. In this case the surgeon will encounter a gas-distended viscus immediately deep in the peritoneum. After gas is removed from the viscus, it will be possible to identify the connection to the reticulum cranially at the diaphragm and trace from the reticulum caudally along the greater curvature of the abomasum (marked by the attachment of the greater omentum) to the pylorus as described for LDA. The firmer omasum should be palpable but not visible dorsal to the abomasum and against the right body wall. A brief but thorough exploration of the accessible parts of the abdomen should be completed before performing an abomasopexy.

If a volvulus is present, following a direct and continuous path from reticulum along the greater curvature to the pylorus will be impossible. With a counterclockwise volvulus, the surgeon will first encounter either the serosal surface of the abomasum or the greater omentum covering the abomasum deep to the peritoneum. The reticulum will often be pulled caudally, medial to the abomasum. The distended body of the abomasum will fill the right side of the abdomen. The descending duodenum will cross the ventral aspect of the right abdomen but be buried between the abomasum and omasum or between the omasum and rumen ventral to the caudally pulled reticulum.

In most cases gas decompression alone provides enough room and flexibility to manually correct the volvulus. The goal is to shift the fluid from the abomasum to the pylorus: this can be done in multiple ways. The surgeon places the

right hand palm up, fingers together, underneath the abomasum and attempts to rock the abomasum forward and toward the incision; this should move some fluid through the duodenum and lessen the weight of the abomasum. Significant effort is needed to accomplish this maneuver. An alternative option is to grasp the duodenum with the left hand and move it laterally and dorsally so it is lower than the fluid level in the abomasum. A third method involves applying pressure on the omasum toward the dorsum of the cow (slightly caudally); this will transfer pressure to the abomasum so it either rocks forward or its fluid content moves ventrally toward the duodenum. A combination of these techniques is needed and it may be necessary to extend the incision so that both arms can be used. The right arm pushes the omasum caudally and the left arm rocks the abomasum out of the incision. If correction is not obtained, one can drain the abomasum in a manner similar to what was described for the standing approach. The key difference is that the gas in the abomasum is usually not sufficient to bring the abomasum to the incision, and it is usually very difficult to elevate a fluid-filled fundus or body of the abomasum to the incision, much less exteriorize a section for drainage. Rocking the cow slightly to the right may help exposures. In some cases the duodenum is the only available structure (the abomasum is against the dorsal body wall). The duodenum is easily elevated to the incision, and a purse string is placed as previously described. A stomach tube is then passed into the duodenum through the pylorus and on into the abomasum so the fluid can be evacuated.

After correction of the volvulus, all of the landmarks described for the right-paramedian approach to LDAs previously described should be evaluated to ensure correct repositioning. Tears in the greater omentum are possible and should be managed as described previously in the right-flank approach. Debris from fluid decompression should be carefully removed before placing the abomasopexy layer, as described for LDAs. Additionally, a water-soluble antibiotic can be used to lavage the incisional layers. Closure of the remaining incisional layers is as described for LDAs.

ABOMASAL DISPLACEMENT TO THE RIGHT (RDA AND RVA): GENERAL POSTOPERATIVE CARE

Regardless of the approach used, the cow should be carefully monitored after surgery. Return to normal water and feed consumption after treatment of an RVA is expected to be slower than with RDAs and LDAs. Continuous fluid therapy is often necessary to fully restore normal hydration and electrolyte balances. If preexisting infection or contamination was found or excessive contamination occurred during surgery, a therapeutic course of antibiotic therapy should be initiated after surgery until at least 3 days after the last clinical sign (3 days after surgery if signs do not occur). Analgesics may improve comfort and speed return to feed.

General Prognosis and Complications

The prognosis for survival and return to productive function with right-sided complications is largely determined by the degree of tissue damage, which is in turn a reflection of the amount and duration of the volvulus. Complications related to tissue damage include those associated with direct tissue damage (abomasal perforation, peritonitis, septicemia, omental tearing) and persistent abomasal neuromuscular dysfunction (decreased or altered abomasal motility, intermittent bloat, dehydration, electrolyte disturbances, poor nutrient absorption, abomasal impaction). Complications related to the surgical procedure itself (redisplacement, malpositioning) are less significant in comparison to those associated with tissue damage but are still important considerations for the surgeon.

Adult cattle with a surgical diagnosis of RDA would be expected to have minimal vascular compromise and a favorable prognosis for short-term survival and return to successful production similar to that for cattle with LDAs. In one of the few studies that used a consistent surgical definition to differentiate between RDA and RVA, 99% of the 218 cows diagnosed with RDA were discharged from the hospital. Of those discharged, the majority (199; 92%) returned to their expected levels in attitude, feed consumption, fecal production, and milk production at the time of discharge. Information on long-term productivity in the herd was not collected in this study, and it is difficult to reliably isolate RDAs specifically from other studies. Long-term productivity similar to or better than LDAs is expected because the concurrent diseases responsible for the majority of LDA losses from the cattle herd are less common in RDAs.

More information on short-term survival and long-term productivity is available for cows with RVA, although the variation in definitions used between, and sometimes within, studies suggests the need for caution, particularly when interpreting data from multiple institutions over extended periods of time or both. One study reported a 99% short-term survival until discharge for cows with RDA, and 218 of 240 cows (91%) with a surgical diagnosis of RVA survived until discharge, making the in-hospital fatality rate 9%. Of the 218 cows with RVA that were discharged, only 147 (67%) were considered to have returned to their expected levels in attitude, feed consumption, fecal production, and milk production at the time of follow-up. In another study of 100 surgically corrected RVAs that used a similar classification system, 18% died or were euthanized before discharge; 14% were discharged but had not met expectations for feed intake, defecation, or milk production; and 68% had returned to expected levels before discharge. A multiinstitutional study of veterinary teaching-hospital admissions showed an even higher in-hospital fatality rate of 23.5%, with an additional 15.7% of cattle discharged after surgery failing to become productive in the herd. Reported in-house fatality rates from several smaller studies of cows with abomasal volvulus ranged from 24% to 31%. Phone follow-up 1 to 6 months after surgical treatment of 80 cattle with right abomasal volvulus classified 59 (73.8%) as productive, 10 (12.5%) as salvaged for slaughter, and 11 (13.7%) as dead or euthanized by the time of follow-up.

The difference in survival rates is significant and must be considered before the decision to proceed with treatment is made. Despite the difficulty of preoperatively differentiating between RDA and RVA in an individual animal, several clinical and biochemical parameters can be used with caution as prognostic indicators. At least one study has shown the following biochemical parameters as predictive of nonsurvival due to death, euthanasia, or slaughter as a result of poor production: preoperative tachycardia (>100/min), dehydration (>6%), hypochloremia (<79 mEq/L), hyponatremia, hypokalemia, decreasing base excess, base excess plus serum lactate concentration, base excess plus hypochloremia, increasing anion gap, serum alkaline phosphatase greater than 100 IU/L, and superimposed metabolic acidosis with a high anion gap. Tissue ischemia and necrosis in cows with a prolonged or extremely tight volvulus can develop a concurrent metabolic acidosis. As a result, the blood pH returns toward normal, the anion gap increases, and the base excess may fall into a negative range. These findings as a group are indicators of an extremely poor prognosis in adult cattle. Surgical findings that may be associated with a poor prognosis include a large volume of fluid in the abomasum

that requires fluid decompression and serosal inflammation or necrosis.

Conversely, when cattle with RVA were divided into productive (expected appetite, weight, and milk production) and nonproductive (slaughtered for low production, died, or were euthanized) groups at follow-up 1 to 6 months after surgery, several factors were found to have significant positive predictive value for productivity. These factors included normal hydration status, serum creatinine ≤1.5 mg/dL, serum alkaline phosphatase activity ≤100 IU/L, serum Cl ≥95 mEq/L, and heart rate ≤80 beats/minute.

ABOMASAL OUTFLOW OBSTRUCTIONS WITHOUT DISPLACEMENT

Abomasal outflow can be disrupted in a number of ways that do not involve displacement. These conditions are typically categorized as either mechanical or functional disturbances, based on the etiology. Classically, obstructions that result from an identifiable physical obstruction to aborad flow are classified as mechanical, whereas all others are believed to result from chemical or neurologic interference with normal motility and are considered functional. In practice, many cases of abomasal outflow obstruction involve both mechanical and functional mechanisms at some stage in their course. Effective management decisions require that all mechanisms be addressed.

Mixed Mechanical and Functional Obstructions: Abomasal Impactions

The term *impaction* is typically reserved to describe distention of a viscus beyond its normal volume with contents that have less fluid content than normal. This definition is consistent with the syndrome of abomasal impaction (Figure 14-106) as it is seen in cattle. However, the condition called *abomasal impaction* in sheep involves abomasal distention with contents varying in consistency from fluid to dry. It is likely that the term is used to describe two different conditions in the two species.

The abomasum can theoretically become impacted as a result of a variety of mechanical and neurologic etiologies. Potential mechanical causes include abnormal or dry luminal contents (hair, placenta, sand, gravel, and poor-quality roughage in the face of restricted water intake) that lodge in the pyloric region, mural lesions (lymphosarcoma, fibrosis) that prevent normal contraction and dilation of the pyloric antrum or cranial duodenum, and extraluminal lesions (adhesions, masses) that distort or compress the abomasal outflow tract. Multiple cases of abomasal impaction have been identified during severe winter weather in range cattle with poor-quality roughage and limited access to water and in groups of cattle with high concentrations of indigestible materials, such as sand and gravel, in their diet. Sand and gravel impaction may be of particular risk in cattle maintained in dry lots with bunker feeders and with limited access to fiber. Pregnant cattle near the end of gestation appear to be more commonly affected. Alternatively, lesions that might interfere with the normal function of the abomasum or coordination of orad and aborad flow at the pyloroduodenal juncture have been implicated in many cases without a clear initiating mechanical cause. These include vagal nerve irritation in the thoracic or abdominal cavity, focal mural lesions at key foci, peritoneal inflammation with secondary ileus, and direct nerve or neuromuscular damage after abomasal volvulus. Individual cases of impaction have been specifically linked with traumatic reticuloperitonitis, perforating abomasal ulcers, and abomasal volvulus. The wide range of proposed and confirmed etiologies suggests that multiple factors may result in a similar clinical result.

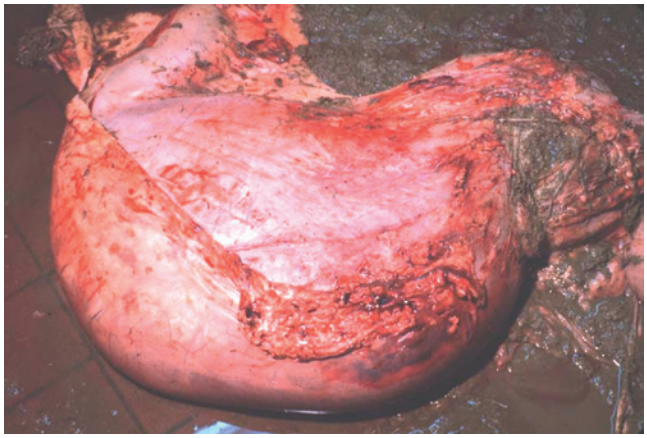


Figure 14-106 Abomasal impaction diagnosed on gross postmortem examination. Arrow points to the pyloric part of the abomasum. (Courtesy of Dr. John King.)

Clinical signs of abomasal impaction develop gradually and include right ventral or bilateral ventral abdominal distention, progressive anorexia, decreased fecal production, and loss of condition. In some cases ruminal hypomotility with or without distention will also be present. The pulse rate may be normal or slow throughout much of the course, although an elevated rate has been reported in the terminal stage of the condition and is considered a poor prognostic sign. Dehydration may be mild to severe. Electrolyte disturbances vary from none to severe hypochloremic metabolic alkalosis with normal or decreased sodium and potassium. Metabolic acidosis can develop in chronic cases from starvation or tissue necrosis. Elevated anion gap and elevated ruminal chloride may also be present.

Abomasal impaction should be considered as a differential in cases with the clinical signs described and an appropriate history. However, diagnosis is often difficult to make in adult cattle without exploratory surgery. A firm distended viscus can often be detected by ballottement in the right paracostal region, although it may be difficult to differentiate between an impacted abomasum and a fetus in cattle in their last trimester of pregnancy. Ultrasound can be used to confirm the presence of the impacted viscus or a thickened abomasal wall, as seen in abomasal lymphosarcoma (Figures 14-107 and 14-108). In extreme cases, it may be possible to palpate the impacted abomasum in the right cranioventral abdomen, but in most cases the abomasum is not detectable by rectal palpation.

Cows with abomasal impaction have a guarded to poor prognosis. The prognosis worsens with the chronicity of the impaction and increasing age of the cow. The prognosis is poor to grave in cases in which the cause can be identified but not eliminated (lymphosarcoma, pyloric strictures) and in many cases for which a cause is never identified. Even in cases initiated by intraluminal materials that can be removed, severe prolonged distention can lead to abomasal perforation or permanent neuromuscular dysfunction. However, some cases in the early stages of distention can be treated successfully by relieving distention and eliminating the cause.

Several options for managing abomasal impaction exist. Slaughter and euthanasia should be considered initially in all cases because of the relatively poor overall prognosis. If the owner considers the animal to be economically worth

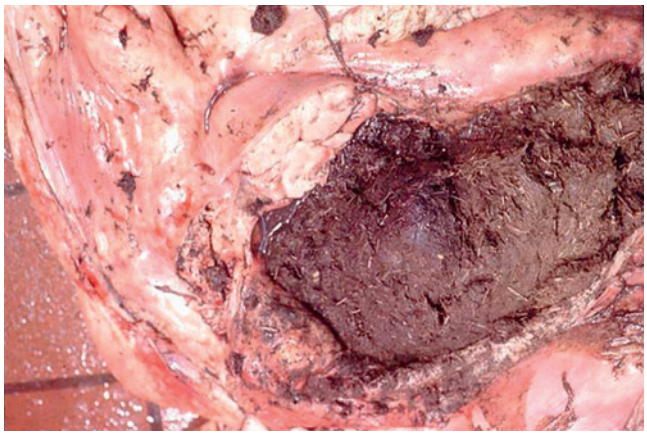


Figure 14-107 Lymphosarcoma at the pylorus (postmortem image).

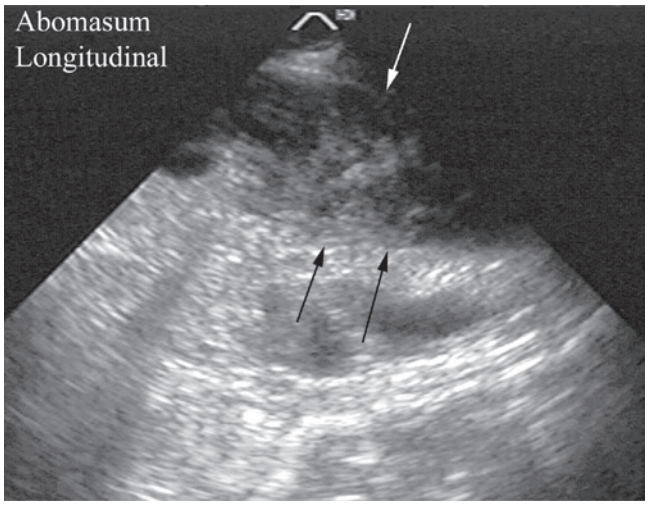


Figure 14-108 Longitudinal sonogram of the abomasum in an adult Holstein cow with a 3- to 2-MHz phased-array sector probe. The wall of the abomasum is very thick (3.5 cm) and hypoechoic with loss of the normal layering. Necropsy confirmed the presence of lymphosarcoma within the abomasum. (Courtesy of Dr. Amy Yeager.)

treatment, two basic approaches to management exist: medical management and surgical decompression.

Medical Management

Medical management of early cases of abomasal impaction associated with intraluminal material has been reported to be effective in a few cases and may be the only option available to manage multiple cases in herd outbreaks. However, a significant risk exists that reliance on medical management alone will delay surgical exploration to confirm the diagnosis and may delay more definitive treatment beyond the point of salvage. Prolonged administration of lubricants and stimulants in animals with untreatable etiologies such as lymphosarcoma is neither effective nor humane. No evidence suggests that lubricants administered per os or by stomach tube reach the abomasum in sufficient quantities to improve outflow. Motility stimulants alone have been reported to be unsuccessful and carry the risk of inducing a rupture if outflow is physically obstructed. The limited evidence of success is unsurprising in that materials administered orally in mature ruminants are unlikely to be transferred into the abomasum before deactivation in the rumen. Administration of intravenous fluids is an important tool in managing dehydration and electrolyte disturbances but will not in itself restore function and must be continued as long as the impaction persists. Metoclopramide (0.3 mg/kg subcutaneously 4-6 times daily) may theoretically improve ingesta movement through the pylorus but has not been evaluated objectively in cases of abomasal impaction in cattle.

Medical therapy may be a useful adjunct to surgical therapy in some cases. In addition to providing access for more specific diagnosis and possible therapy, surgical exploration provides the opportunity to establish a direct route of administration for parenteral agents into the abomasum. This can be done at the time of a rumenotomy by manually directing the distal end of a nasogastric tube through the reticuloomasal orifice and stabilizing the nasal end for continued infusion of lubricants (procedure description will follow). Better success has been anecdotally reported when lubricants (mineral oil, magnesium hydroxide, magnesium sulfate, dioctyl sodium sulfasuccinate) were introduced directly into the abomasum (or omasum) in small doses over an extended period of time. Use of neostigmine, cascara sagrada, carbamylcholine chloride, and a variety of systemic stimulants has been proposed to have some value in conjunction with the direct infusion of lubricants, but administration should be delayed at least 24 hours until the lubricants have had time to soften the intraluminal contents. Controlled studies are not available.

Surgical Management

Although most reports suggest a poor outcome with surgical management, it has been the more successful approach in the author's hands. The following three surgical approaches exist: 1) rumenotomy to access content in the lumen of the omasum such as foreign bodies (plastic materials, etc.) or deliver lubricants via the omasum into the abomasum; 2) right-paracostal or right-paramedian approach to allow access to the extraluminal and intraluminal cause of impaction and examination of most of the abomasum and to allow emptying of the abomasum through abomasotomy; and 3) in very selected cases, a right-flank celiotomy because it allows access to the pylorus and cranial duodenum. The benefits of electing surgical treatment include the following: First, it is the best available way to differentiate between potentially treatable and untreatable causes of impaction, granting that a cause may not be determined for a significant number of cases. Second, it may allow direct management of the cause in a few cases. Third, it can allow more direct—and potentially more effective—administration of adjunctive medical therapy. Finally, it provides the quickest means of relieving pressure on the distended abomasal wall, a critical consideration if abomasal function is to be preserved.

Surgical intervention is not without risks. Affected animals are often in poor systemic condition. This is particularly true for direct approaches to the abomasum that require recumbency because many affected cattle have a distended rumen as well as abomasum and omasum. Even when apparently successful surgery is completed, unidentified or poorly addressable causes may persist in interfering with abomasal function. Finally, the abomasal wall may be too badly damaged to recover even if the initial source of obstruction can be removed.

The risk of recumbent abomasotomy can be reduced by first performing a rumenotomy to decompress the rumen before considering an abomasotomy. This adds two surgeries to the potential cost but enhances the prognosis and should be an option understood by the owner in his or her decision

for therapy versus slaughter. If the decision is made to treat a suspected case, the following two-step process of rumenotomy and abomasotomy is recommended.

Surgical Management: Left-Flank Exploratory/ Rumenotomy (Step 1)

The cow should be prepared for a standing left-flank exploratory and potential rumenotomy as described previously.

An initial and thorough exploration to confirm abomasal impaction and to identify any potential extraluminal cause of impaction is critical. Reexploration after completion of a rumenotomy carries an unacceptably high risk of causing peritonitis; therefore every effort to palpate all accessible structures of interest should be taken at the beginning of the surgery. Initial palpation of the caudal abdomen should include close evaluation of lymph nodes and the uterus for enlargement or irregularities suggestive of lymphosarcoma or lymphadenitis. The size, position, and consistency of the abomasum should be evaluated by reaching around the caudal aspect of the rumen and palpating the visceral surface of the abomasum. The pyloric region should be palpated for irregularities that might suggest lymphosarcoma (Figure 14-109), ulceration, or postulcer scarring. Firm masses in the omentum adjacent to the pylorus might suggest fat necrosis (Figure 14-110). The cranial abdomen is examined for masses or signs of inflammation that might indicate traumatic reticuloperitonitis, liver abscesses, abomasal ulceration, or neoplasia.

Once exploration has been completed, the surgeon should proceed to a rumenotomy. Once the rumen is stabilized by suture or rumen board, transruminal palpation should be performed to verify exploratory findings and to examine poorly accessible areas. Next, intraluminal structures should be examined. The position, size, and consistency of the abomasum can be easily defined by transruminal palpation. The rumenoreticular fold, esophageal orifice, and omasal orifice should be palpated for lesions and to assess the strength of contractions against the hand. Abnormalities at multiple sites might help localize a neurologic lesion. In all but the largest cows, it is usually possible to reach with the left hand through the reticuloomasal orifice into the omasal canal to evaluate the consistency of omasal contents. In some cases of abomasal and omasal impaction, the omasal canal will be packed with dense, dry material that must be manually scraped back into the reticulum to allow palpation of the canal.

A nasogastric tube passed by an assistant into the reticulum can be manually redirected by the surgeon through the omasal orifice and, if the canal is clear or can be cleared, all the way into the abomasum. Once the tube tip is at its desired location in the abomasum, the assistant should mark the tube's point of entry into the nostril. The external tip of the tube can be stabilized by suturing the tube or attached tape to the nares or taping the tube to a halter after completion of the celiotomy. Repeated abomasal infusion of lubricants or motility stimulants can be administered via the tube after surgery.

At this stage, a decision should be made whether to follow the rumenotomy with an abomasotomy. An abomasotomy would be indicated to relieve abomasal pressure if distention is severe and may have therapeutic value if a probable cause is not identified during exploration, thus leaving the possibility of an intraluminal obstruction. If an abomasotomy is planned, ruminal content should be reduced to a small volume to minimize the risk of aspiration and respiratory stress during abomasotomy. Regardless of subsequent plans, decreasing the volume of a distended rumen will improve the animal's comfort level and may enhance the quality of contractions and improve appetite. Closure of the rumenotomy and flank incisions is described in the Surgery of the Ruminant Forestomach Compartments section.

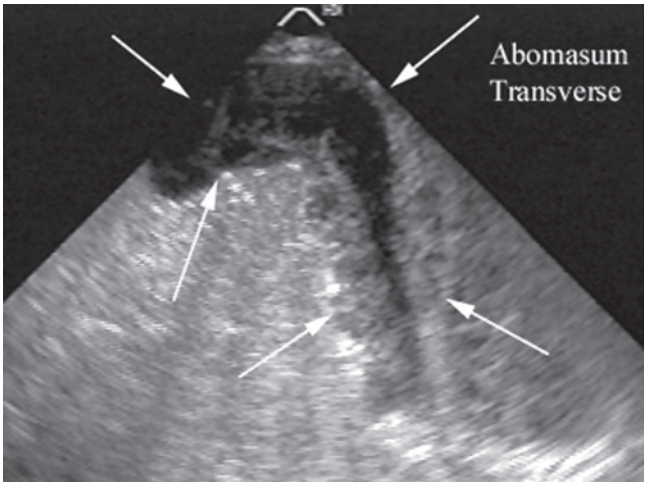


Figure 14-109 Transverse sonogram of the abomasum near the level of the pylorus in an adult Holstein cow with a 3- to 2-MHz phased-array sector probe. Note the very thick hypoechoic wall with loss of discernible layers (*arrows*). Necropsy confirmed the presence of lymphosarcoma within the abomasum. (Courtesy of Dr. Amy Yeager.)

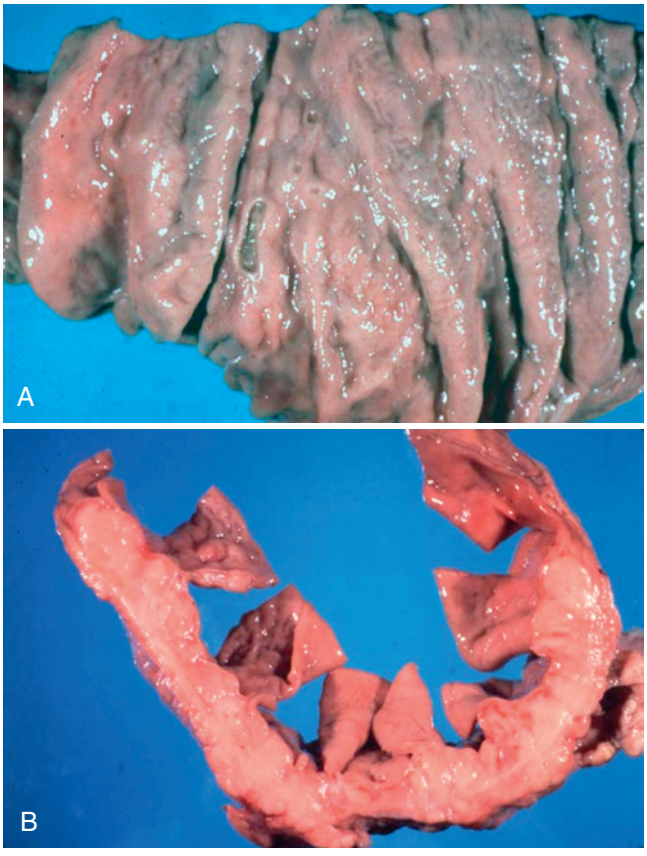


Figure 14-110 Abomasal lymphosarcoma. *A*, Note the thickened mucosal leaves of the abomasum. *B*, Note the thickened abomasal wall on cross section. (Courtesy of Dr. John King.)

Surgical Management: Abomasotomy (Step 2)

Ideally abomasotomy should be performed within 12 to 24 hours of a rumenotomy to take advantage of the empty rumen. Surgical antibiotic prophylaxis should be repeated before surgery. The safest approach is a low right-paracostal or right-paramedian celiotomy with the cow positioned in left-lateral recumbency. A paracostal approach is preferred if access to the pylorus and cranial duodenum is also needed, as this incision can be extended into the right paralumbar fossa. Transection of two nerves (ventral thoracic and lumbar nerves) is of no clinical consequence, but transection of a third nerve can result in abdominal wall denervation, which can cause bulging of the abdominal wall after surgery. Therefore efforts should be made to limit the length of a paracostal incision to 30 cm or less. The abomasum can only be partially exteriorized; therefore removal of ingesta requires repeated movements of hand or instruments in and out of the lumen. Careful isolation of the abomasotomy site with sterile impervious drape is needed because the risk of abdominal contamination is high. Alternatively, a large sterile plastic bag can be used as a wound protector. The middle of the bag is first fenestrated and placed over the intended incision site. The edge of the bag is sutured to the wall of the abomasum before the abomasotomy to prevent abdominal contamination. A large (No. 1) suture material is placed into the seromusucular wall of the abomasum (avoiding the lumen) in a simple continuous pattern encircling the intended abomasotomy site and incorporating the plastic bag. Once the abomasum has been exposed and isolated, a 12- to 15-cm incision can be made in the exposed serosal surface of the abomasum and at least 2 cm is left between the abomasal incision and drape or plastic bag at each end of the incision. The abomasum may also be sutured directly to the skin in the same manner used for rumenotomy before incising the abomasum. Care should be taken to avoid incising the pyloric antrum and pylorus to avoid postoperative strictures and abomasal outflow obstruction.

Once hemorrhage from large submucosal vessels has been controlled, ingesta should be removed from the abomasum and omasal canal to allow assessment of mucosal surfaces and ingesta composition. The composition of ingesta at the pyloric antrum should be closely examined for foreign bodies or compacted material that may have led to a mechanical outflow obstruction. The lumen of the pyloroduodenal juncture should be palpated for patency, masses, or scarring. In many cases of impaction from poor-quality feed, a compacted ball of feed will be present at the pyloric antrum and the duodenum will be empty. Whether motility disturbances caused the compacted ball of feed that initiated the obstruction is difficult to tell. Ruptures, ischemic necrosis, and ulceration are fatal complications of abomasal impaction. The lesser curvature of the abomasum is a common site for these complications to occur and should be examined closely.

After the lumen has been thoroughly evaluated, the exposed serosa should be lavaged with sterile isotonic fluid, and the abomasal incision should be closed using an appositional layer (simple continuous) followed by an inverting layer (Cushing or Lembert). Care should be taken to fully invert the mucosa between serosal surfaces during abomasal wall closure. The serosa should be lavaged again before removing the isolating drapes, wound protector, or sutures holding the abomasum to the skin. The serosa should be carefully examined and any remaining debris removed before releasing the abomasum into the peritoneal cavity.

Although the right-paracostal approach provides access to the pyloric portion of the abomasum, it does not allow complete exploration of the proximal abomasum or omasum in large cows and may not allow safe exteriorization of the pylorus if the abomasum is extremely distended. If either of these conditions exists, a right-paramedian approach is recommended. With the cow in left lateral recumbency, a 25- to 30-cm cranial right-paramedian incision is made. The serosal surface of the abomasum is sutured to the skin circumferentially around the incision using the same process described for rumenotomy. Once the suture line is complete and a good seal is confirmed, the abomasum is incised and mucosal hemorrhage controlled. A wound protector is recommended to minimize contamination and serosal trauma. Content may be removed and the abomasal lumen can be explored at this point. Particular attention should be paid to the proximal lesser curvature of the abomasum, which is a common site for ischemic necrosis and perforation in chronic impaction cases. Following exploration, the wound protector should be removed, the abomasal surface lavaged, and the abomasal incision closed in an appositional layer followed by an inverting pattern with an absorbable suture material such as polyglactin 910 or polydioxanone. The sutures between the skin and abomasum and any debris can be removed before the abomasum is allowed to return to the abdomen.

Postoperative care should include analgesics and supportive care. Antibiotics initiated prophylactically before surgery should be continued at therapeutic levels for at least 3 days beyond clinical signs of infection if significant contamination occurred or if signs of preexisting infection were identified during surgery. If the abomasal wall has been permanently damaged or the original cause of the impaction persists, the abomasum will gradually refill. The process may take weeks to become apparent, and the owner should be made aware that an initial improvement in signs might not indicate full recovery.

Alternative Surgical Management: Right Flank Exploratory

Surgery is typically performed with both diagnostic and therapeutic goals. The standing right flank approach provides adequate access for diagnosis and identification of lesions in the pyloroduodenal region. Successful treatment of two cases that resulted from gravel ingestion has been reported with this approach. In one case, with an accumulation of gravel in the pyloric antrum, manually breaking down the mass and massaging the material back into the abomasal body was possible. In a second case with gravel in the descending duodenum, the material was removed by enterotomy. This approach does not provide adequate access for abomasotomy unless the abomasum is chronically distended enough to expose the pyloric antrum through the incision. If material in the abomasum cannot be disrupted manually and the abomasum is not stretched enough to expose through the incision, a second surgery will be necessary. If the rumen is distended, an intermediate step of a left-flank rumenotomy may be indicated to improve safety for the abomasotomy.

Mixed Mechanical and Functional Obstructions: Adhesions

Adhesions secondary to perforating abomasal ulcers or a periabomasal inflammatory focus can create partial or complete abomasal outflow obstruction by preventing the normal wall motility necessary for propulsion of feed or by distorting the normal position of the outflow tract. Iatrogenic adhesions caused by improper placement of an omentopexy, abomasopexy, or pyloropexy can also impair outflow by the same mechanisms. Adhesions to the abomasum or adjacent structures can also produce pain by placing tension on parietal or visceral surfaces or can interfere with abomasal innervation, thus creating some degree of functional motility impairment.

The treatment goals for inflammatory and iatrogenic adhesions are to restore the normal functional position of the abomasum and maintain or restore the integrity of the abomasal wall. This usually requires lysis (separation) of the adhesions. Early fibrinous adhesions (<10 to 14 days) are relatively fragile and can generally be lysed by blunt dissection. In the case of poorly placed left-flank abomasopexy, blind tack, or toggle pin surgeries, external release of the sutures within the first week of placement is often sufficient to allow the abomasum to return to a more functional position. Other methods of surgical stabilization require reexploration, generally through the original incision, for release of sutures and lysis of adhesions.

After 10 to 14 days, spontaneous and artificial adhesions will generally have sufficient fibrous tissue to make lysis by blunt dissection difficult and, in some cases, impossible. The integrity of the abomasal wall must be carefully protected because it is often difficult to see or feel a separation between the adhesion and wall of the viscus. Excessive tension is as likely to tear through the abomasal wall as it is to lyse the adhesion. Techniques for management of mature adhesions are described in management of LDA with adhesions). If control of the site cannot be achieved, a decision to abort the procedure and recover the cow for another approach or for slaughter should be considered. The right-paramedian or right-paracostal approaches tend to provide the best access for adhesions involving the abomasum. Defects in the abomasal wall should be oversewn and any full-thickness defects in the omentum should be closed.

If adhesions were producing an outflow obstruction by changing the position of the outflow tract without otherwise compromising the lumen, release of the adhesions and restoration of the abomasum to its normal position will generally be sufficient to restore function. Adhesions commonly recur at the site of adhesion lysis but, in the case of the bovine abomasum, small intestinal loops are separated by the omental sling and are unlikely to be occluded by new adhesions. If the abomasum has been replaced in a normal position, new adhesions should stabilize the abomasum in the desired location. Performance of an abomasopexy or omentopexy may not be essential because of the presence of freshly broken adhesions in the area, but one should still be performed in most cases to ensure a functional anatomic position. Inflammation is, by definition, present at the site of adhesion lysis, and multifilament nonabsorbable sutures should be avoided.

If the adhesions were producing an outflow obstruction by constricting the lumen in the narrow parts of the outflow path, it may be appropriate to decrease or prevent development of postlysis adhesions. In general terms, this will involve efforts to minimize tissue trauma by gentle tissue dissection and precise hemostasis, use of tissue lubricants (carboxymethylcellulose, 1% solution, molecular weight from 250 to 1000 kd) to avoid serosal and peritoneal abrasion, minimizing the amount of foreign material (that is, sutures) and blood left at the wound site, and leaving peritoneal defects (with the exception of full-thickness omental tears) unsutured. Addition of surface-coating agents that protect surfaces and/or promote plasminogen activation should be considered.

MECHANICAL OBSTRUCTIONS

Intraluminal Obstructions

Purely mechanical intraluminal obstructions are relatively uncommon causes of abomasal obstruction in the adult cow. The reticuloomasal orifice in adult cattle normally prevents passage of material that has not been reduced to the small size necessary for digestion and also serves as a filter for many metal objects that might lodge in the pylorus or duodenum. Baling twine, placenta, gravel, and trichobezoars do occasionally lodge in the pyloric region and cause an obstruction in adult ruminants. Compacted solid ingesta is often present in the pyloric antrum of cattle with abomasal impactions, although the compacted material is probably secondary to an initial neuromuscular dysfunction rather than the primary cause of the obstruction Other causes of intraluminal obstruction are uncommon and sporadic in nature.

Intraluminal obstruction of the abomasum in adult cattle can be expected to result in the same fluid and electrolyte disturbances described previously for LDA (i.e., hypochloremic metabolic alkalosis with possible hyponatremia and hypokalemia). However, fluid and electrolyte values may remain in the normal range if the obstruction is partial and allows fluids to pass through the pylorus. In the rare case in which the intraluminal material penetrates the wall or causes pressure necrosis, signs of peritoneal inflammation and possibly infection may be present.

Treatment involves surgical removal of the obstructing object, correction of fluid and electrolyte imbalances, and management of any associated inflammation or infection. Surgical access to the primary site of obstruction (i.e., the pylorus) is generally limited in adult cattle to a right-paracostal or right-paramedian approach with the cow positioned in left lateral recumbency. These approaches are described in detail in the Abomasal Impaction section. If the pylorus has been obstructed because of fibrosis or perforation, an abomasoduodenostomy can be performed between the serosal parietal surface of the abomasum and the descending duodenum as described in the following discussion.

Mural Lesions

Mural lesions can obstruct outflow by several mechanisms including narrowing or distortion of the lumen, interference with normal contractions, and damage to intrinsic nerves and signaling mechanisms. Lesions must generally be in the narrow distal end of the abomasum to produce a mechanical obstruction. Mural lesions include tumors, abscesses, and fibrosis. Intestinal tumors are relatively uncommon in cattle compared with humans or dogs, but several have been reported in the abomasum. The most common is lymphosarcoma (see Figure 14-110*A* and *B*). Adenocarcinoma can occur in the abomasum but is more typically found in the small and large intestines. Fibrosis and intramural abscesses most commonly result from ulcers. Intraluminal obstructions that create pressure necrosis and loss of the mucosal barrier can also lead to fibrosis of the wall.

Cows with mural tumors of the abomasum have a very poor prognosis, and treatment is not generally recommended. Small mural lesions in the proximal pyloric antrum or abomasal body may be resectable, although bypass is often the only method of restoring aborad flow. A side-to-side anastomosis can be performed between the parietal surface of the abomasum and the descending duodenum or proximal jejunum via a standing right flank (adults only) or recumbent right-paracostal or right-flank approach. In the authors' experience, this has been successful in a very limited number of cases (and is rarely indicated) when the anastomosis is between the pyloric part of the abomasum and the descending duodenum and is best done in standing animals by using stapling instruments. On the contrary, anastomosis between the pyloric part of the abomasum and the jejunum has not been successful. If the proximal jejunum is used, the omental sling must be transected at the intended level of the anastomosis and the edge of the transected omentum sutured together to close the omental bursa. Access is more limited in adult cattle than in calves, and if possible, cows should be

held off feed for up to 48 hours before surgery to improve access.

Extraluminal Masses

Any extraluminal mass adjacent to the pyloric antrum or proximal duodenum that compresses the lumen can lead to a partial or complete outflow obstruction. Omental fat necrosis (Figure 14-111) and abscesses are the most commonly recognized extraluminal masses that produce abomasal outflow obstruction. Drainage or marsupialization of abscesses may improve motility by decreasing the diameter of the abscess and decreasing pressure on the abomasal outflow tract. Care must be taken to maintain a relatively normal anatomic relation for the abomasum and duodenum if abscess marsupialization is planned. If fat necrosis has become extreme enough to impair pyloric outflow, bypass of the pylorus to the descending duodenum might relieve the obstruction. However, fat necrosis is rarely limited to the pyloric region, and the limited mobility of the omentum makes apposition for bypass difficult if not impossible.

Functional Obstructions

Functional obstructions can develop from any stimulus that interferes with the normal coordination of contractions in the abomasum and outflow tract. Diagnosis is generally based on eliminating all mechanical sources of obstruction and identifying signs consistent with possible physiologic disturbances. Regardless of the source and extent of the functional motility disturbance, involvement of the abomasum or proximal duodenum is likely to produce the characteristic fluid and electrolyte changes associated with abomasal outflow obstruction (i.e., dehydration with a hypochloremic metabolic alkalosis with or without hyponatremia and hypokalemia). Identification of these changes alone does not usually help differentiate between mechanical and functional outflow obstructions. Although surgery is often involved during diagnostic evaluation to rule out mechanical disturbances and may be of some benefit in temporarily relieving abomasal distention, it does not commonly play a role as a primary treatment method of most functional obstructions.

Functional Obstructions—Ileus

Abomasal motility is regulated by a range of local and systemic mediators, as discussed in the introductory section Physiology and Function. Although the role of many causative factors is still under debate, evaluation and treatment of potential contributing factors should be routine parts of case care. Hypocalcemia, hypokalemia, alkalosis, and ketosis are all possible primary causes of depressed abomasal motility, and correction of these disturbances can restore motility in some cases. Nutritional factors commonly are implicated as a cause of altered abomasal motility that leads to displacement in adult cattle and calves. Adjustment of diet to eliminate or reduce risk factors may resolve some cases. Gastrointestinal motility can be depressed by painful or inflammatory stimuli located elsewhere in the peritoneal cavity or body. Conditions associated with endotoxemia are an example and include such widespread problems as liver abscesses, endometritis, coliform mastitis, and septicemia. Treatment should focus on correcting potential initiating causes, including relief of pain and control of inflammatory stimuli. Macrolide antibiotics such as erythromycin have shown promise in increasing motility during the interdigestive period (between meals) and may have promise in some cases. Functional obstruction following surgical correction of an abomasal volvulus is associated with lesions of the abomasal wall and carries a very poor prognosis with either medical or surgical therapy. However, the veterinarian should first confirm that the omentopexy and/or pyloropexy sutures were properly placed and, if not, remove them.

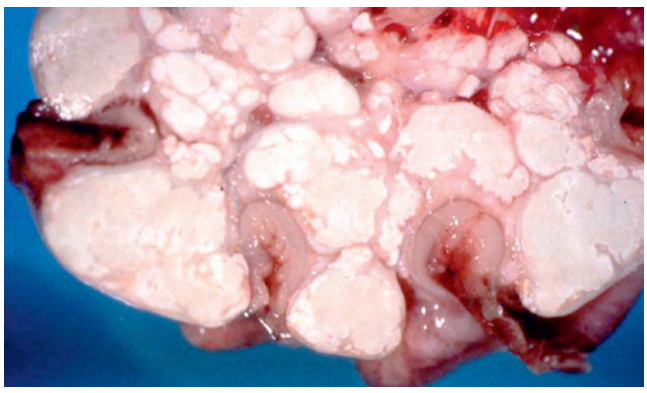


Figure 14-111 Fat necrosis in a Guernsey cow. (Courtesy of Dr. John King.)

LOSS OF ABOMASAL MUCOSAL INTEGRITY

Loss of the abomasal mucosa barrier can occur as a result of persistent luminal pressure from stationary intraluminal objects (trichobezoars, foreign bodies, etc.), abomasal ulcers, mural lesions that interfere with mucosal blood flow or expand through the wall (lymphosarcoma, abscesses, etc.), and extraluminal lesions that invade the lumen (surgical incisions, suture material, foreign bodies). The result is exposure of acidic abomasal fluid and any pathogenic organisms to the abomasal muscular and serosal layer with potential erosion of submucosal vessels and/or leakage into the peritoneal cavity. Abomasal ulcers and fistulation are reviewed in the following discussion.

Abomasal Erosions and Ulcers

Definition

Abomasal ulcers are lesions that penetrate the basement membrane of the abomasal mucosa. Erosion of the mucosa presumably precedes the development of an ulcer. Once the basement membrane has been invaded, the clinical presentation is based on the depth of penetration and the structures involved. Four different types of abomasal ulcerations have been described: Type 1) nonpenetrating ulcers; Type 2) ulcers with profuse intraluminal hemorrhage; Type 3) perforations with localized peritonitis (Figure 14-112); and Type 4) perforations with diffuse peritonitis. The Type 1 category of ulcers has been used to describe both erosions and true ulcers that have penetrated the basement membrane but have not fully broken through the abomasal wall (nonpenetrating ulcers). Perforation on the visceral surface of the abomasum can lead to the syndrome known as *omental bursitis* (see Intraabdominal and Retroperitoneal Abscesses, considered in this text as a subset of Type 3 ulcers). An individual cow may have multiple ulcers that fall into more than one category.

Predisposing Factors

Abomasal ulcers have been recognized in cattle of all ages and breeds but are more common in cattle in intensive-management settings. Specific groups recognized to be at risk for ulcers in general include high-production dairy cows, feedlot cattle, veal calves, and beef calves. Abomasal ulceration in calves is of sufficient concern in Europe to receive

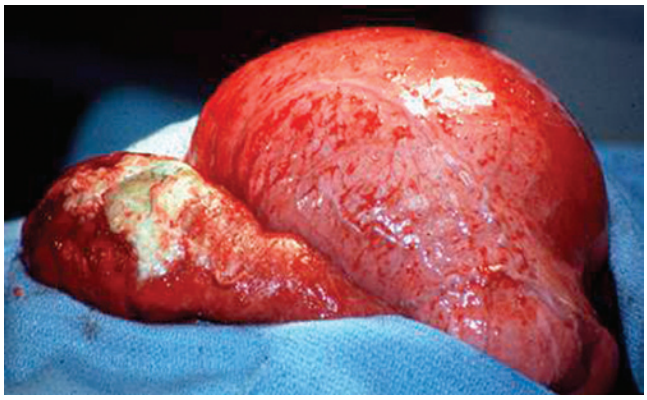


Figure 14-112 Perforating abomasal ulcer with localized peritonitis.



Figure 14-113 Perforating abomasal ulcer with diffuse peritonitis.

attention in the recommendations of the Council of the European Community's minimum standards for protection of calves. Some reports indicate that the incidence of clinically significant abomasal ulcers is increasing.

Diffuse nonperforating erosions/ulcers are commonly recognized in some groups of cattle, including veal calves, 2- to 8-week-old calves, weanling calves, and fattening cattle, primarily at the time of slaughter. Stress from a variety of sources including changes in housing or feed, straw ingestion, exposure to infectious agents, and high milk production have been implicated as predisposing factors. The overall prevalence of Type 1 ulcers in veal calves in one study that compared the effects of different types of housing was 86.8%. However, because most cases of Type 1 ulcers are believed to be subclinical, the incidence in groups of cattle that are not routinely seen at slaughter or necropsy is difficult to estimate.

Type 2 (bleeding) ulcers may be multiple or single, but the category is generally reserved for ulcers that cause severe intraluminal blood loss. Cows with bleeding ulcers represented 26 (0.41%) of 6385 cattle admitted to one referral center over a 14-year period. Bleeding abomasal ulcers can be divided into two groups based on etiology: those associated with lymphosarcoma and those that are not. Cows with lymphosarcoma-associated bleeding ulcers are generally over 5 years of age and are diagnosed throughout the lactation period. Cows with ulcers unassociated with lymphosarcoma generally are less than 4 years of age, present in the first few weeks after parturition, and typically have one or more concurrent postparturient diseases (LDA, metritis, mastitis, and ketosis).

The occurrence of perforating ulcers in adult cattle appears to be more sporadic and associated with episodes of metabolic stress, including recent parturition, peak milk production, and one or more concurrent diseases (abomasal displacement, metritis, mastitis, and ketosis). Diets high in concentrate and corn silage have also been implicated. In a review of cases over a 14-year period in one referral hospital, 43 cases of perforating ulcers were admitted and represented 0.63% of cases admitted during this period. One early study reported that 85% of perforating ulcers resulted in localized peritonitis in the omental bursa, although a more recent study showed an equal or greater percentage of perforating ulcers resulting in diffuse peritonitis.

Diagnosis and Prognosis. The clinical signs produced by abomasal ulcers depend largely on the category of ulcer and range from vague signs of digestive disturbance to signs consistent with peritonitis or anemia.

Type 1 Ulcers

Type 1 ulcers often lack any detectable clinical signs. However, the presence of Type 1 erosions/ulcers may be suspected in cattle known to be at risk and that show signs of poor appetite, decreased weight gain, and decreased ruminal motility. Concurrent disease is common. Affected animals may be positive for fecal occult blood, but a negative test does not rule out the diagnosis. Erosions do not penetrate the mucosal basement membrane and can heal without contraction or scarring (Figure 14-113). They produce little detectable change when viewed from the serosal surface of the abomasum and can only be diagnosed with certainty at necropsy or during abomasotomy. However, when erosions progress to ulcers, they produce a local inflammatory response with peripheral thickening and occasional serositis that can be detected by palpation of the abomasal wall during abdominal exploration. The contraction and scarring that occurs as a part of healing is also detectable by palpation during exploratory surgery. Nonperforating ulcers are also commonly associated with concurrent diseases, but up to 50% of affected animals may have clinical signs associated with ulceration, including abdominal pain, melena, or pale mucous membranes.

Type II Ulcers

The hallmark signs of bleeding abomasal ulcers are melena caused by blood digested in the abomasum and a positive fecal occult blood test (Figure 14-114). This test is very sensitive, and fresh feces should be collected for examination before performing abdominal palpation per rectum to avoid false-positive results. Other sources of gastrointestinal hemorrhage must be considered as differentials.

Cows with bleeding ulcers unrelated to lymphosarcoma are initially identified by the acute drop in milk production and the appearance of dark loose feces. Pale mucous membranes are common. Cows with non–tumor-associated ulcers are usually anemic (packed cell volume <25%) and are likely to have severe anemia (packed cell volume <15%) with signs of regeneration (nucleated red blood cells and/or increased reticulocyte counts). Signs of abdominal pain may also be present. Ulceration over large submucosal arteries or veins can produce acute severe blood loss that leads to death before external signs are detectable in either adults or calves.

The initial signs in cows with lymphosarcoma are more variable and depend on the effect of the tumor on abomasal function, the amount of bleeding, and the involvement of other viscera. Cows with tumors isolated to the abomasum are typically recognized based on signs associated with altered abomasal motility (abomasal displacement, anorexia,

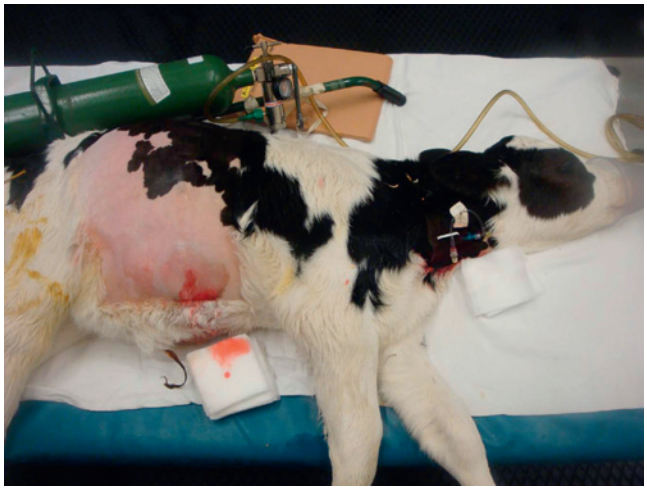


Figure 14-114 3-week-old calf became acutely distended and obtunded.

or hemorrhage, depression, dark loose stool, pale mucous membranes, and tachycardia). Only 50% of cows with lymphosarcoma-associated abomasal ulcers were found to be anemic in one study, and only 25% had severe anemia (packed cell volume <15%). Other signs of lymphosarcoma—including lymphadenopathy, lymphocytosis, and abnormal lymphocytes in peritoneal fluid—may also be present in some cases.

Type III and IV Ulcers

The outlook for cattle that present with perforating ulcers depends on the perforation depth, ulcer location, the animal's age, and the presence and nature of concurrent diseases. Ulcers that penetrate slowly in areas covered by omentum are more likely to produce localized peritonitis or omental bursitis (Type III ulcers) with less noticeable clinical signs. Cases of perforation associated with LDA also fall into this category, even though they may occur on the uncovered serosal surfaces of the abomasum. It has been hypothesized that the distended abomasum enhances the contact between the perforation site and the body wall, thus allowing better localization of the contamination. Ulcers that occur rapidly in areas that are not covered by omentum are more likely to produce generalized peritonitis (Type IV ulcers) with severe acute clinical signs (see Figure 14-113).

In adult cattle, Type III ulcers may lack any clinical signs specific to the perforation, with identification occurring during investigation of concurrent diseases. Signs, when present, include intermittent anorexia, ruminal stasis and/or distention, abdominal distention, abdominal pain, melena, and anorexia. Perforation on the visceral surface of the abomasum can lead to the syndrome known as *omental bursitis*, with partial confinement of contaminants between the two layers of the greater omentum. In these cases clinical signs tend to progress gradually and include anorexia, decreased milk production, bilateral ventral abdominal distention, decreased rumen contractions, loose or scant feces, and loss of body condition.

Physical examination with manual pressure on the ventral abdomen may localize abdominal pain to the right cranioventral body wall. This can help distinguish the localized peritonitis caused by Type III ulcers from that caused by traumatic reticuloperitonitis, which is more commonly associated with left cranioventral pain. Localization is not always possible and overlap in location does occur; therefore results should be considered as supportive rather than diagnostic.

Laboratory results are also seldom diagnostic but may provide supportive information. Feces will be positive for occult blood in some but not all cases. Nonspecific systemic signs of inflammation (pyrexia, neutrophilia, hyperfibrinogenemia) may be present in the acute stages of perforation and intermittently afterward. Peritoneocentesis can indicate peritonitis, but the adult cow's ability to localize peritoneal contaminants results in many false negatives in the face of established infection. Elevated peritoneal white blood cell counts and normal to increased peritoneal protein in the face of a systemic hypoproteinemia suggest peritonitis. Cows with Type III localized perforating ulcers in one study were observed to have a mild hypochloremic, hypokalemic metabolic alkalosis. However, 83% of the cows in this group also had LDAs, and the metabolic and electrolyte changes may reflect the abomasal displacement rather than the ulcer. In cows with a diagnosis of LDA or RDA/RVA, the presence of pneumoperitoneum, signs of abdominal pain (arched back, pain on abdominal pressure), and pyrexia that is not explained by other concurrent disease suggests the presence of perforating ulcers. Ultrasonography can be used to help identify or confirm cranial right abdominal peritonitis. Ultrasonography can also help identify fibrin accumulation and/or abscess formation along the cranioventral abdomen. In some cases the fibrin accumulation is sufficiently localized to the abomasal body to suggest abomasal ulcers. However, it is often difficult to differentiate between traumatic reticulitis and abomasal ulcers by ultrasound alone.

Cows with Type IV abomasal ulcers present with acute signs of depression, anorexia, agalactia, and systemic shock. Tachycardia, tachypnea, pyrexia, and abdominal pain are common clinical signs. Other gastrointestinal disturbances, including LDA and ruminal tympany, are less common than in cows with Type III ulcers but still present in about half of cases. A normal or low serum total protein in the face of hemoconcentration that results from loss of protein into the peritoneal cavity is often present in cows with diffuse peritonitis. Ultrasonography can confirm a diffuse peritonitis. Leukocytosis, neutrophilia, and left shift are also common in affected cattle. Elevated white cell counts and protein concentrations in peritoneal fluid can be expected in some—but not all—cases. Cows with Type IV ulcers may show a metabolic acidosis with hypokalemia and hypocalcemia.

Cows that survive an acute episode of either Type III or Type IV abomasal ulcers may develop chronic recurrent signs associated with adhesions or chronic abscessation.

Treatment. Treatment of individual animals with Type I or multiple Type II ulcers should focus on medical management, with tools directed at reduction of metabolic stress, resolution of concurrent diseases, and supportive care for systemic disturbances. Management changes to reduce stress should be considered for the herd in general. Treatment is not recommended for cows with Type II ulcers associated with lymphosarcoma because of the poor prognosis for lymphosarcoma in general. Medical management tools are also important as the sole means of management or as an adjunct to surgical therapy for isolated Type II, III, or IV ulcers.

Surgical therapy is rarely the first choice for managing ulcers of any type, even when an isolated ulcer is suspected. By the time of diagnosis, cattle with isolated bleeding ulcers are often in poor condition and may not tolerate the recumbent approach necessary for access to the abomasum. The extensive omentum and propensity for fibrin deposition in adults provide a reasonably effective initial seal for ulcers that perforate gradually. Surgical intervention can disrupt tentatively localized infection, which leads to more diffuse distribution and increases the risk of septicemia and systemic shock. In most cases the cow's own defense mechanisms are

better capable of safely localizing and sealing a perforating abomasal ulcer than is the surgeon. However, surgery is commonly involved in treating concurrent abomasal displacements and diagnostic evaluation of cases with nonspecific signs of forestomach motility disturbances, and ulcers may be encountered incidentally. The goals for surgical therapy are to control hemorrhage, eliminate further peritoneal contamination, eliminate any outflow obstruction produced by ulcers or their sequelae, and ensure a functional abomasal position. The primary surgical procedures performed are submucosal vessel ligation, ulcer resection, or ulcer inversion and oversew.

Surgical access to the abomasum for therapy is limited. The standing left-flank approach will allow separation of adhesions from some Type III ulcers with concurrent LDA and restoration of normal abomasal position but does not provide adequate access for any other procedure, with or without abomasal displacement. The preferred approaches in adult cattle are low right paracostal or right-paramedian incisions with the animal positioned in left lateral or dorsal (right-paramedian only) recumbency. Surgical antibiotic prophylaxis is indicated when planning surgery in which ulcers may be encountered.

Type II Ulcers

Surgical intervention is not generally recommended as the primary approach for treatment of bleeding ulcers. However, when bleeding ulcers are encountered during surgery (thickened and discolored area) for treatment of abomasal displacement or diagnostic exploratory, it is possible in some cases to identify the site of hemorrhage and decrease or eliminate bleeding. This requires identification of the site or sites of hemorrhage and ligation or compression of the involved submucosal vessels. The quantity of hemorrhage seems to decrease once the abomasum is returned to its normal position.

After the abomasum is exposed, the site of hemorrhage should be identified by palpating focal abomasal wall thickening. Whenever possible, the involved area should be exteriorized, packed off from the adjacent tissues, and isolated with intestinal forceps before full-thickness excision of the ulcerated area. Stay sutures (No. 1 monofilament) should be placed at either end of the exposed site to support the intestinal forceps and maintain control of the site, should it be necessary to release the forceps to identify and ligate submucosal vessels. The abomasal serosa should be lavaged to remove debris if the lavage fluid can be directed out of the peritoneal cavity. The abomasal defect should be closed in one or two layers.

If the ulcer is located in the lesser curvature or near the omasal orifice, gaining direct access to the serosal surface over the lesion may be impossible. In a few of these cases, it may be possible to oversew the lesion and compress the involved vessels without entering the abomasal lumen. Large-gauge (No. 1 or No. 2) synthetic absorbable suture material should be used to place large overlapping horizontal mattress pattern sutures across the course of the involved vessels. Alternatively, exposing the luminal surface of the lesion on the lesser curvature may be possible by suturing the parietal surface of the abomasum to the skin as described previously for treatment of abomasal impactions. This technique will allow ligation of bleeding ulcers and will potentially allow the site to be oversewn, although it carries an increased risk of peritoneal contamination and peritonitis.

Type III and IV Ulcers

The majority of Type III ulcers that are identified ante mortem are found during exploratory surgery for LDA. Type IV ulcers that perforate rapidly on the parietal surface are often impossible for the peritoneal cavity to contain and lead to rapid deterioration and death. However, no reports suggest that surgical intervention can improve the outcome. Acute perforation of a partial-thickness or fibrin-sealed ulcer during exploratory surgery is an exception to the rule. If the ulcer can be quickly isolated and oversewn, a combination of debridement, extensive abdominal lavage, antibiotics, and supportive care can be successful (see Figure 14-114 and Figure 14-115*A* and *B*).

Adult Cattle and Feedlot Steers. After exposure of the abomasum, the site of ulceration should be identified. The perforation is generally located at the site of the most well-established adhesions. Once the site has been identified, it should be isolated from as many surrounding adhesions as possible and elevated toward the incision if it is mobile. Before beginning adhesion lysis, the abomasal wall in the vicinity of the perforation should be clamped with atraumatic intestinal forceps or, if this is not possible, isolated manually and the surrounding tissues packed off to help control accidental leakage. Peripheral thin fibrinous adhesions may be gently separated manually, whereas thicker fibrous adhesions may require sharp incision. If the ulcer is in a location that cannot be safely isolated, the adhesions should be left in place and the cow recovered. At this time, a decision to treat medically, perform a second surgery

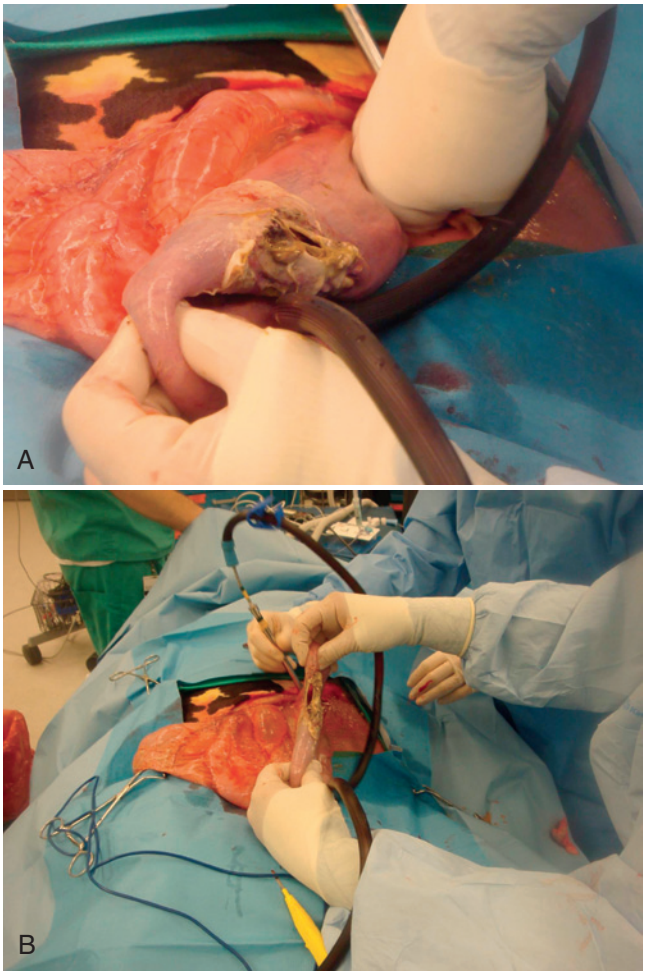


Figure 14-115 *A* and *B,* Two surgical views of acute perforated ulcer in the calf from Figure 14-114. The calf survived following oversew of the ulcer and abdominal lavage.

through another approach, or elect slaughter/euthanasia will be needed.

Once the site has been isolated, the area of ulceration should be resected and oversewn with an inverting pattern with an absorbable suture material such as polyglycolic acid, polyglactin 910, or polydioxanone. Chromic gut has been used for this purpose but is not recommended because of the potential for premature absorption in the presence of abomasal acid and the enzyme activity of bacteria and white blood cells. Some authors have described successful management of perforated ulcers by inverting the ulcer site without resecting the ulcer and oversewing the site with an inverting pattern. Care should be taken to avoid spreading debris or contaminated fluid beyond the local site of contamination. The incision should be closed routinely, taking care to lavage each layer of the incision thoroughly before closure. Antibiotic therapy should be continued to treat the peritonitis as indicated based on the level and stage of infection.

If ulceration has produced a localized abscess adjacent to the ventral body wall or within the omental bursa, it may be possible to marsupialize the abscess and treat it by drainage and lavage. Once drainage has stopped, it may be necessary to surgically close the artificial tract.

Prognosis

Type II Ulcers

The prognosis for cows with bleeding ulcers associated with lymphosarcoma is grave. The prognosis for cows with non–tumor-associated bleeding ulcers is guarded to poor. Nine of 12 cows survived in one study, whereas 0 of 4 survived in another study. The author of the latter study reports better results in cases presented after the study period.

Type III Ulcers

The prognosis for adult cattle with localized peritonitis is guarded to fair with surgical intervention if the ulcer can be isolated and oversewn without disseminating contaminants throughout the abdomen, and if the inflammatory response does not permanently impair normal function. Ten of 17 cows (59%) approached surgically in one study were successfully discharged. The other seven cows were euthanized because of abomasal rupture during manipulation (n = 3) and extensive adhesions that interfered with digestive function (n = 4). Seven of 12 cases (58%) with localized peritonitis and concurrent abomasal displacement treated surgically were discharged in a second study. Little information is available on prognosis for cows treated conservatively, but it is presumed to be poor.

Type IV Ulcers

The prognosis for adult cattle with diffuse peritonitis is very poor. Two of 22 (9%) affected cattle survived to discharge in one study. One of 9 (11%) cases with concurrent abomasal displacement treated surgically survived to discharge in a second study.

Abomasal Fistulas

Definition and Predisposing Factors

Abomasal fistulas are tracts that communicate from the lumen of the abomasum to the skin surface or occasionally to the lumen of another viscera (reticulum, rumen, and omasum), organ (liver), or body cavity (thorax). Fistulas between the abomasum and skin are most commonly recognized as a technique-related complication of right-paramedian abomasopexy (Figure 14-116) or of blind tack (see Figures 14-69 and 14-70) or toggle pin (Figure 14-117) fixation of abomasal displacement. The primary predisposing factor



Figure 14-116 Ventral abdomen of a cow with an abomasal fistula after a right-paramedian abomasopexy. (Courtesy of Dr. Brett Woodie.)



Figure 14-117 Ventral abdomen of a cow with an abomasal fistula after a toggle pin application. The sutures of the toggle were tied through a needle case and left in place inadvertently. Note that the needle case is still in the fistula. (Courtesy of Dr. Brett Woodie.)

that leads to fistulation after abomasopexy is most likely penetration of abomasal mucosa, particularly with multifilament nonabsorbable materials that trap organisms between filaments. Failure to release the tack suture 2 to 4 weeks after surgery is considered the major reason for fistulation after a blind tack or toggle pin procedure (Figure 14-118). Most cases of fistulation after right-paramedian abomasopexy occur within several months; cases can occur as early as 2 weeks and occasionally as late as 8 months after surgery. Fistulation typically takes longer to develop (10 to 12 months) after a blind tack. Abomasal fistulation in association with ventral body wall hernias—particularly umbilical hernias in calves—have also been reported. Other fistulas have been attributed to abomasal ulcers or penetrating foreign bodies migrating from the reticulum to the abomasum or out of the abomasal lumen.



Figure 14-118 Large abomasal fistula in a cow 4 weeks after a right-paramedian abomasopexy.



Figure 14-119 Oversew of the fistula, from the cow in Figure 14-118, before surgery.

Diagnosis

Internal fistulas have a wide variety of clinical signs based on the path of the fistula, including signs consistent with local or diffuse peritonitis and motility disturbances. A specific diagnosis is seldom made before exploration. On the other hand, external fistulas are quite easy to diagnose based on the drainage of abomasal fluid and/or blood from the center of an area of cellulitis, usually located in the right-paramedian area of the abdomen. Fistulas related to right-paramedian abomasopexy can involve part or all of the incision, whereas those associated with blind tacks or toggle pins are more localized to the site or sites of suture penetration. Necrotic abomasal mucosa may also protrude through the fistula. Other clinical signs vary with the duration and amount of abomasal fluid lost and amount of blood lost from eroded submucosal vessels. Fluid and blood loss can be severe with extreme electrolyte disturbances (hypochloremia, hypokalemia, hyponatremia, metabolic alkalosis, dehydration), and hemorrhage (anemia, hypovolemia, and tachycardia).

Treatment

The continued loss of abomasal fluid through a fistulous tract will eventually lead to life-threatening fluid and electrolyte disturbances. Hemorrhage from exposed submucosal vessels can rapidly lead to severe anemia and hypovolemic shock. Treatment goals are to adequately stabilize the cow before surgery, resect the fistulous tract, and close the affected viscera.

Preparation

The amount of preparation that can be completed before surgery will depend on the severity of ongoing hemorrhage. Ideally, surgery is delayed for 24 to 48 hours to allow correction of fluid imbalances (including a blood transfusion if there is severe anemia) and to reduce rumen fill. This is possible when ongoing hemorrhage is minimal or when the surgeon can control hemorrhage in the standing cow. If hemorrhage cannot be controlled, it may be necessary to proceed more quickly to surgery and administer fluids and blood before and during surgery. Preoperative antibiotics are indicated because of the potential for contamination of adjacent tissues during surgery. Antibiotics should be continued after surgery if the contaminated tissue is not well contained during surgery.

The cow should be restrained in dorsal recumbency under general anesthesia or cast and restrained with ropes. General anesthesia has the distinct advantages of better airway control, better immobilization, and reliable analgesia but has the obvious disadvantage of cost. Manual restraint should be combined with an inverted-L block with 2% lidocaine for analgesia. Light sedation with xylazine hydrochloride can be used in manually restrained animals to help control movement but is not recommended in animals in poor systemic condition.

As much of the cranioventral abdomen as possible should be clipped while the cow is standing to minimize time in recumbency. It will usually be necessary to complete clipping around the tract once the cow is in dorsal recumbency. Any exposed necrotic tissue should be removed and the tract oversewn, if possible (Figure 14-119). If the tract cannot be oversewn, the exposed contaminated tissue should be isolated as much as possible from the adjacent surgical field by covering it with an adhesive drape or towel.

Procedure

An elliptical or fusiform incision should be made around the tract through the skin and body wall. The dissection continues into the peritoneal cavity (Figure 14-120). Limited mobility exists in the tissues in this location, and the incision should be as close to the tract as possible without entering the tract lumen. Elevating the tissues during the entry into the abdomen is helpful to avoid inadvertent perforation of underlying structures. Once in the peritoneal cavity, it may be necessary to separate adhered omentum and, occasionally, other structures from the tract. This is usually possible with blunt dissection alone, but firmly adhered structures may require sharp resection with subsequent defect repair. Once the tract and attached abomasum have been freed (Figure 14-121), the tract and abomasum should be elevated to the incision. Stay sutures should be placed in the abomasal wall 2 to 4 cm from either end of the tract to help maintain control of the abomasum. Noncrushing intestinal forceps can then often be placed across the abomasum at the base of the tract. Laparotomy sponges or sterile bath towels should be used to pack off adjacent tissues before resecting the tract and attached abomasal wall. The abomasal wall is then

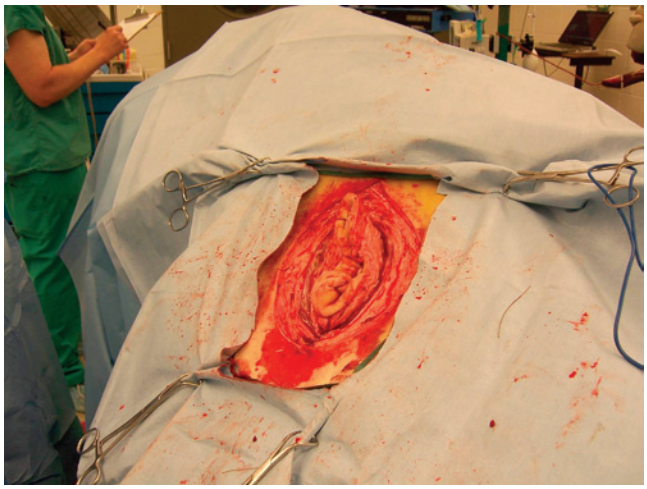


Figure 14-120 Initial incision on the abomasal fistula in Figures 14-118 and 14-119.

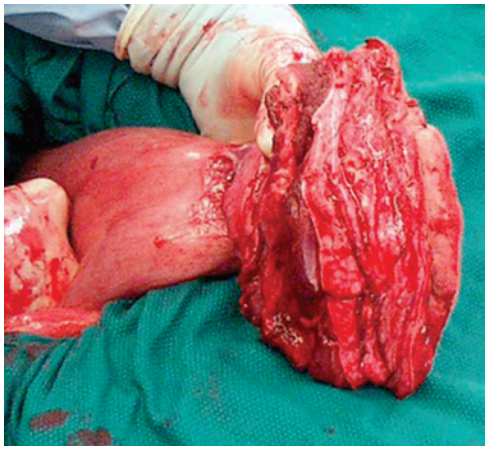


Figure 14-121 En bloc resection of an abomasal fistula and body wall.

sharply incised and the tract removed. The resulting defect in the abomasum should be closed in a simple continuous pattern followed by an inverting layer with an absorbable suture material such as polyglactin 910 or polyglycolic acid. Chromic gut has been used, but the absorption rate is less reliable because of the action of hydrochloric acid in the lumen of the abomasum and is not recommended.

Closure of the body wall can be difficult with the limited mobility of tissues, size of the defect, and loss of defined tissue layers around the fistula. The areas should be copiously lavaged, and surgeons should change gloves and instruments for closure. New, sterile drapes should be applied. Use of 18-gauge, stainless steel wire in a through-and-through vertical or horizontal mattress pattern provides the most secure closure under these circumstances (see Figure 14-118). The steel mattress sutures can be used as the sole means of closure or in conjunction with primary closure. Quills (rubber, buttons) can be used to help distribute tension from the steel sutures on the skin surface (Figure 14-122). In cases with defined tissue layers and reasonable tension, standard primary closure patterns have been used with good success. However, the through-and-through pattern has been recommended in cases with significant wound contamination to facilitate drainage.

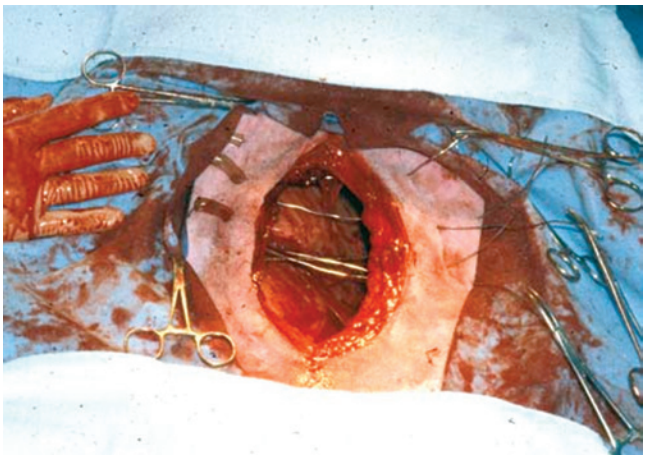


Figure 14-122 After en bloc resection of an abomasal fistula and body wall resection, closure is done by preplacing stainless steel sutures in a vertical mattress using plastic tubing to distribute the tension on the skin underneath the steel sutures.

Postoperative antibiotics are recommended to treat cellulitis associated with fistula development, and analgesics are advised to relieve discomfort and speed return to feed. Supportive therapy, including fluids and calcium, may be indicated for a period of time after surgery as well. Nonsteroidal antiinflammatory agents are recommended for 2 to 3 days after surgery to ease discomfort and encourage eating but should not be continued indefinitely because of their potentially ulcerogenic effect on abomasal mucosa. If through-and-through steel sutures were used, they are loosened periodically as the body wall granulates closed. The incision should be cleaned daily.

Prognosis and Complications

In a report on nine adult cows with abomasal fistula secondary to right-paramedian abomasopexy (6), blind tack (2), and unknown cause (1), one cow was euthanized at surgery because of extensive peritonitis and pyloric involvement, one cow was euthanized 8 days after surgery because of peritonitis secondary to abomasal rupture, and seven were discharged. Three subsequently died or were culled for apparently unrelated reasons 8 to 12 months after discharge, and the rest were productive members of the milking herd.

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SMALL-INTESTINE SURGERY IN CATTLE

Rolfe M. Radcliffe
(The editors and the author would like to acknowledge the contribution of the previous authors, Drs. Susan L. Fubini and Ava M. Trent.)

ANATOMY

The small intestine of the cow measures from 27 to 49 meters. The cranial part of the duodenum runs dorsally from the pylorus toward the liver, where it takes an S-shaped turn and adheres tightly to the visceral surface at the hepatoduodenal ligament. It continues dorsocaudally to the right-paralumbar fossa as the descending duodenum suspended from the dorsal body wall by the mesoduodenum. The fused superficial and deep walls of the greater omentum attach to its ventral surface. The descending duodenum is usually seen upon entry into the abdomen when a right-paralumbar fossa celiotomy is performed in an adult dairy cow, interposed between the mesoduodenum dorsally and the greater omentum ventrally. At the level of the fifth and sixth lumbar vertebrae, the duodenum turns around the caudal edge of the greater omentum at the caudal duodenal flexure and continues cranially to the left of the mesenteric root as the ascending duodenum. The ascending duodenum terminates as it passes to the right side cranial to the mesenteric root at the duodenojejunal flexure. The duodenocolic fold attaches the duodenum to the descending colon at the duodenojejunal flexure.

The jejunum is 26 to 48 meters long and is tightly coiled at the edge of the sheetlike mesentery that suspends it. The mesentery of the most proximal jejunum is short, which makes it impossible to exteriorize this portion of the bowel from the abdominal cavity. The mesentery lengthens at the more distal segments of the jejunum and ileum. The distal jejunum and proximal ileum are suspended by a narrow, mobile portion of the mesentery, which has been termed the *distal flange*. The majority of the small intestine is contained within the supraomental recess, a region between the deep leaf of the greater omentum and the dorsal body wall on the right side of the abdomen. The distal flange may extend caudally beyond the recess.

The ileum consists of proximal coiled and distal straight segments that form the terminal portion of the small intestine. The ileocecal fold runs from the ileum to the cecum. For purposes of relevant surgical anatomy, the combined jejunum and ileum has been called the *jejunoileum*. The ileum enters the large intestine obliquely on its ventral surface at the ileocolic junction. In the adult cow, this junction is obscured by fat.

The cranial mesenteric artery and its branches provide the blood supply to the entire small intestine. Proximal branches of this major vessel include the pancreatic branches, caudal pancreaticoduodenal artery, middle colic artery, and ileocolic artery. In the cow, a large collateral branch leaves the cranial mesenteric artery, crosses the right side of the spiral colon, and rejoins the cranial mesenteric artery distally. This vessel is not present in small ruminants. The continuation of the cranial mesenteric artery supplies jejunal arteries that form a series of anastomosing arches. Branches from the cranial mesenteric artery supply the proximal part of the ileum and anastomose with the mesenteric ileal branch of the ileocolic artery. The extent of the ileum may be estimated by the presence of an antimesenteric artery, from the ileocolic artery, that courses in the ileocecal fold. In the cow the mesenteric lymph nodes are located in the mesojejunum between the jejunum and the last centrifugal coil of the spiral colon. In contrast, the mesenteric lymph nodes of small ruminants are located between the first centripetal and last centrifugal coils of the spiral colon.

SURGICAL APPROACH

The decision for surgical access and patient positioning regarding intestinal surgery in cattle is important. Standing surgery is well tolerated in adult cattle under local analgesia techniques, and much of the gastrointestinal tract can be either examined or palpated for the determination of a diagnosis. In addition, many gastrointestinal diseases may be treated with surgery in the standing animal, and the location of the flank incision may be modified to improve access to the desired location. However, because mesenteric pain arising from excessive tension on the mesentery during manipulation leads to movement and risk of the animal lying

down, surgery on poorly exteriorized structures, such as the small intestine, is often challenging in standing cattle. Therefore we recommend performing intestinal resections, or other procedures where mesenteric tension is considered likely, on recumbent cattle. Further, based upon our experience, we suggest that adult bulls are more sensitive to small-intestinal mesenteric manipulation while standing compared with cows. General anesthesia is preferred in valuable cattle to minimize the risk of aspiration pneumonia and ingesta contamination of the abdomen during surgery; however, recumbent surgery under sedation and local anesthesia is also possible. The animal's head should be kept low. Exploration of the bovine gastrointestinal tract is most commonly performed via a right paralumbar fossa laparotomy, as this approach provides access to the small and large intestines, duodenum, cecum, liver, and kidneys. The left-paralumbar fossa laparotomy allows evaluation and access to the rumen and uterus, but limited availability to other parts of the gastrointestinal tract, whereas ventral approaches are most commonly reserved for surgery of the umbilicus, bladder, and abomasum in cattle.

SMALL-INTESTINAL ACCIDENTS

Obstructive lesions of the small intestine are an uncommon cause of abdominal problems in cattle. Similar to the horse, obstructive diseases of the bovine small-intestinal tract may be divided into two general categories: nonstrangulating (simple and functional) and strangulating. Functional causes of intestinal obstruction are most common and include various causes of ileus often associated with inflammation or infection. Nonstrangulating simple obstructions are less common and usually caused by a trichobezoar, phytobezoar, or enterolith. Obstruction of the small intestine by a trichobezoar in 15 cattle was reported to be more common in younger animals, and surgical treatment was recommended. In many instances, it is difficult to distinguish a true obstruction from a functional disorder such as indigestion or enteritis, making a differential diagnosis challenging. Strangulating lesions of the small intestine include intussusception and volvulus, and although relatively uncommon, they still occur regularly.

The cause of small-intestinal accidents is not always apparent. Intussusception has been associated with viral enteritis, alteration of diet, and a nidus such as a small polyp or nodule that causes aberrant intestinal motility. Torsion of the mesenteric root has been reported rarely after casting and rolling cows for surgery, uterine torsion correction, or rolling required to position animals during imaging procedures.

Severe abdominal pain is apparent when a strangulating intestinal obstruction is present. This results from tension on the mesentery and bowel distention proximal to the lesion. If the strangulated tissue becomes nonviable, the pain may become less intense for a period of time if left untreated. A localized peritonitis develops; fluid and protein are lost into the abdominal cavity, and eventually the animal deteriorates rapidly as more generalized sepsis ensues. Endotoxemia, shock, and a metabolic acidosis typically develop as the animal's condition deteriorates.

The most common location of small-intestinal obstruction in the adult cow is the distal jejunum and ileum, which results in ileus and sequestration of fluids in the upper gastrointestinal tract. This fluid trapping along with decreased water intake results in dehydration. Because transit of abomasal fluid rich in hydrochloric acid is impeded, hypochloremic metabolic alkalosis is usually present. Hypokalemia results from the lack of dietary intake of potassium-rich foods and extracellular fluid shifts. Calves may also present with obstructive lesions of the small intestine, as well as other parts of the gastrointestinal tract. Depending on a calf's age, the electrolyte derangements may be less pronounced than an adult's.

Clinical Signs

A characteristic sign of cattle with obstructive small-intestinal diseases is abdominal pain manifested by treading and stretching out (Figure 14-123). They may kick at the ventral abdomen and become recumbent if pain is severe (Figure 14-124). Affected animals are depressed and anorexic, with decreased rumen contractions and a precipitous drop in milk production. The heart rate is usually elevated associated with pain and hypovolemia. Fever is atypical unless generalized peritonitis occurs, and the respiratory rate is usually normal unless the abdominal distention is severe.

As the disease progresses, fluid accumulates in the bowel proximal to the obstruction and cattle develop abdominal distention, usually low and bilateral. Succussion of the abdomen yields a fluid wave. Small areas of tympanitic resonance may result from gas accumulation in bowel proximal to the obstruction. Manure becomes scant or absent. In some cases melena is passed, presumably from sloughing of devitalized intestine mixed with mucus and fecal material (Figure 14-125).



Figure 14-123 Abdominal pain manifested by stretching and treading in a cow with a small-intestine obstruction.



Figure 14-124 Abdominal pain characterized by kicking at the abdomen in a cow with an intussusception.

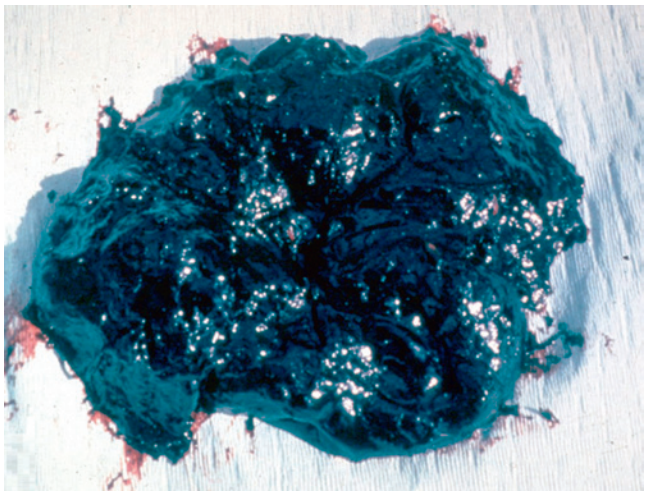


Figure 14-125 Blackberry jam–like feces typical of a cow with a small-intestine strangulating obstruction.



Figure 14-126 Abdominal fluid collected using an 18-gauge, 3.81-cm needle.

Abdominal-fluid analysis may be helpful in determining whether an inflammatory process is present. Fluid can be obtained from an avascular portion of the abdomen (ventral abdominal vessels should be avoided), either close to the midline or paramedian in front of the udder (Figure 14-126). Normal peritoneal fluid in cattle is similar to horses: clear and light yellow with <5000 nucleated cells/μL and total protein <2.6 g/dL. Elevations in total protein (>2.5 g/dL) and cell count (>10,000 cell/μL) are indicative of inflammation. Large volumes of abdominal fluid usually indicate a grave prognosis associated with diffuse peritonitis, even though nucleated cell counts may remain within the normal range. Cloudy, serosanguinous, or foul-smelling fluid should alert the clinician to possible ischemia or other intestinal accident and is likely associated with a poor prognosis. However, it may be challenging to obtain fluid with localized peritonitis because of loculation by fibrin. In addition, similar to horses, the comparison of plasma and peritoneal L-lactate concentrations may be useful to predict the need for surgery and intestinal resection. Although not studied in cattle, peritoneal-fluid lactate concentrations may be twice or more than that of plasma concentrations with intestinal strangulation in horses. Plasma L-lactate alone has been used preoperatively to predict the outcome of cattle having surgery for right-abomasal displacement or volvulus, with values ≥2 mmol/L and ≥6 mmol/L associated with a positive versus negative outcome, respectively.



Figure 14-127 A transabdominal ultrasound image of a calf with a 5-MHz probe. Note the multiple loops of thickened small intestines filled with a mixture of fluid and gas. This image represents small intestines orad to a small-intestinal obstruction.

Ultrasound and rectal examination can be very helpful in identifying fluid pockets in the abdomen, distended viscera, and in some cases, the actual cause of the obstruction (Figure 14-127). For example, it may be possible to image or palpate the coiled loops of involved intestine with intussusceptions, and fibrin surrounding the lesion may be detectable at later stages of the disease.

Ultrasound is especially useful in small calves when a rectal examination is not possible. Calves with small-intestinal obstruction behave similarly to cattle, although the signs of colic and abdominal distention may be subtler. Enteritis is common in calves and can be very difficult to distinguish from other obstructive diseases. Signs of abdominal pain, scant or absent manure, progression of signs, and ultrasound findings of bowel distention are reasons to consider surgical exploration.

Functional and Non-strangulating Obstruction

Functional obstruction is usually secondary to motility dysfunction often associated with enteritis, whereas nonstrangulating lesions result from many disorders. The duodenum is most commonly affected, and obstruction may result from duodenitis, ulcers, electrolyte disturbances, stricture, foreign bodies, obstruction by displacement of viscera, obstruction associated with omento- or pyloropexy, and extraluminal compression by abscessation or neoplasia. Obstruction of the ileum has also been reported in cows, possibly associated with the seasonal ingestion of coarse, poor-quality hay forage. Although uncommon, nonstrangulating small-intestinal obstruction in calves is usually associated with intraluminal obstruction with hair, feed, or enterolith formation. Such foreign bodies often form in the rumen or abomasum and obstruct the small intestine or spiral colon during transit through the intestinal tract. Providing essential roughage in the diet and appropriate lice parasite control may help prevent ingestion of hair and secondary intestinal obstruction.

DUODENAL OUTFLOW OBSTRUCTION

Sporadic cases of duodenal outflow obstruction caused by inflammation of the duodenum that results from ulcers,

penetrating foreign bodies, intraluminal or extraluminal masses, or adhesions in the vicinity of the sigmoid flexure have been reported. In 1980, Van der Velden from Utrecht described a syndrome of functional duodenal outflow obstruction, which he hypothesized resulted from a disturbance in normal retrograde motility patterns that originate at the sigmoid flexure. Van der Velden subsequently reported 18 cases in 1983. A condition of duodenal sigmoid flexure volvulus causing outflow obstruction has also been reported in dairy cattle and usually responds to manual reduction at surgery.

Reports of spontaneous obstructions and those with identified lesions have a number of similarities. Cases have been reported predominantly in female dairy breeds from 1 to 8 years of age. Common clinical signs in both groups include anorexia, decreased milk and fecal production, tachycardia, variable degrees of depression, and decreased ruminal contractions. Other signs present in some cattle include abdominal distention, colic, scant feces, and ruminal distention. In contrast to the occasional right-ventral abdominal distention found with right-sided abomasal volvulus, cows with duodenal outflow obstructions tend to have bilateral ventral abdominal distention. Cattle with identified duodenal lesions all had marked fluid and electrolyte disturbances, including dehydration, hyponatremia, hypokalemia, hypochloremia, hyperphosphatemia, hyperglycemia, hyperproteinemia, metabolic alkalosis, and elevated anion gap. Electrolyte disturbances were comparable to—or more severe than—values reported for cows with abomasal volvulus; however, the anion gap was attributed to accumulation of a different set of anions in the two conditions. Protein and phosphate increases were considered to account for most of the anion gap in cows with duodenal obstruction as opposed to increases in sulfates and organic acid anions resulting from tissue necrosis and anaerobic metabolism in abomasal volvulus. Van der Velden's report included less complete information on fluid and electrolyte disturbances, but the available information is consistent with that reported by Garry with additional information on base excess (10 to 32 mmol/L), serum chloride (45 to 90 mmol/L), and elevated rumen chloride concentrations (up to 75 mmol/L).

A definitive diagnosis requires exploration from the right side, preferably a standing right-flank exploratory. The characteristic sign of this condition is distention of the cranial portion of the duodenum with a flaccid descending duodenum. The abomasum may also be dilated and dorsally displaced. The initial cases of spontaneous duodenal obstruction were actually diagnosed as RDA and treated by omentopexy without success. Careful palpation of the area of the sigmoid flexure may reveal a specific lesion that can account for the outflow obstruction. However, the normal ligamentous thickening in this area supports the fragile pancreatic and biliary ducts that should not be misinterpreted as an adhesion.

Treatment/Prognosis/Complications

Treatment involves removal of any identified obstructing lesions (adhesions, masses), or if the lesion cannot be removed or identified, a duodenal bypass around the site of obstruction needs to be done. The cranial part of the duodenum is anastamosed to the descending duodenum usually in a side-to-side manner. Supportive fluid and/or antibiotic therapy are usually indicated based on the cause of obstruction and the status of the patient.

Although this syndrome appears to be uncommon and bears many similarities to an RDA, definitive treatment for a functional or mechanical duodenal obstruction should be considered if, on initial exploration for an RDA, abomasal dilation/displacement without volvulus and proximal duodenal distention extends to but not beyond the sigmoid flexure. Reexploration with definitive treatment is also a legitimate consideration if a cow with the signs mentioned has been treated by omentopexy, and fluid and electrolyte disturbances have progressed during the first 2 days after surgery.

STRANGULATING OBSTRUCTION

Intussusception

Intussusception is the invagination of a portion of intestine (intussusceptum) into the lumen of the adjacent bowel (the intussuscipiens). This action drags the mesentery and associated blood vessels of the intussusceptum into the neighboring bowel, creating an intestinal obstruction. Eventually, the affected bowel becomes nonviable because of its compromised blood supply and peritonitis results. Untreated cattle usually die 5 to 8 days after the onset of clinical signs.

Intussusception in cattle may result from problems that alter normal intestinal peristalsis including enteritis, intestinal parasitism, mural granuloma, abscess or hematoma, neoplasia, sudden diet changes, and medications affecting gastrointestinal motility. Overeating on lush pasture has been suggested as another cause for abnormal motility and development of intussusception.

In a review of 336 cases of intussusception from 17 veterinary medical teaching hospitals between March 1, 1964, and December 31, 1990, no sex or seasonal predilection for developing intussusception was documented. However, an increased prevalence in Brown Swiss cattle relative to Holsteins was found and a decreased risk existed for Hereford cattle. The most common locations of intussusception were the small intestine (84%), colocolic (11%), and ileocolic (2%). Calves 1 to 2 months of age were at greater risk for developing intussusception, and animals with intussusceptions distal to the ileum were more likely to be calves. It has been suggested that more fat in the mesentery and a prominent ileocecal ligament may stabilize the bowel and prevent intestinal invagination in adult cattle. The length and mobility of the jejunal mesenteric attachments, especially the distal third, may be why the majority of cattle have jejunojejunal or jejunoileal intussusceptions.

Cattle with intussusception usually exhibit low mild to moderate abdominal pain, manifested by treading, stretching out, and kicking at the abdomen. Animals are often anorectic, lethargic, reluctant to walk, or recumbent. The heart rate is elevated in proportion to the degree of abdominal pain, intestinal damage, and dehydration. Fecal material that contains mucus or melena is scant and may eventually be absent all together. A pronounced fluid wave upon succussion of the right side of the abdomen and low bilateral abdominal distention are typical, except for cattle with proximal intussusception. Cattle show no interest in feed, stop cleaning their noses, and eventually become dehydrated and metabolically deranged. Rectal and ultrasound examination may reveal a distended proximal small intestine, and the intussusception may be discerned in some instances. The lesion is almost never reducible. Single intussusceptions are most common, although a double intussusception has been described. A few reports of cattle surviving after sloughing an intussusception exist, but this is rare.

Affected cattle should be stabilized with appropriate fluid therapy, nonsteroidal antiinflammatory drugs, and calcium solutions preoperatively. Broad-spectrum perioperative antimicrobials are indicated. An epidural should be given before a standing procedure if the cow is straining. Epidural anesthesia is discussed in the anesthesia chapter, but a low dose should be used so that the cow does not suffer

from any hind-limb weakness, especially if standing surgery is elected.

A right-paralumbar fossa celiotomy provides the best exposure to the intestinal tract distal to the pylorus. It is possible to perform an exploratory celiotomy and resection and anastomosis in a standing cow, but a more complete, thorough procedure can be done with a recumbent or anesthetized animal. Unfortunately, this requires more people and specialized facilities. Some clinicians advocate starting with a standing celiotomy. If the lesion is too extensive or complicated, or exposure is inadequate, the incision can be temporarily closed and the cow anesthetized or sedated in left lateral recumbency before continuing the procedure. In lateral recumbency, the incision will extend farther ventrally so the right lower flank needs to be prepared. It is always a quandary whether to attempt an exploration standing. A standing approach may be more appropriate when the nature of the problem is known. If a complete exploration is necessary, it is more easily accomplished in the anesthetized (preferably) or sedated recumbent animal. Calves should be explored in lateral recumbency under sedation with a local anesthetic or general anesthesia (Figure 14-128).

The abdominal incision should be located halfway between the tuber coxae and the last rib but may be adjusted in the cranial or caudal direction depending on the suspected location of the problem. In a standing cow, the incision should not be carried too far ventrally because of the risk of viscera prolapsing out of the abdomen. If the cow is recumbent or anesthetized, a more ventral incision can be made so the majority of the intestinal mass can be exteriorized and inspected.

The surgeon should explore the abdomen in situ while palpating for any obvious bowel distention, tight bands, adhesions, or mass lesions. A complete exploration of the abdominal cavity is indicated, as distended bowel is often displaced and may even be wedged into the pelvic inlet. Distended bowel should be handled gently, cupping the hands during suspension, using careful manipulations to prevent injury or rupture. The color and quantity of peritoneal fluid should be noted. To access the caudal abdomen, the omental sling is pulled forward and the apex of the cecum, usually in the pelvic inlet, is identified and exteriorized. The cecum is rotated 90 degrees outside of the abdomen, bringing the ileum into view. The ileum can be followed to the distal flange of the intestine, which can be rocked out of the abdomen. In a standing cow, the rest of the small intestine is palpated within the abdomen and any abnormal section brought to the incision if possible. In the recumbent cow, the majority of the small intestine and cecum can be delivered and evaluated. Bowel proximal to the obstruction is usually distended, whereas bowel distal to the lesion is empty. An intussusception usually presents as tightly coiled loops of firm, distended intestine (Figure 14-129). The lesion is typically nonreducible, and attempts to manipulate the bowel are contraindicated because it may be friable and rupture is a risk. The vasculature should be ligated close to the affected bowel to avoid impinging on the blood supply of adjacent bowel. In edematous mesentery, it can be difficult to visualize the individual mesenteric vessels. Much of the dissection can be done bluntly with a gauze sponge gently separating the fat to see the vasculature. Besides individual vessel ligation, large overlapping simple interrupted sutures or the use of electrosurgical vessel sealing instruments (for example, LigaSure, Covidien, Mansfield, MA) may be used to occlude the vasculature before resection and anastomosis (Figure 14-130). The authors prefer the use of electrosurgical vessel transection and have had excellent results in cattle, despite an often thick, fat-laden mesentery. The use of a vessel-sealing device provides secure hemostasis and, compared with vessel ligation with suture, reduces bleeding during the intestinal resection, minimizes the amount of suture left within the abdomen, and decreases surgical time. Before the resection, a Penrose drain is placed proximal and distal to the diseased bowel to minimize spillage of intestinal contents. The area should be isolated from the rest of the abdomen with moist, sterile towels or laparotomy pads.

A one- or two-layer end-to-end anastomosis is usually performed, although some surgeons prefer a side-to-side anastomosis. In the horse, a one-layer small-intestinal

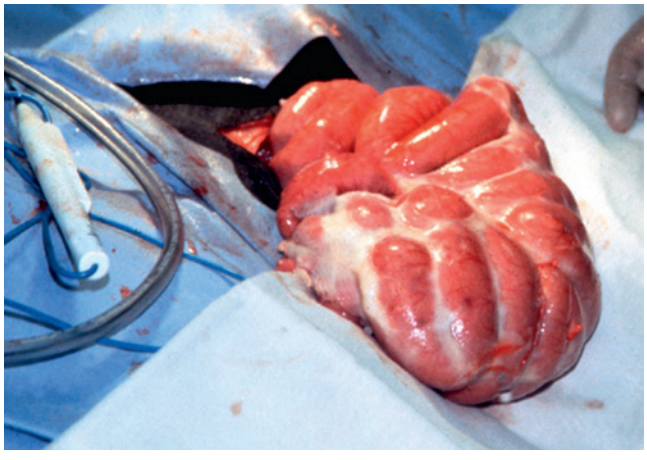


Figure 14-128 A severe fibrinous peritonitis in a calf explored from a right-paralumbar fossa celiotomy.



Figure 14-129 This is a jejunal intussusception in an adult cow exteriorized through a right-paralumbar fossa celiotomy. Note the coiled loops typical of an intussusception. (From Rebhun WC: *Diseases of dairy cattle*, Philadelphia, 1995, Williams & Wilkins.)



Figure 14-130 Example of a vessel-sealing instrument (LigaSure, Covidien, Mansfield, MA) used for vessel ligation during a small-intestinal resection and anastomosis in cattle.

anastomosis using an inverting suture pattern such as the Lembert is preferred over two-layer closures because it reduces surgery time and the amount of suture material and maximizes lumen diameter and provides a strong, leak-free seal. The authors have also used this type of closure in cattle for small-intestinal anastomosis with excellent results. Although an interrupted or continuous Lembert pattern may be used, the authors prefer a continuous pattern, interrupted at the mesenteric and antimesenteric borders to prevent a purse-string effect. To improve visualization and allow easier closure near the mesenteric attachments, each side of the anastomosis closure begins at the mesentery working toward the antimesenteric surface. Rotating the ends of the bowel to offset the mesenteric regions when performing an end-to-end anastomosis has been suggested in the literature. This is because cattle have a large serosal-free area at the mesenteric attachment to the small intestine and the rotation provides at least one serosal-covered surface for the entire anastomotic circumference, thus allowing subsequent fibrin deposition and healing. A 2-0 absorbable suture on a taper needle is an appropriate choice for small-intestinal anastomosis in adult cattle. A 3-0 suture size should be used in young calves, with fragile small intestine. After the anastomosis, the mesenteric defect is closed using 2-0 absorbable suture, the site rinsed copiously with sterile fluids, and the bowel replaced into the abdomen. Replacing the distended intestine back into the abdomen can be difficult, especially in the recumbent cow. It is helpful to decompress the rumen with gas suction and to gently replace handfuls of small intestine starting proximally and working distally. Following contaminated procedures including resection and anastomosis, surgeons should change gloves and instruments before closure of the abdominal incisional. Closure of the abdomen is routine.

Passing large amounts of liquid manure within 24 hours after surgery is a good sign because it signifies a patent intestinal tract. Manure should return to normal over the next 3 to 4 days. Reports of small numbers of cattle doing well after surgery have been made; however, Constable's report with a larger number of cattle may be more realistic. He found a postoperative survival rate of 43% and an overall survival rate of 35%. Reasons for such a poor outcome are multifactorial including duration of illness before admission, peritonitis present at the time of surgery, postoperative ileus, and/or extensive amounts of devitalized small intestine.



Figure 14-131 Volvulus of the distal jejunum and ileum in a cow explored under general anesthesia from the right-paralumbar fossa. The cecum is empty; the distal small intestine is compromised; and the proximal small intestine is dilated proximal to the obstruction.

INTESTINAL VOLVULUS

Segmental Small-Intestinal Volvulus

Twisting of a segment of intestine upon itself, thereby creating an obstruction and strangulation of the blood supply, is referred to by many as a *volvulus of the intestine* and *torsion of the mesentery*. The cause of the twist is unknown but may be secondary to ileus. Because of the long mesentery of the distal jejunum and ileum—the so-called *distal flange*—these sections of intestine are more mobile and prone to volvulus. All ages can be affected. Abdominal pain is apparent with signs similar to—but generally more severe than—those of cattle with intussusception. Abdominal distention develops as the proximal intestine fills with gas and fluid. Feces are passed initially, then become scant, and finally absent or mucoid. Rectal and ultrasound examinations usually show distended small intestine often wedged in the pelvic inlet. Cows become tachycardic and dehydrated. Initially a hypochloremic metabolic alkalosis is typical, but as the disease progresses bowel may become nonviable and a metabolic acidosis results.

Treatment

Cattle should be hydrated and prepared for surgery. Perioperative antibiotics and nonsteroidal antiinflammatory drugs are indicated. A right-paralumbar fossa celiotomy is performed as described previously. Affected animals are painful enough that they may be reluctant to stand, thus making left-lateral recumbency desirable. However, the final decision for standing versus down surgery will depend on the surgeon's preference, available facilities, and the temperament of the animal. Upon the surgeon's entry into the abdomen, the nature of the abdominal fluid is noted and an in situ palpation is performed by feeling for any tight bands or mass lesions. The proximal intestine usually is greatly distended with fluid and gas. The twisted bowel feels turgid and, if its location is distal, the intestine may be wedged up in the pelvic inlet. With the animal in lateral recumbency, exteriorizing the majority of the small intestine, correcting any displacement, and checking its orientation are possible (Figure 14-131). In the standing animal, the bowel is gently untwisted as it is delivered to the incision. A line of demarcation between noninvolved and involved bowel confirms the diagnosis. The surgeon should be able to tent the mesentery and sweep it up to the root of the mesentery and it should

feel straight. Usually the intestinal color and contractility will improve within 5 minutes of correcting a volvulus.

There are very few reported methods to determine intestinal viability in cattle, and often these techniques are not practical. It is important not to condemn the bowel without first considering whether the fluid sequestered within the thin-walled, dilated intestine is dark and blood tinged. This fluid can make the intestine look very dark and congested (Figure 14-132). The surgeon should push the fluid away from the wall of the intestine and evaluate the color. Because of the convoluted loops of small intestine, it is not practical to perform an enterotomy and milk out intestinal contents so that the small intestine is less distended. The bowel is too friable, and its coiled nature makes moving fluid and ingesta difficult. Replacing the distended intestine back into the abdomen may also prove extremely difficult. The rumen should be decompressed and the bowel kept moist. It is replaced in handfuls from proximal to distal with a gentle rocking motion.

The prognosis depends on the duration of the obstruction and the viability of the intestine. A resection and anastomosis can be performed if indicated, but it lengthens the surgery time and makes the procedure more complicated. Furthermore, the amount of bowel involved with small intestinal volvulus often precludes a resection. During resection and anastomosis for segmental volvulus, it is easy to contaminate the site because the proximal intestine is usually greatly distended with fluid and gas. Nonsteroidal antiinflammatory drugs are indicated to interrupt the arachidonic cascade in an attempt to reduce inflammation, block the effects of endotoxin, and decrease adhesion formation.

TORSION OF THE MESENTERIC ROOT

Volvulus of the entire small-intestinal tract is a dramatic illness because so much of the bowel is involved. Only part of the duodenum and dorsal colon is spared. Affected animals experience profound pain. They may actually throw themselves on the ground, get up, and go down again. Bilateral abdominal distention becomes apparent, and cows are tachycardic and tachypneic. Tight bands can be palpated per rectum. Distended viscera can be palpated rectally or imaged via ultrasound.

Treatment

Prompt surgical intervention is essential. Perioperative fluids, antibiotics, and analgesics are indicated. Because of extensive intestinal involvement, affected adult cattle rapidly deteriorate and die. A liberal right-paralumbar fossa celiotomy is made, and any gas in the viscera is decompressed. By following the mesenteric root, the twist may be identified and corrected. Some surgeons perform this procedure standing, whereas others (including the author) prefer lateral recumbency. Untwisting such a massive intestinal mass can predispose the intestine to absorb large amounts of endotoxin and death may ensue. The rapid progression of signs makes the prognosis for adult cattle grave. A few calves have been saved in our hospital when astute owners recognized the early signs of abdominal discomfort as well as one adult cow that suffered a massive volvulus following an imaging procedure.

Miscellaneous Causes of Small-Intestinal Obstruction

Incarceration, Entrapment

Sporadic reports of the small intestine becoming entrapped in adhesions, embryonic remnants, or mesenteric rents have been made. Some specific examples include the following:

1. Internal herniation through the greater omentum into the omental bursa
2. Herniation through mesenteric rents in the mesoduodenum or mesojejunum
3. Persistent vitelloumbilical band coursing from the ileum to the umbilicus
4. Persistent round ligament of the liver running from the liver to the umbilicus (Figure 14-133)
5. Persistent urachal remnant traveling from the urinary bladder to the umbilicus
6. Paraovarian bands located between the ovary or broad ligament and the omentum. Remnants of the ductus deferens in steers
7. Incarceration of small intestine in the epiploic foramen in calves

The small intestine can either become wrapped around one of these bands or entrapped within a loop. The bowel becomes obstructed, and the band can compromise the blood supply at the site of the incarceration.

Clinical signs are similar to those of cows with intussusception with moderate signs of abdominal pain. It may be



Figure 14-132 Small-intestinal volvulus in a cow under general anesthesia with a right-paralumbar fossa celiotomy. Note the dark fluid within the lumen of the bowel.

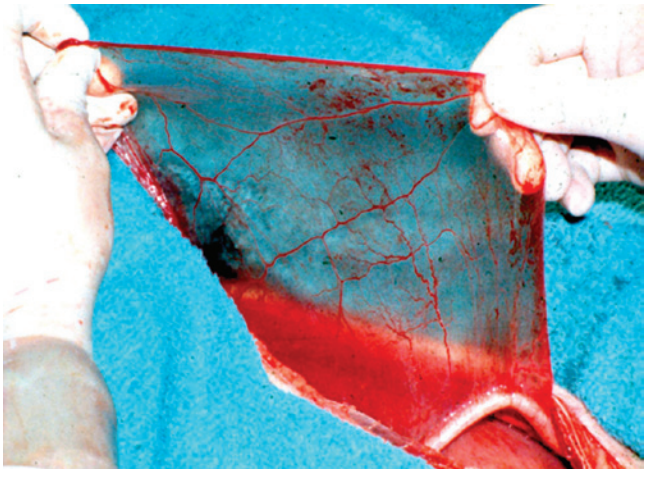


Figure 14-133 This is an incidental finding of a persistent round ligament on a right-paramedian approach. Small intestine has been reported to twist around such bands.

possible to palpate a taut band per rectum. As with other small-intestinal obstructions, a right-paralumbar fossa celiotomy is performed and the abdomen is explored. The band is palpated and, if possible, exteriorized. If it cannot be visualized, the band may have to be transected blindly using scissors. The bowel that was entrapped should be examined to determine whether an area of ischemia was created that might necessitate a resection and anastomosis.

The small bowel can become entrapped in a mesenteric rent, either spontaneously or secondary to intestinal surgery in which the mesentery was not closed properly. In some cases, the mesenteric defect may need to be enlarged before replacing the bowel in a normal position and closing the defect. Three cows were reported to have proximal jejunum entrapped in a mesenteric rent, possibly associated with trauma during parturition. The strangulating lesions were inaccessible from a standing right paralumbar fossa celiotomy, and none of the cows survived.

JEJUNAL HEMORRHAGE SYNDROME

Jejunal hemorrhage syndrome (JHS) or *hemorrhagic bowel syndrome* has been recognized as an emerging and highly fatal intestinal disease of adult dairy cattle. The condition usually presents in early lactation during the first 3 to 4 months postpartum. Descriptions of this disease vary from acute death with no premonitory signs to animals that show visible signs of colic shortly before death. At necropsy, the major finding consistent within these animals has been severe hemorrhage of the jejunum. Most often, this is seen as an intraluminal blood clot, but some cases have been reported with subserosal hemorrhage (Figure 14-134). If the animal lives long enough for observation, clinical signs include vocalization, diaphoresis, bruxism, enophthalmia, tachycardia, pale mucous membranes, and small-bowel distention. Eventually shock, recumbency, and death ensue.

The prognosis for survival of cattle affected with JHS is poor, with the case fatality rate reported to exceed 85%. However, early diagnosis and immediate intervention may allow survival of some animals. A recent study comparing outcome of JHS following surgery reported higher survival rates of 58% to discharge and 42% at 12 months. In most instances, medical therapy with a blood transfusion, fluid therapy, antiinflammatory and analgesic medications, and antimicrobials are essential. In addition, early surgical intervention may help relieve the small-intestinal obstruction and allow for the removal of damaged intestine. Surgical options include manual clot dissolution, enterotomy for removal of intraluminal blood clots, and resection and anastomosis of affected intestine. A poor surgical outcome is often associated with multiple segments of affected intestine, septic peritonitis, or bowel rupture during intestinal manipulation. Manual clot breakdown is recommended over more aggressive enterotomy or resection/anastomosis techniques to prevent secondary complications including adhesions and peritonitis. A recent study comparing surgical outcome with JHS reported that manual massage compared with enterotomy or enterectomy was associated with higher short-term survival. Increased long-term survival was associated with early referral within 24 to 48 hours after onset of clinical signs. Cattle having involvement of multiple segments of intestine are challenging patients, and these animals likely have a worse prognosis for survival, even though length of obstructing clots was not associated with outcome in one study. Recurrence of JHS has also been reported, most likely within the first 12 months following surgery.

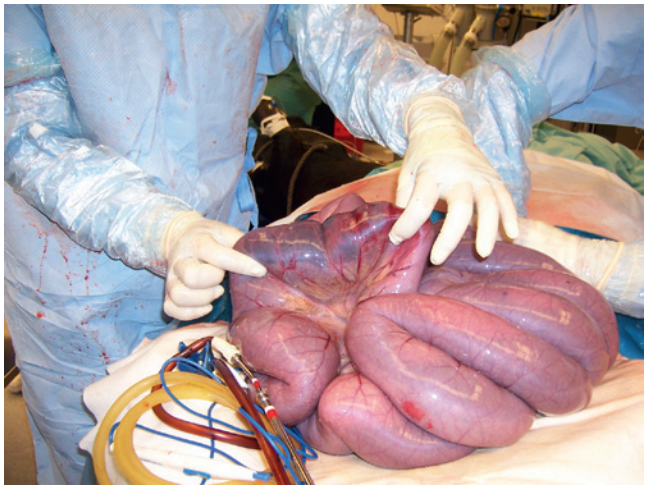


Figure 14-134 Small intestine delivered though a right-paralumbar fossa celiotomy with a cow under general anesthesia. Note the section of intraluminal hemorrhage typical of jejunal hemorrhage syndrome. The surgeons were able to massage the blood clot and reestablish patency of the bowel. (Courtesy of Dr. Ashlee Watts.)

Although the definitive cause of JHS is currently unknown, the only reliable finding seems to be the presence of *Clostridium perfringens* Type A at the site of the jejunal lesion. Several reports have proposed C. *perfringens* Type A as the causative organism of this disease; however, this is quite controversial because the bacterial growth could be a primary insult to the intestine or secondary to other factors. In addition, a role for the fungus *Aspergillus fumigatus* has also been suggested. Regardless of the specific etiology, JHS is considered a multifactorial disease with many risk factors including feeding silage, a total mixed ration or finely ground corn, high production, early lactation, and free-choice feeding. A combination of these factors likely allows for the overgrowth of C. *perfringens* Type A bacteria or other organisms in the gastrointestinal tract, and a high-energy, low-fiber ration is crucial for initiating the disease.

Interestingly, this disease can present as a herd problem. One study surveyed dairy practitioners in Iowa, Minnesota, and Wisconsin and found that risk factors included advanced age and early lactation. The syndrome was reported more frequently in herds that milked more than 100 cows and were fed a total mixed ration. This was only one study, and it could involve biases such as large herds being more likely to perform necropsy examinations. More information regarding this disease should become available in the future.

Fat Necrosis

It is rare—but possible—for fat necrosis or lipomatosis to encroach on the intestinal lumen, especially in older overconditioned animals. Affected cattle have a very insidious onset of disease with decreased amounts of loose manure, abdominal distention, and mild colic. It may be possible to palpate hard intraabdominal masses rectally or image them with ultrasound. In valuable animals, an exploratory celiotomy or ultrasound-guided biopsy may be indicated. The prognosis is grave, although resecting or bypassing the affected bowel may be possible in some instances.

Neoplasia

Another cause of extraluminal intestinal obstruction is neoplasia. The most common tumors found in cattle include adenocarcinoma and lymphosarcoma. In rare instances, it may be able to resect or bypass a localized neoplasm. Lymphosarcoma has a predilection for the pylorus, but it can occur at other locations. Signs are vague as with fat necrosis.

The prognosis is grave. Surgical resection in most cases is impractical.

Spontaneous Rupture of the Small Intestine

Dr. John King (Professor Emeritus of Pathology at Cornell University) has observed spontaneous rupture of jejunal segments at postmortem, which he postulated might be secondary to entrapment between the uterus and body wall during parturition.

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SURGERY OF THE CECUM

Adrian Steiner

ANATOMY

The cecum is a large, mobile tube with a blind apex directed caudally. Cranially, the cecum is continuous with the proximal loop of the ascending colon (PLAC), through the cecocolic orifice, no valve separates these two segments of the large intestine (Figure 14-135). The ileocolic junction

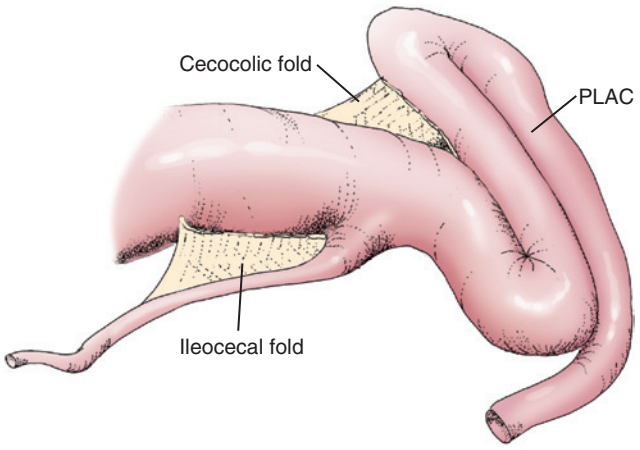


Figure 14-135 Diagrammatic representation of the normal anatomy of the ileum, cecum, and proximal loop of the ascending colon (PLAC). The ileocecal and cecocolic folds are labeled.

represents the division between the cecum caudally and the colon cranially. The main part of the cecum is situated within the supraomental recess whereas the free cecal apex is directed toward the pelvic cavity. The cecum is attached dorsally to the PLAC by the short cecocolic fold and ventrally to the ileum by the ileocecal fold (see Figure 14-135). The PLAC extends cranially from the cecum to the level of the 11th rib and then doubles back to the level of the caudal flexure of the duodenum. There it turns from to the left, continues cranially, and returns to the right side, just caudal to the root of the mesentery where it is continuous with the centripetal loop of the spiral colon. The ileocolic artery with its three colic branches is responsible for the blood supply of the ileocecocolic area. The ileocolic artery supplies the ileum, cecum, proximal loop of the colon, the spiral colon, and the distal loop of the colon. The right colic artery supplies the centrifugal loops of the spiral colon and the distal loop of the colon. Colic branches supply the centripetal loops of the spiral colon and the proximal loop of the colon. The ileocolic artery continues in the ileocecal fold, giving off the mesenteric ileal artery, and continues as the cecal artery. The cecal artery supplies the cecum and gives off an antimesenteric ileal artery that travels in the ileocecal fold to the antimesenteric surface of the ileum. The arteries are accompanied by sympathetic and parasympathetic autonomic innervation, whereas satellite veins accompany each artery and serve as tributaries to the cranial mesenteric vein that contributes to the formation of the hepatic portal vein. Muscarinic receptor subtypes M(1), M(3), and M(5); alpha and beta adrenergic receptors; 5-hydroxytryptamine receptor subtypes 5-HT1, 5-HT2, and 5-HT4; and interstitial cells of Cajal are present in the wall of the ileum, cecum, PLAC, and colon. They are likely to play a relevant role in the regulation of the motility of the ileocecocolic (ICC) area.

PHYSIOLOGY

In cattle, the cecum and colon are the main sites for microbial digestion besides the reticulorumen. In the cecum and colon of the cow, 11.6% to 17% of the total dietary cellulose, 2% to 11% of the total starch, and 20% of the soluble carbohydrates are digested. Cecocolic fermentation accounts for 8.6% to 16.8% of total volatile fatty acid (VFA) production in sheep. The efficiency of the large intestine for VFA production is similar to that of the rumen. Principal end products of microbial carbohydrate fermentation in the hindgut are acetate, propionate, and butyrate, which are found up to 99% in the dissociated form because the pH of large-intestinal contents is usually considerably higher than pKa values of the individual VFA. VFA are absorbed through the cecal epithelium. Absorption takes place by passive diffusion of the undissociated ions through the cell membrane, whereas the anions are absorbed at a considerably slower rate by diffusion through hydrophilic pores. The absorption of VFA from the cecum of sheep is about twice as high at pH 6.2 (equilibrium shift toward undissociated ions) as at pH 7.7 (equilibrium shift toward anions). The cow is able to partially compensate for the removal of the cecum, including the ICC junction. In a study of five steers, digestibility of dry matter and cellulose returned to preoperative values within 16 weeks after cecal amputation. Consistency of feces, however, did not return to preoperative firmness, thus illustrating the importance of this segment of the gut for water resorption.

CECAL DILATION/DISLOCATION

Etiopathogenesis

Hypocalcemia and/or an inhibitory effect of elevated VFA concentrations in the cecum on cecal motility has been reported. Diets excessively rich in rumen-resistant starch have therefore been implicated in the development of spontaneous cecal dilation and dislocation (CDD), as a consequence of increased carbohydrate fermentation in the large intestine. In a controlled study on VFA concentrations in the large intestine of cows, dissociated and undissociated VFA were elevated in the contents of cecum, PLAC, and rectum of cows with CDD compared with healthy control cows. However, whether this elevation of VFA was the cause or the consequence of reduced motility and stasis of digesta remained unclear. In a subsequent study, contractility of ex vivo intestinal wall specimens from the cecum and spiral colon of healthy cows was found not to be affected by preincubation with butyric and valerianic acid.

In an individual case, a colon-associated cystic mass occurred in conjunction with CDD in a Holstein cow and was thought to impair intestinal function. Myoelectric activity patterns similar to that observed orad to an intestinal obstruction were recorded from the cecum and PLAC of cows with delayed recovery or recurrence after surgical correction of spontaneous CDD. Hence, it was hypothesized that some motility disturbance of the spiral colon rather than the cecum itself might be implicated in the development of spontaneous CDD. Physiologic myoelectric motility patterns of the spiral colon were described in detail. In healthy control cows, already at day 1 after typhlotomy, physiologic myoelectric activity was recorded in all intestinal segments. At day 1 after surgery for spontaneous CDD, however, normal myoelectric activity was evident in the ileum, but myoelectric activity patterns in the cecum, PLAC, and spiral colon were disrupted to a variable degree with only slow normalization over time. After an abrupt increase of starch-rich concentrates in diet from hay to a ration of 50% hay and 50% starch-rich concentrates within 60 hours, pH values decreased and VFA concentrations increased significantly in the colon of healthy experimental dairy cows. Significant changes in patterns of myoelectric activity of the spiral colon, however, were restricted to phases III and IV of the bovine migrating myoelectric complex and to propagation velocity. The classical hypothesis that an abrupt increase of the concentration of VFA might be responsible for atony of the cecum and spontaneous occurrence of CDD was not

supported by the aforementioned recent findings. Etiology and pathogenesis of spontaneous CDD are still unknown.

Epidemiological Factors

In an epidemiologic study realized in Switzerland, similar prevalences of CDD and abomasal displacement (DA) were found. Breed predilection for occurrence of CDD does not exist, but there is an increased risk for the development of CDD during the production phase until the end of lactation and in cows without supplementation of stock salt and/or minerals. The latter is supported by a recent finding that 296 of 348 (85.1%) cows with spontaneous CDD had hypocalcemia.

Classification of Cecal Dilation/Dislocation

Cecal *dilation* is distention of the cecum without a twist. The cecal apex is directed caudad and positioned in front of or within the pelvic cavity. Rotation along its long axis is called cecal *torsion* (Figure 14-136) and rotation in the area of the ICC junction or the PLAC—when viewed from the right side of the cow—is termed *clockwise* or *counterclockwise twist* or *volvulus*. The author prefers the terms *dorsal retroflexion* (retroflexio ad dorsam) and *ventral retroflexion* (retroflexio ad ventram) to better define the previously used terms *clockwise* and *counterclockwise twist/volvulus*, respectively (Figure 14-137). The degree of rotation in cases of retroflexion may vary from 90 degrees to more than 360 degrees. The term *dislocation* can refer to any twist, torsion, volvulus, or retroflexion. In a retrospective case series over 11 years, preoperative diagnosis based on rectal palpation revealed cecal *dilation* in 291 cases (71.9%), cecal *dilation* and *retroflexion* in 94 cases (23.2%), and cecal *dilation* and *torsion* in 20 cases (4.9%).

Symptoms and Diagnosis

Symptoms of simple cecal *dilation* are not specific. They include a drop in milk yield, reduced appetite and amount of feces, and occasionally discrete signs of colic. Ruminal motility and small intestinal peristalsis are often reduced. The right-paralumbar fossa is distended (Figure 14-138); percussion (ping) and succussion auscultation in the right flank are positive in the majority of cases, extending from the tuber coxae to the last rib. The distended cecum is identified through rectal examination or by abdominal ultrasonography through the right flank with a 3.5-MHz linear transducer. The apex of the cecum reaches the pelvic cavity and can be palpated as a tense dome-shaped hollow organ with a smooth surface. In very rare cases, it can be difficult to tell a distended cecum from an enlarged RDA. The cecum usually has thinner walls than the abomasum and is oblong in shape. At ultrasonography of the right-paralumbar fossa, the dilated cecum closest to the abdominal wall appears as an echogenic semicircular line immediately adjacent to the peritoneum. A distended right-sided abomasum is a rounded structure located more cranially in the abdomen. Hematological and most serum biochemical parameters are usually within normal range, whereas calcium concentration is frequently decreased. These signs become more severe in case of retroflexion or torsion. In case of retroflexion, animals are anorectic and have more obvious signs of colic. Reduction of milk yield is more pronounced, heart rate is elevated, and atony of the rumen is common. Feces are absent or very sparse and of dry consistency covered with mucus. The area of the ping and the positive succussion auscultation is larger, extending further craniad than in a case of simple dilation. Upon rectal examination, the body—but not the apex—of the cecum can be palpated in the right upper quadrant as a

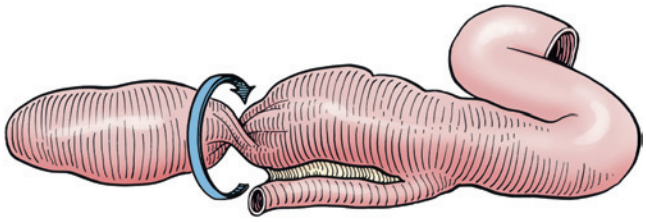


Figure 14-136 Schematic representation of cecal torsion. (Reprinted with permission from Fubini SL: Surgery of the bovine large intestine. In Bristol DG, editor: *Surgery of the bovine digestive tract, Vet Clin North America, Food Animal Practice,* Philadelphia, 1990, WB Saunders.)

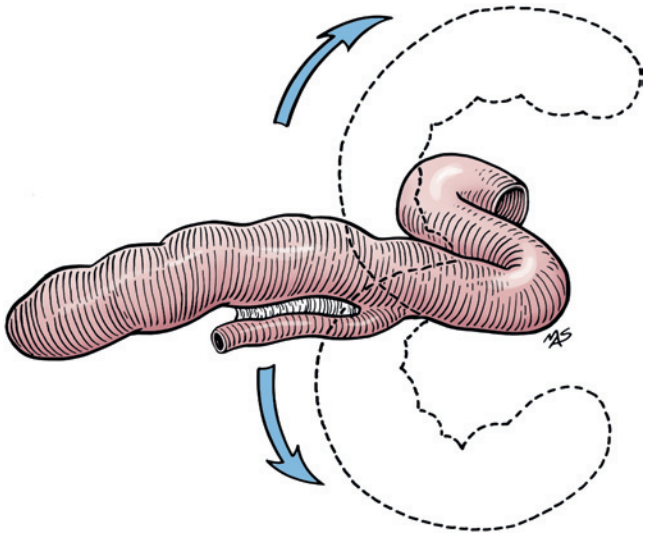


Figure 14-137 Schematic representation of cecal dislocation or volvulus. Dorsal retroflexion (retroflexio ad dorsam) and ventral retroflexion (retroflexio ad ventram) of the cecum may occur. (Reprinted with permission from Fubini SL: Surgery of the bovine large intestine. In Bristol DG, editor: *Surgery of the bovine digestive tract, Vet Clin North America, Food Animal Practice,* Philadelphia, 1990, WB Saunders.)

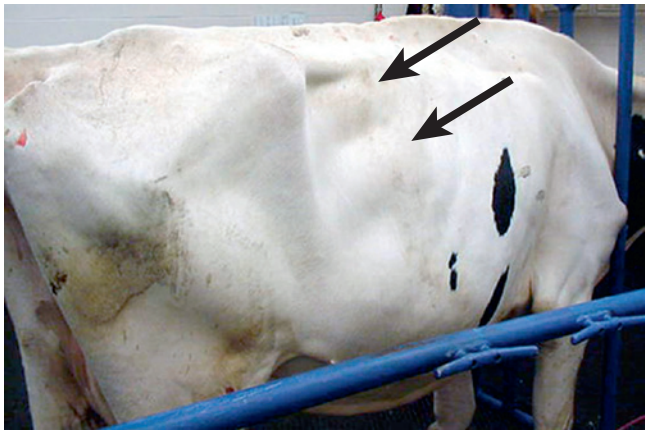


Figure 14-138 Mature white Holstein-Friesian cow with cecal dislocation. The distended cecum has resulted in two outlines of distended viscera (*arrows*) in the right-paralumbar fossa. (Courtesy of Dr. Gillian Perkins.)

tense tubular hollow organ with a diameter of about 15 to 20 cm. Biochemical analysis of blood may rarely reveal a hypochloremic, hypokalemic metabolic alkalosis caused by stasis or even reflux of intestinal contents.

Torsion of the cecum occurs less often than retroflexion, but symptoms are similar. Cecal torsion can be diagnosed through rectal examination. The cecal apex is directed caudad, and the tense ICC ligament, which may have pain elicited upon palpation, is identified as a tense structure that spirals around the cecum.

Therapy and Prognosis

Medical therapy is indicated if the general condition of the animal is normal or only slightly disturbed, defecation is still present, and rectal examination does not reveal any torsion or retroflexion. If the prerequisites for medical therapy are not fulfilled, or medical treatment is revealed as unsuccessful within 24 hours after initiation, typhlotomy is indicated. Cecal amputation is indicated only in cases of CDD recurrence or devitalization of the cecal wall.

Medical treatment consists of intravenous fluid administration supplemented with potassium chloride as needed, purgatives, and nonsteroidal antiinflammatory drugs as needed. For motility modulation, bethanechol may be administered subcutaneously at 0.07 mg/kg body weight tid for 2 days or neostigmine (42.5 mg/cow) in 5 L sodium chloride/glucose solution as an intravenous drip infusion. Alternatively, some authors have reported beneficial effects from oral administration of one pound of instant coffee. Supplementary medication may include correction of calcium deficiency (initial supplementation with 500 mL of a 40% calcium borogluconate solution with 6% magnesium hypophosphite) and treatment of ketosis. Feed is completely withheld for at least 24 hours, and small amounts of hay are then gradually offered, provided defecation is present and CDD has resolved. In a recent retrospective study, 122 of 461 cattle (26.5%) with spontaneous CDD fulfilled the criteria for medical treatment, 42 of which needed surgical treatment 1 to 2 days after initiation of medical treatment because of deterioration of the general condition, and 80 cattle were discharged healthy from the clinic without any surgical intervention (17.3%). If recovery does not become evident within 24 hours after initiation of medical treatment, surgical intervention is recommended.

TYPHLOTOMY

Surgery is performed through a right-flank approach, preferably in the standing animal under local anesthesia. The abdomen is opened through a 25-cm incision that starts dorsally about 8 cm below the lateral processes of the lumbar vertebrae and 8 cm cranial to the tuber coxae, extending slightly oblique in a cranioventral direction parallel to the internal oblique abdominal muscle. The abdomen is then thoroughly explored, and the cecum, PLAC, and spiral colon positions identified (Figure 14-139). Decompression of any large gas-filled viscus may make more room for manipulations and decrease the possibility of intestinal rupture. If the cecum is simply dilated, the apex is found in or in front of the pelvic cavity, directed caudally. In case of (dorsal or ventral) retroflexion of 180 degrees, the apex of the cecum is directed craniad and in case of torsion the apex is directed caudad. Manipulation of the ICC ligament is painful and reveals spiraling around the cecum along its longitudinal axis.

Dislocations are carefully corrected intraabdominally. The cecum and as much of the PLAC as possible are exteriorized (Figure 14-140) by gently pushing with the palm(s) of one or both hands from the inside toward the outside of the abdomen to reduce the risk of rupture and/or perforation of the distended bowel. If the bowel is compromised or severely distended it may be appropriate to perform a typhlotomy before any attempt is made to untwist the dislocation. The apex of the cecum is isolated from the rest of the abdomen and a typhlotomy is performed at the most ventral location (Figure 14-141). Digesta are first passively drained from the extraabdominal part of the cecum and then gently milked from the intraabdominal part of the cecum and the PLAC to the incision site. The exteriorized cecum is rinsed with copious amounts of prewarmed 0.9% saline solution, and the incision site closed with a simple inverting continuous or an inverting seromuscular suture pattern (that is, Cushing or Lembert) with size 3-0 or 2-0 monofilament absorbable suture material. The exteriorized sections are again copiously rinsed and placed back into their physiologic position within the supraomental recess. The cecum is

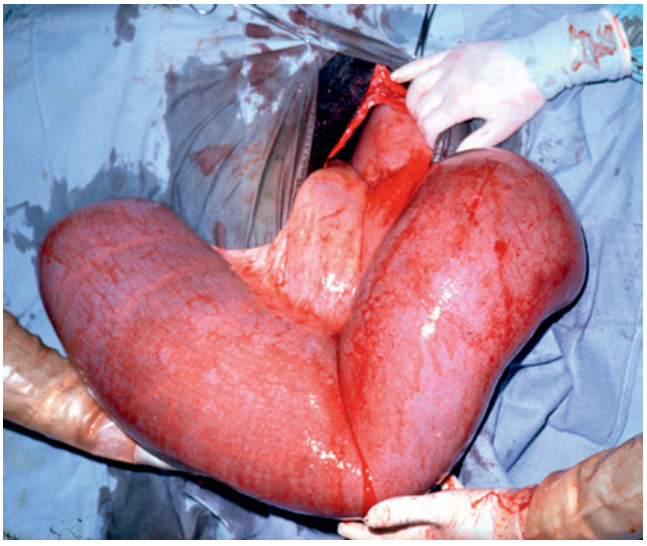


Figure 14-139 Cecal dilation exteriorized through a right-paralumbar fossa celiotomy.



Figure 14-140 Cow under general anesthesia in left-lateral recumbency. Intraoperative view of the dilated cecum and proximal ascending colon in a case of spontaneous cecal dilation/dislocation exteriorized through a right-paralumbar fossa celiotomy.

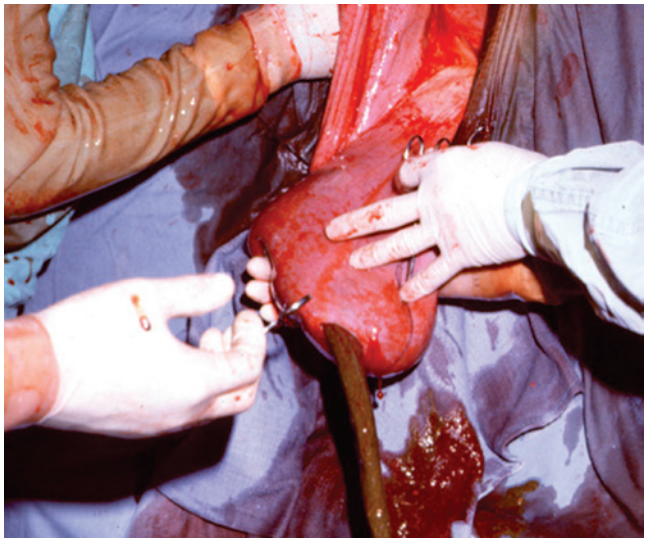


Figure 14-141 Typhlotomy performed from a right-paralumbar fossa celiotomy.

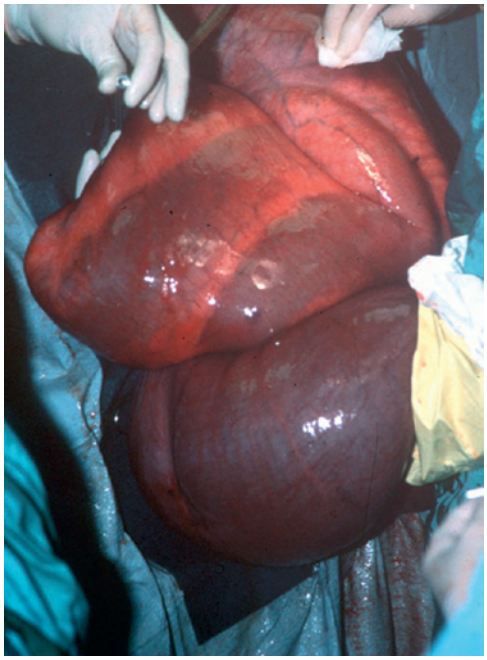


Figure 14-142 Right-paralumbar fossa celiotomy showing the spiral loops of the ascending colon located abaxially and dorsal to the cecum. This indicates that correct anatomic positioning has not yet been achieved.

evaluated again 10 minutes later, and if it has refilled, a second typhlotomy is done to relieve the cecum and PLAC of digesta that may have accumulated within these segments by propulsion from the ileum or reflux from the spiral colon. The typhlotomy site is finally oversewn twice (one layer should be in an inverting pattern). At this point, the orientation of the distal flange of small intestine and the spiral loop of the ascending colon should be checked for correct anatomic positioning. The spiral loop of the ascending colon should be axial to the cecum and PLAC (Figure 14-142). Closure of the abdominal wall is performed in a routine manner.

Postoperatively, bethanechol (0.07 mg/kg body weight, subcutaneous, tid for 2 days or neostigmine (42.5 mg/cow) in 5 L sodium chloride/glucose solution as an intravenous drip infusion) may be administered to help restore intestinal motility. Antimicrobials (for example, sodium penicillin, 30,000 IU/kg body weight IV) are administered perioperatively. If contamination is severe, prolonged administration of a broad-spectrum antimicrobial for 3 to 5 days may be indicated. If necessary, intravenous or oral rehydration to correct electrolyte imbalances and calcium deficiency and to treat ketosis should be performed. Operated cows are put on a restricted diet for 24 to 48 hours. The restricted diet is followed by a medium coarse-forage ration of increasing quantity to finally reach the normal ration within 5 to 7 days. Manure is usually very loose initially and becomes more formed over time. Recovery (i.e., restoration of appetite and gastrointestinal motility) may be expected within 2 to 5 days after the surgical intervention.

Possible complications after typhlotomy include septic peritonitis as a result of severe intraoperative contamination or suture-line leakage and persistent motility disorder of the large intestine leading to short-term recurrence of CDD. In the latter case, cows should be reoperated on, and cecal amputation leaving the ileocecal junction intact should be performed. Overall, long-term recurrence rates after typhlotomy have been reported to range from 10% to 22.5%. A recurrence rate of 12.9% (48 of 371 cattle) within 2 to 29 days (median, 2.5 days) after initial surgery was recently described. Although recurrence is theoretically impossible after cecal amputation, this procedure is not recommended during the initial surgical intervention because the long-term success rate is not significantly different from that after typhlotomy alone. In a retrospective study with 80 cows treated surgically for CDD within a period of 19 months, short-term (release from the clinical) survival rate was 91%. With a mean of 11 months after surgery, 67.5% of cows were still productive members of their herds. Anecdotal reports describe dilation of the cecal stump after amputation anywhere from 3 months to 1 year after typhlectomy distal to the ileocecal junction. In these cows, recurrence was treated by resection of the remaining cecal stump.

CECAL INTUSSUSCEPTIONS

Because cecal intussusception is primarily a disease of calves, it is described in detail in Chapter 17.

AMPUTATION OF THE CECUM

In case of recurrence of CDD or devitalization of the cecal wall, cecal amputation immediately distal to the ICC junction is recommended. This procedure may be performed in the standing animal after local analgesia of the right flank. The cecum is evacuated as described before, and the ICC ligament is anesthetized by infiltration of 30 mL of a 2% lidocaine solution, injected near the ICC junction to block the cecal nerve. The cecal branches of the cecal artery and vein are ligated close to the attachment of the ICC ligament to the cecum to preserve blood supply to the ileum. Ligature of the blood vessels may be accomplished either by direct visualization after blunt dissection of the overlying fat or by blind mass ligatures of the ligament. The ICC ligament is transected. Two intestinal clamps—one from the mesenteric and one from the antimesenteric side—are placed a few centimeters aboral to the intended site of amputation, just proximal to the ICC junction. The cecum is transected and the cecal stump closed with two

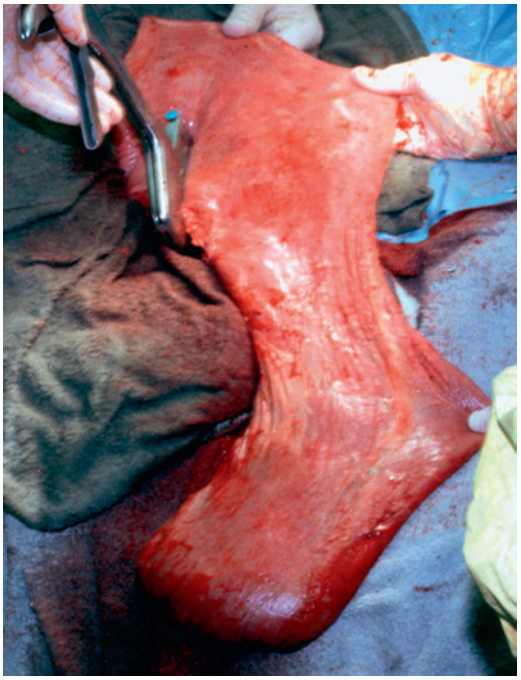


Figure 14-143 Resection of the apex of the cecum for recurrence of cecal dilation and dislocation. The cow is under general anesthesia in left-lateral recumbency. Autosuture equipment (the TA-90) is being used to place a double row of staples across the lumen of the cecum. A second application of the stapling instrument would be necessary before transection of the cecum.

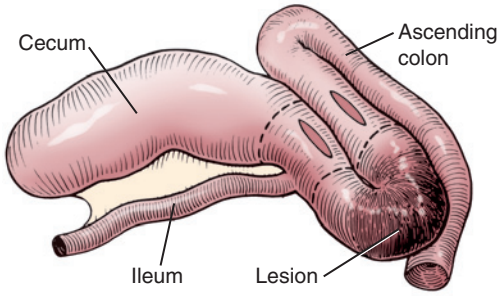


Figure 14-144 Resection of the apex of the cecum and the devitalized bowel located at the first turn of the proximal loop of the ascending colon. A side-to-side anastomosis is done to reestablish intestinal continuity. (Reprinted with permission from Fubini SL: Surgery of the bovine large intestine. In Bristol DG, editors: *Surgery of the bovine digestive tract, Vet Clin North America, Food Animal Practice*, Philadelphia, 1990, WB Saunders.)

continuous inverting seromuscular suture patterns (i.e., Cushing or Lembert) with size 2-0 or 3-0 resorbable (calves) suture material. Alternatively, the stump may be closed by using a stapling instrument[11] and two linear 90-mm cartridges. The staple lines overlap in the center of the stump (Figure 14-143).

If retroflexion has been present for a prolonged period of time and/or the degree of rotation exceeds 270 degrees, vascular compromise and concurrent hemorrhagic strangulating obstruction of the PLAC may occur. This condition requires partial resection of the PLAC, followed by side-to-side anastomosis. The ICC junction is left intact (Figure 14-144). This procedure is technically difficult and is preferably performed under general anesthesia with the cow positioned in left-lateral recumbency to minimize contamination and facilitate manipulation of the intestinal segments being operated. Aftercare is according to that described for typhlotomy.

A complete typhlectomy with ileocolic anastomosis has been reported as a surgical treatment for severe cecal dislocation with devitalization of the entire cecum (Maala, 1983). This is a difficult, long procedure in most instances and should be done under general anesthesia. The entire cecum is resected and an end-to-side or side-to-side anastomosis performed as shown in Figure 14-145.

Cattle successfully treated for CDD have a significantly higher rectal temperature, have a significantly lower heart rate, and show less often a ruminal atony at the initial examination, compared with cattle in which treatment is not successful.

[11]GIA stapler, Covidien, Boulder, CO, USA.

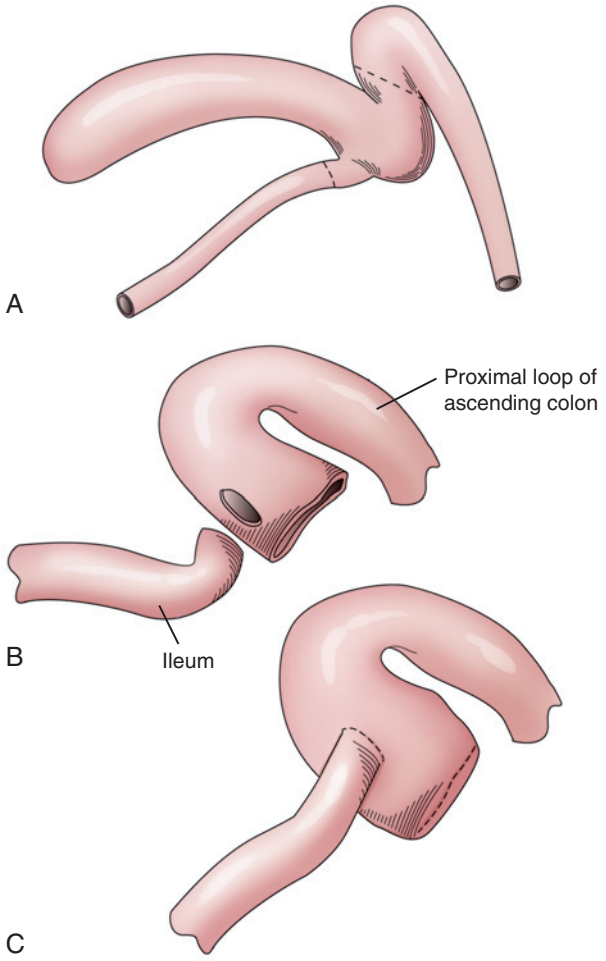


Figure 14-145 *A*, Line diagram of complete cecal resection. The lines of transection on the ilium and proximal loop of the ascending colon are indicated by the dotted line. *B*, Preparation for an end-to-side anastomosis between the ileum and the ascending colon. *C*, Completed anastomosis.

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SURGERY OF THE COLON

Adrian Steiner

ANATOMY

In cattle, the colon consists of the ascending, transverse, and descending parts. The ascending colon is divided into three sections: proximal loop, spiral colon, and distal loop (Figure 14-146). The proximal loop of the ascending colon (PLAC) continues from the cecum on the lateral side of the mesenteric root and terminates in the spiral colon on the medial side. The spiral colon in cattle consists of two centripetal coils, a central flexure, and two centrifugal coils. The distal loop of the ascending colon represents the communication between the spiral and transverse colon. The short transverse colon is situated cranial to the cranial mesenteric artery and passes from right to left. The descending colon courses in a caudal direction and at the level of the pelvic inlet is continuous with the longer peritoneal and shorter retroperitoneal part of the rectum. The rectum terminates at the level of the anus, which is surrounded by internal and external anal sphincter muscles that are responsible for closing the anus. The fat-filled mesentery in adult cattle is theorized to maintain the relationship of the large intestine's various segments, thus minimizing the occurrence of intussusception in this region. In contrast, the calves' mesenteric fat is usually minimal, which may allow increased mobility of the colon, explaining why intussusception of the cecum and colon is nearly exclusively seen in calves, not in adult cattle.

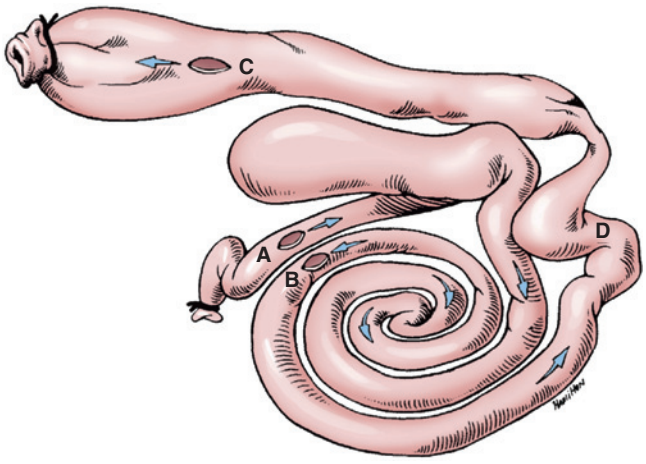


Figure 14-146 Schematic representation of normal anatomy of three parts of the ascending colon (proximal, spiral, and distal [D]), transverse colon, descending colon, and rectum. *Arrows* show the flow of ingesta. The cecum has been elevated dorsally to allow a better view of the spiral colon. If extensive adhesions existed in the outermost loop of the spiral colon, the ileum (A) or the spiral colon (B) can be anastomosed to the descending colon (C). (Reprinted with modifications by permission from Smith DF, Donawick WJ: Obstruction of the ascending colon in cattle: 1, clinical presentation and surgical management, *Vet Surg* 8:93-97, 1979.)

PHYSIOLOGY

Three major functions of the colon are the following: 1) together with the cecum, it is the main site of microbial digestion besides the reticulorumen; 2) it is an important site of water absorption; and 3) it allows aborad transportation of digesta to the rectum. The rectal ampulla is able to store considerable amounts of intestinal contents before defecation. Motility of the spiral colon in healthy dairy cows was recently described in detail. Myoelectric activity of the spiral colon was closely associated with motility of the ileum and proximal colon, and it showed the typical phases and organization of migrating myoelectric complexes. The migrating myoelectric complex in the bovine spiral colon had a mean duration of 188.6 ± 30.8 minutes.

INTUSSUSCEPTION OF THE SPIRAL COLON

Intussusception of the spiral colon is rare but has been seen more commonly in calves than adult cattle. It may be that the fat in the mesentery of the adult intestinal tract prevents invagination of the bowel.

OBSTRUCTION OF THE SPIRAL COLON

Etiopathogenesis

Obstruction of the spiral colon is either a consequence of dysmotility, a sequela of cecal dilation/dislocation, or caused by lesions extrinsic to the bowel. Extraluminal constriction may be caused by fat necrosis; cystic mass; lymphosarcoma; hematoma from an expressed corpus luteum; or adhesions that resulted from perimetritis, traumatic reticuloperitonitis, perforating abomasal ulcer, intraperitoneal injection of irritating drugs, or previous intraabdominal surgery.

Clinical Signs and Diagnosis

Clinical signs occur gradually over several days or weeks and include reduced milk yield, appetite, and fecal output. Adhesions may be palpated at rectal examination and visualized by ultrasonographic examination through the right paralumbar fossa.

Surgical Management

Surgical correction is performed in the standing animal by a right-flank laparotomy. Because adhesions usually involve more than just one part of a spiral colon loop, resection and anastomosis rarely comprise a useful surgical option. The involved bowel is left in situ, and the obstruction is bypassed with a side-to-side anastomosis between the bowel proximal and distal to the obstruction. This can be between loops of spiral colon or between the ileum and outermost centrifugal loop of the spiral colon. If the latter is involved in the adhesion, a side-to-side anastomosis between the ileum and descending colon may be performed (see Figure 14-146). For side-to-side anastomosis, a side-to-side stainless steel stapling instrument[12] may be used after the two bowels to be

[12]GIA stapler, Covidien, Boulder, CO, USA.

anastomosed have been adapted with stay sutures, or the bowel can be sutured by hand.

Prognosis

Prognosis depends on the cause of the extraluminal obstruction. In one report, three of four cows with adhesions of the spiral colon that underwent this surgical procedure survived. Depending on the extent of the loss of absorptive function of the spiral colon, fecal consistency may not return to normal at all or not until after significant delay. In an experimental bypass procedure (side-to-side anastomosis of the ileum with the outermost centrifugal loop of the spiral colon) in four calves, fecal dry matter had not reached preoperative values by 4 weeks after surgery.

RECTAL PROLAPSE

Occurrence and Classification

Any breed, sex, or age can be affected; however, rectal prolapse occurs most commonly in feedlot cattle from 6 months to 2 years of age. In a Type I prolapse, only the rectal mucosa projects through the anus. A Type II prolapse is a complete prolapse of all layers of the rectum. In a Type III prolapse, a variable amount of descending colon intussuscepts into the rectum in addition to a Type II lesion. In a Type IV prolapse, variable lengths of the peritoneal rectum and/or descending colon form an intussusception through the anus. Types I and II are much more common than Types III and IV.

Pathogenesis and Predisposing Factors

Rectal prolapse generally results from an increase of the pressure gradient between the abdominal/pelvic cavity and the anus. In normal conditions, the sphincter effectively creates a barrier for the normal pressure gradient. Conditions that cause inadequate tone of the sphincter and/or a high pressure gradient can result in eversion of mucosa. Exposure of the mucosa to the environment further irritates the mucosa and may initiate a vicious cycle of straining until a complete prolapse of the rectum occurs. Short exposure causes damage to the superficial layer, which quickly resolves when the prolapsed tissue is replaced. Prolonged exposure results in progressively deeper involvement. Unreduced prolapses become edematous, hemorrhagic, and finally necrotic. Predisposing factors that contribute to rectal prolapse include increased abdominal pressure or fill, excessive coughing, colitis, cystitis, diarrhea, and tenesmus from dystocia.

Clinical Signs and Diagnosis

The usual presentation of a prolapse is a mucosal mass protruding beyond the anus with a variable amount of edema, inflammation, and necrosis (Figure 14-147). On manual palpation, Types I to III are continuous with the mucocutaneous junction of the anus, whereas Type IV represents a protrusion with a palpable trench inside the rectum.

Management

Generally, management of rectal prolapse includes elimination of predisposing factors, soothing of the irritated mucosa, elimination of straining, and resolving the prolapse. The condition of the prolapsed tissue plays the most important role in choosing the treatment method. The color of the membranes, degree of edema/hemorrhage, and presence and depth of erosions are the parameters used to decide whether the tissue is salvageable. In general, the rectum recovers from injury well, and attempts should be made to salvage the prolapsed tissue unless deep necrosis or trauma to the tissue exists. Caudal epidural anesthesia is performed first. This temporarily eliminates straining, allows evaluation of the tissue, facilitates repositioning, and allows surgical intervention, if necessary. The prolapsed tissue is cleaned with a mild antiseptic. The tissue is evaluated for necrosis, trauma, or tears. The treatment options include replacement and purse-string suture, submucosal resection, or amputation. For management of a Type IV prolapse, celiotomy, resection of the affected tissue, and end-to-end anastomosis would be indicated.



Figure 14-147 Type II rectal prolapse in a ewe. (Courtesy of Dr. Richard Hackett.)

Replacement and Purse-String Suture

This technique is indicated for treatment of salvageable rectal prolapses. After caudal epidural anesthesia is performed and the mucosa is cleaned, the edema is reduced by temporary topical application of a hyperosmotic solution, such as a sugar solution. Lidocaine jelly is applied, and the tissue is manipulated back into its normal position. A purse-string suture is applied to the perirectal tissue with 0.2- to 0.5-cm umbilical tape. The rectal opening is tightened to two to three fingers' width to prevent recurrence of the prolapse while allowing passage of fecal material. The umbilical tape is tied in a bow that is placed laterally and readily allows adjustment of the suture. Usually, the purse-string suture is removed within 1 week after placement to reduce fecal contamination and the severity of suture-tract infection. If straining recurs, the caudal epidural may need to be repeated. To prolong the anesthetic effect, epidural anesthesia with tramadol may be administered (5 hours' duration; reversible).

Submucosal Resection

Submucosal resection is the preferred technique if the prolapsed mucosa is necrotic, ulcerated, or traumatized but the underlying tissue is healthy. This technique includes removal of the affected mucosa and salvage of the healthy underlying tissue. After placing caudal epidural anesthesia and cleaning the mucosa, the edema is reduced by temporary topical application of a hyperosmotic solution, and a final preoperative evaluation is performed (Figure 14-148). A piece of

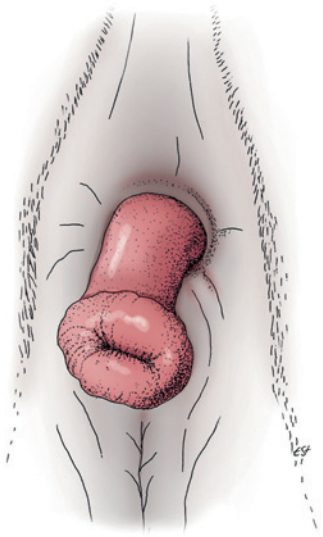


Figure 14-148 Schematic representation of a rectal prolapse Type II before submucosal resection.

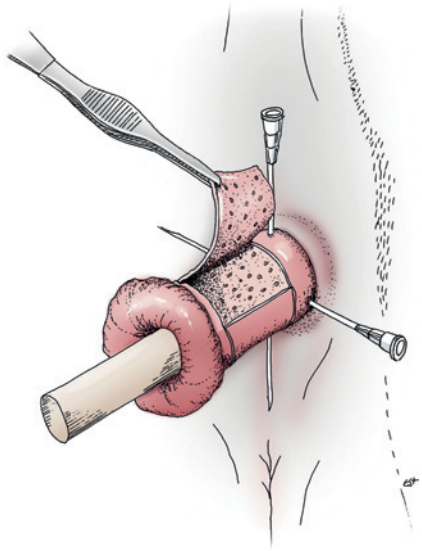


Figure 14-150 Blunt dissection of affected mucosal tissue in the healthy submucosal plane.

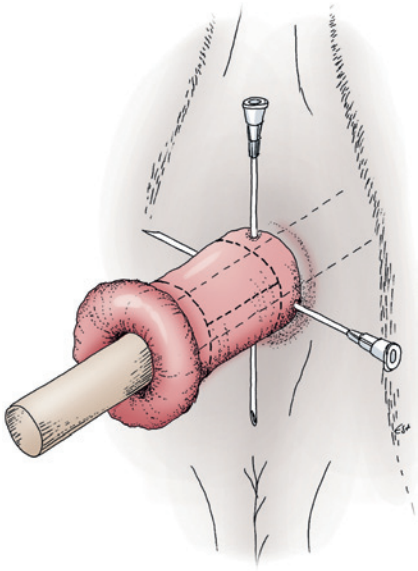


Figure 14-149 A piece of flexible tubing is inserted into the lumen of the prolapse, and cross-pin fixation is performed with two 18-gauge needles. The *dashed lines* represent the intended sites of mucosal incision.

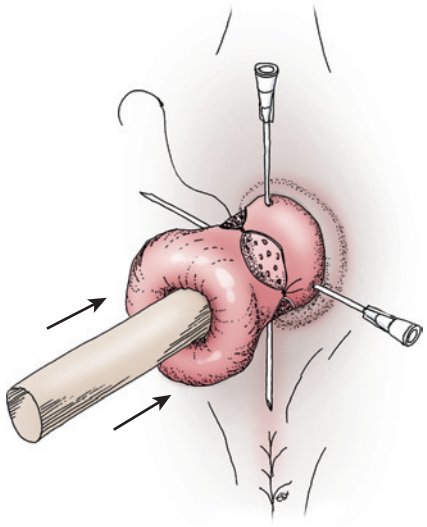


Figure 14-151 The mucosa is aligned with four simple interrupted sutures placed equidistant around the circumference of the prolapse.

flexible tubing of appropriate diameter is inserted into the lumen of the prolapse and cross-pin fixation performed to control movement of the prolapse during surgery. For this purpose, two 15-cm, 18-gauge needles are inserted at a 90-degree angle to each other, close to the anal opening across the prolapse and tubing, exiting at the opposite site (Figure 14-149). Two circumferential incisions are made through the mucosa on either side of the tissue to be removed. A longitudinal incision at the same depth is then made to connect the circumferential incisions. The collar of affected tissue is removed in the healthy submucosal plane by using blunt dissection (Figure 14-150). Hemorrhage may be controlled by ligature of individual vessels. The mucosa is aligned with four simple interrupted sutures that are placed equidistant around the circumference of the prolapse (Figure 14-151). The four quadrants are apposed separately with one simple continuous suture pattern for each quadrant (Figure 14-152). Size 2-0 to 3-0 monofilament absorbable material with a taper-point swaged needle is used. The specific type of suture pattern and tubing that acts as a place holder prevents the occurrence of a purse-string effect at the suture site that might decrease the lumen and provoke postoperative stricture formation. Several advantages of this technique in comparison to amputation have been described and include the following: not exposing the serosal lining minimizes the possibility of peritonitis or perirectal abscess formation; not transecting the main blood supply minimizes the danger of postoperative hemorrhage, less postoperative straining occurs, the lumen is only minimally constricted, healthy tissue is not sacrificed, and healing is faster.

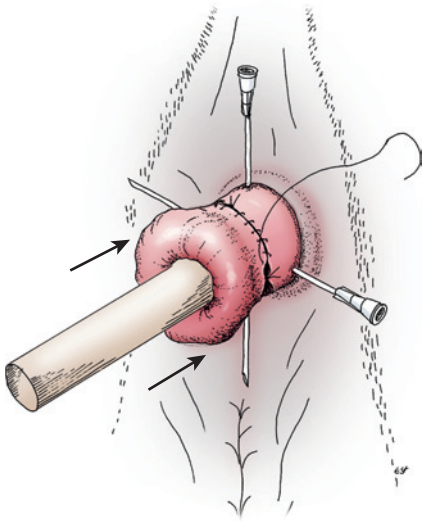


Figure 14-152 Final alignment of the mucosa with continuous sutures.

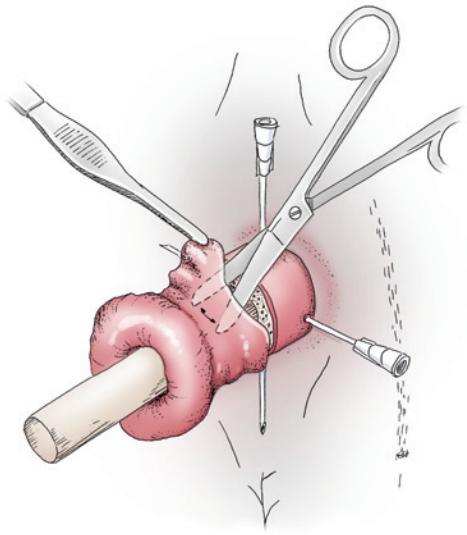


Figure 14-154 A plane is created toward the caudal aspect of the prolapse.

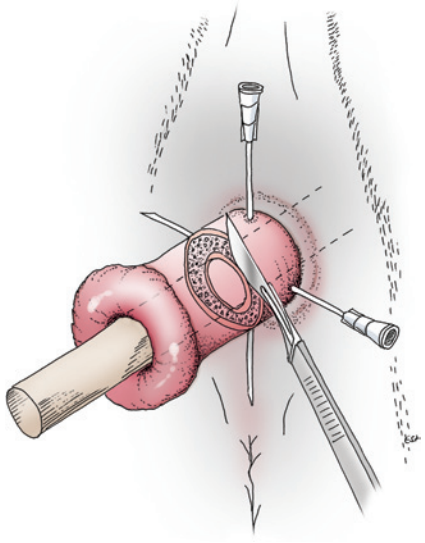


Figure 14-153 Schematic representation of the first step of stair-step amputation to correct rectal prolapse Type II. A circumferential incision is made just cranial to the necrotic area. All tissues except the inner mucosa and parts of the inner submucosa are incised.

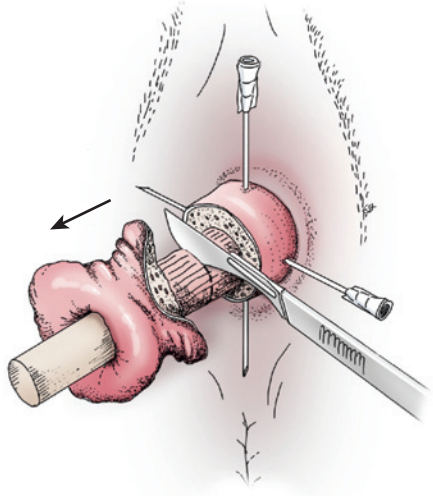


Figure 14-155 The inner segment is amputated.

Stairstep Amputation

When the prolapsed tissue is severely damaged, amputation may be the only alternative. Although several techniques of amputation have been described and accepted, the authors prefer the stairstep technique because the tendency for stricture formation is kept minimal. Preparations—including epidural anesthesia, insertion of tubing, and needle fixation—are identical to those described for submucosal resection. A circumferential incision is made just cranial to the necrotic area. All tissues except the inner mucosa and parts of the inner submucosa are incised (Figure 14-153). With blunt dissection, a plane is created toward the caudal aspect of the prolapse within the inner submucosa between the inner and outer segments (Figure 14-154). The outer segment is pulled forward, and the inner segment is amputated 2 to 3 cm more distal than the outer segment (Figure 14-155). This allows salvage of extra mucosa and facilitates adaptation of the mucosal layers over the bulging fat tissue. Suture pattern and material for adaptation of the mucosal layers are as described for submucosal resection (Figure 14-156).

Aftercare and Complications

After amputation and mucosal resection, the cross-pins are removed and a routine purse-string suture is applied and removed within 1 week. Lidocaine jelly may be applied topically for the first few days after surgery. Potential postoperative complications include stricture formation, perirectal abscess formation, dehiscence, peritonitis, or evisceration of intestines after dehiscence.

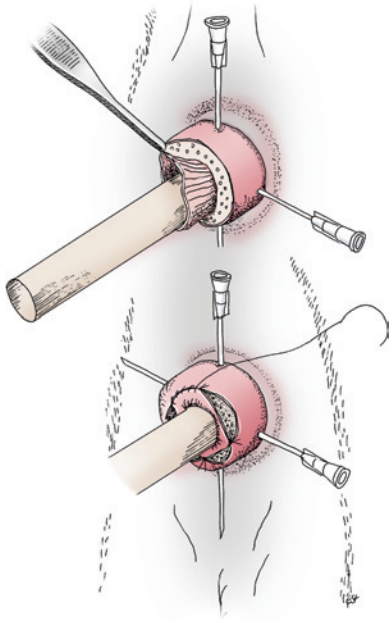


Figure 14-156 Adaptation of the mucosal layers as described for submucosal resection.

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INTRAABDOMINAL AND RETROPERITONEAL ABSCESSES

Susan L. Fubini

Cattle can have intraabdominal abscesses associated with the reticulum, liver, omentum, or uterus and retroperitoneal abscesses secondary to intraabdominal medication, surgical intervention, or pyelonephritis.

PERIRETICULAR ABSCESSES

In most instances, abscess formation adjacent to the reticulum is secondary to hardware disease. Cows with cranial abdominal abscesses often show signs typical of vagal indigestion, including abdominal distention high on the left and low on the right, bradycardia, irregular rumen motility, hypophagia, and hypogalactia.

The chronic antigenic stimulation results in high total protein, gamma globulin, and fibrinogen concentrations. The white blood cell count may be elevated, and total protein in the abdominal fluid is high in some cases. Venous blood gas and plasma electrolyte concentrations are usually within normal limits because the interruption in motility is at the reticuloomasal junction (for example, proximal to the abomasum). A mild hypochloremic metabolic alkalosis present in some cows is most likely a result of ileus or previous treatment with antacids.

If available, radiography of the cranial abdomen may show a radiopaque foreign body and a gas/fluid interface characteristic of an abdominal abscess (see Figure 14-48*A* and *B*). In some instances, ultrasound of the right cranial abdomen can depict a suspicious mass (Figure 14-157). Surgery of the Ruminant Forestomach Compartments discusses treatment of reticular and liver abscesses.

OMENTAL BURSA ABSCESS

Anatomy

The greater omentum consists of superficial and deep walls that are continuous caudally. The superficial wall arises from the greater curvature of the abomasum, cranial part of the duodenum, and ventral border of the descending duodenum (see Figure 14-157). From the right side, it descends along the abdominal wall, crosses ventrally to the left side, and ascends between the ventral sac of the rumen and left abdominal wall to the left longitudinal groove of the rumen. The deep wall of the greater omentum attaches to the right longitudinal groove of the rumen and with the superficial wall attaches to the ventral aspect (antimesenteric surface) of the descending duodenum. Between the superficial and deep walls of the greater omentum is enclosed the caudal recess of the omental bursa, which contains the ventral sac of the rumen and is a potential

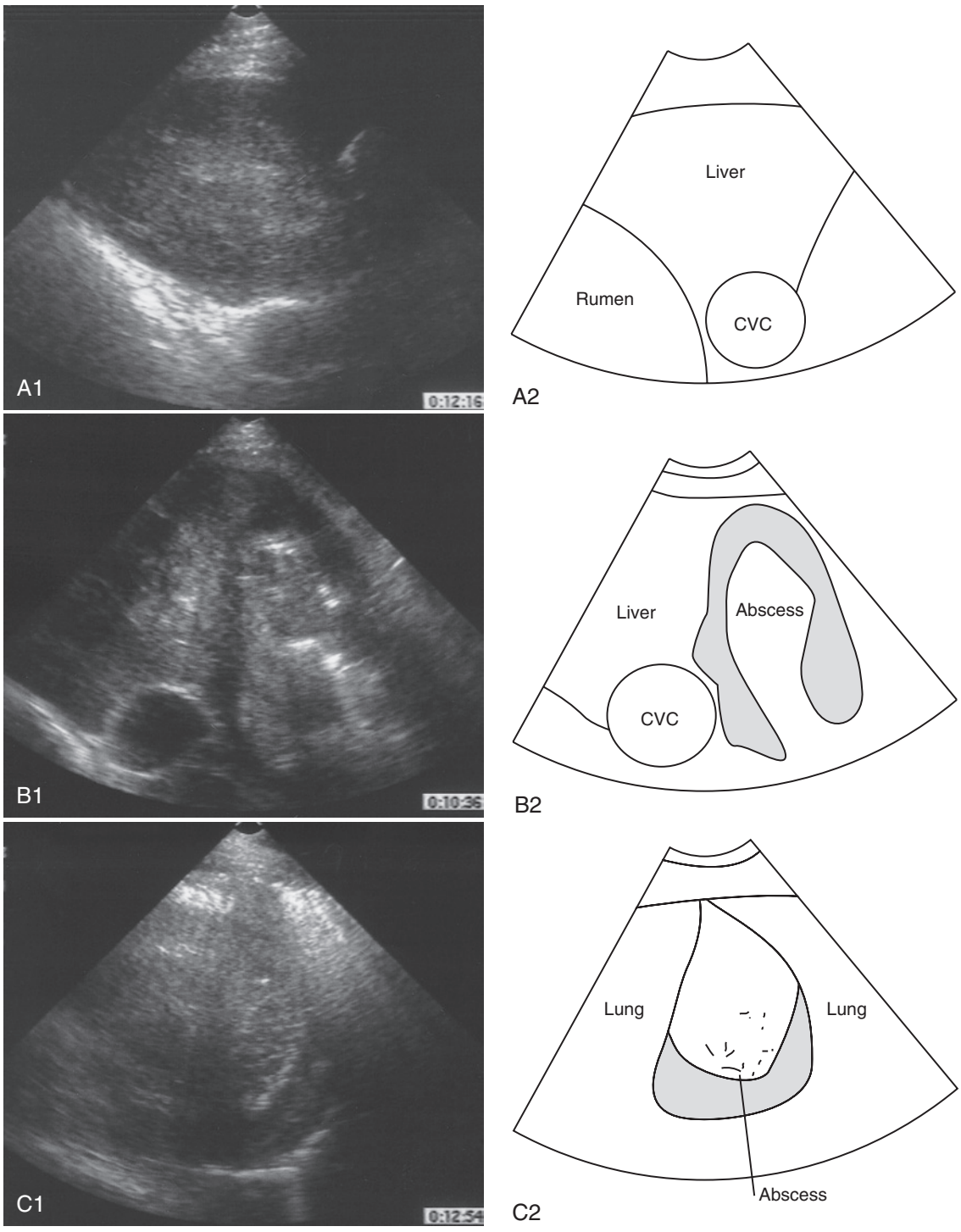


Figure 14-157 Transverse sonograms of the right-dorsal abdomen and adjacent thorax obtained from a 1-year-old Holstein bull with dyspnea and an abscess of the liver, diaphragm, and right lung. A 3- to 2-MHz phased-array sector probe was used. The left side of the sonogram is ventral. *A1*, At the right eleventh intercostal space, there is normal liver, caudal vena cava (CVC), and rumen. *A2*, Schematic representation of *A1*. *B1*, At the right tenth intercostal space, the abscess is contiguous with the liver. During respiration, the abscess did not slide against the liver, suggesting adherence to or origin from the liver. *B2*, Schematic representation of *B1*. *C1*, At the ninth intercostal space, the abscess is contiguous with the lung. The abscess did not slide independently of the lung, thus suggesting adherence to or origin from the lung. *C2*, Schematic representation of *C1*. (Courtesy of Dr. Amy Yeager.)

space in a live animal (Figure 14-158). The omental bursa communicates with the peritoneal cavity via the epiploic foramen. Dorsal to the sling formed by the deep wall of the greater omentum is the extensive supraomental recess that is open caudally and contains most of the intestinal tract. Portions of the intestinal tract, such as the apex of the cecum and distal portion of the small intestine, the flange, protrude from the recess and lie in the region of the pelvic inlet.

Etiopathogenesis

The exact cause of omental bursitis is not known; however, most reports speculate that an ulcer perforating the medial wall of the abomasum along the lesser curvature could result in ingesta spillage into the omental bursa. A perforation of the ventral wall of the rumen or reticulum by a foreign body could also result in omental bursitis. The foreign body seeds the omental bursa and can result in infection. Necrotic rumenitis, secondary to a bacterial or mycotic infection, could cause necrosis of the rumen wall and allow seepage of ruminal fluid into the omental bursa. The spread of an umbilical infection to the greater omentum, extension of another abdominal abscess into the omental bursa, or omental bursitis secondary to postpartum perimetritis are less likely causes.

Regardless of the etiology and treatment options attempted, this disease has vague presenting signs and is difficult to treat, which makes the prognosis guarded.

Clinical Syndrome

Omental bursitis is an uncommon clinical condition in cattle. It is also difficult to make a definitive preoperative diagnosis. Affected animals usually have vague signs of a chronic illness, including decreased appetite, scant manure, and depressed milk production. They may be febrile. In most instances, abdominal distention and a viscus are detectable on the right side of the abdomen. The right-sided viscus may be palpable per rectum and may ping when simultaneous auscultation and percussion are performed. Ultrasound may reveal an accumulation of fluid and exudate that can extend all the way from the mid–paralumbar fossa on the right to a similar position on the left (Figures 14-159 and 14-160). If it is a valuable cow, a right-sided exploratory celiotomy is indicated. Exploration will reveal a large viscus covered by the superficial layer of omentum. An aspirate will show a transudate or, in some cases, purulent exudate. If the omental bursitis was caused by abomasal perforation as a result of a moderate or large ulcer, feed material may also be present in the omental bursa (Figure 14-161).

Surgical Treatment

Surgery is not very rewarding, but it is possible in some instances to marsupialize the omental bursa to the right and/or left lower abdomen. Drainage at the most ventral aspect

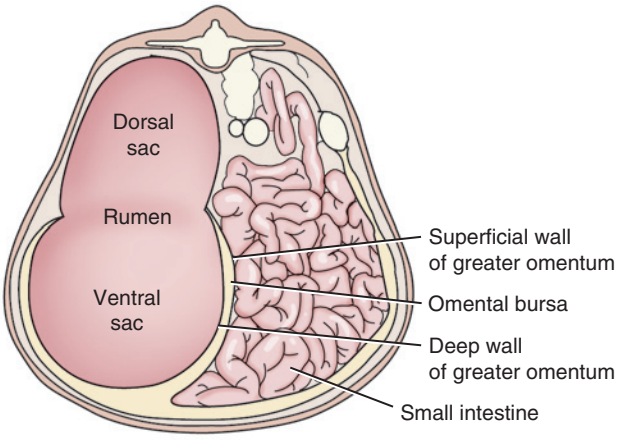


Figure 14-158 A line diagram that shows how the forestomach compartments and abomasum relate to the omentum and the omental bursa.

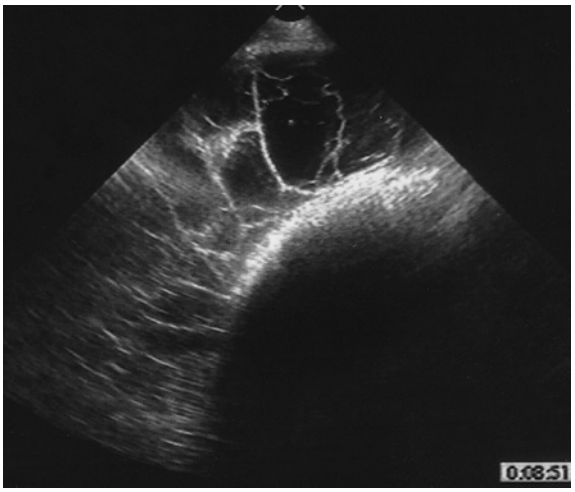


Figure 14-159 Transverse sonogram of the left-caudal abdomen obtained from a 2-year-old Ayrshire cow with omental bursitis secondary to previous rumenotomy. A 5- to 3-MHz phased-array sector probe was used. The left side of the sonogram is ventral. The image of the left side of the abdomen has an extensive collection of fluid and fibrin (8 cm thick) located between the body wall and rumen. This fluid and fibrin collection extended from the dorsal left abdomen across the ventral abdomen to the right side of the abdomen. (Courtesy of Dr. Amy Yeager, Cornell University.)

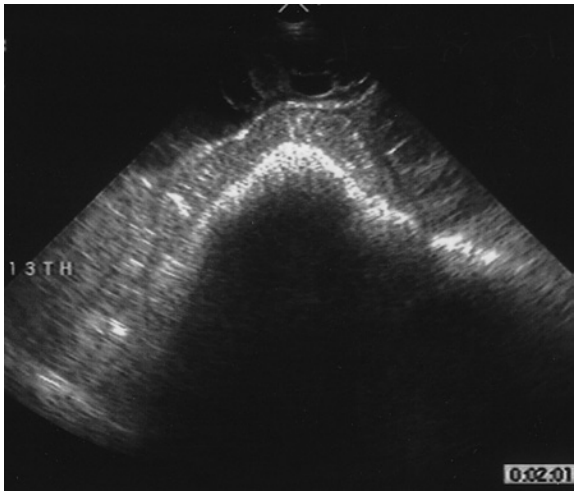


Figure 14-160 Transverse sonogram of the right-caudal abdomen obtained from a 2-year-old Ayrshire cow with omental bursitis secondary to previous rumenotomy. A 3- to 2-MHz phased-array sector probe was used. The left side of the sonogram is ventral. In the right abdomen, fluid and fibrin are located between the body wall and intestines. Unlike peritonitis, the fluid contained within the omental bursa did not mingle between segments of intestine. (Courtesy of Dr. Amy Yeager.)

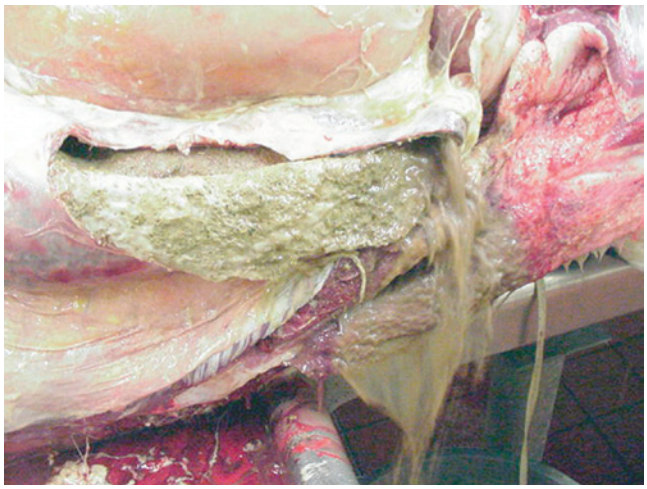


Figure 14-161 A postmortem specimen of a case of omental bursitis in a cow. The cow is in left-lateral recumbency, and the superficial layer of the omentum has been opened showing the large amount of purulent exudate.

of the abdomen should be avoided for fear of herniation of viscera through the wall of the omental bursa into the abdominal incision. Furthermore, an incision at the most ventral part of the abdomen can become occluded by the pressure of intraabdominal contents, which prevents adequate drainage. The omental bursa can compartmentalize the infection so the purulent exudate is localized to one part of the bursa. Surgical drainage should be done at the site that exhibits the most distention, as determined by ultrasound or rectal examination before surgery or by intraabdominal exploration during surgery. After aseptic preparation of the ventral abdomen, local anesthesia is infiltrated at the intended drainage site. The aim is to create a seal between the omental bursa and body wall at the drainage site. A 10-cm incision is made over the swelling on the lower abdomen. The incision is extended through muscle layers and peritoneum by using a combination of blunt and sharp dissection. The omental bursa is identified and aspirated to confirm the presence of purulent material. The superficial sheet of omentum is secured circumferentially to the subcutaneous tissues or dermis of the skin incision, which effectively isolates the site from the rest of the abdomen. The bursa is opened, and the incised edges are sutured to the skin with a simple interrupted pattern. This creates a defect in the body wall that is usually well tolerated. The omentum can be friable and difficult to handle, making this procedure difficult. If the capsule around the omentum is thickened, the surgery is more straightforward because stronger tissue holds the sutures better. Furthermore, a thick capsule allows lavage of the abscess cavity during and after surgery without causing worry about seeding the abdomen or tearing the omentum away from the body wall. In general, postoperative lavage of the omental bursa should be avoided because its wall is so thin it may rupture. Instead, the clinician should keep the incision open with daily gentle manual debridement of the surgical site. The abscess will contract over time. Perioperative antibiotics are appropriate.

OTHER ABDOMINAL ABSCESSES

Abscesses associated with the omentum or uterus may be excised through a celiotomy at the appropriate site. In some instances, it may be necessary to remove a portion of the uterus or omentum at the same time (see Chapter 16). When the location of an abscess prevents removal or drainage (either into a forestomach compartment or through the body wall), treatment with single aspiration and lavage with a dilute antiseptic solution and chronic systemic antibiotic therapy may be successful. This is accomplished by placing a large 14 to 28 French catheter[13] through the omentum or adhesions into the abscess cavity. Suction is applied to the catheter and as much material as possible is drained from the abscess. Following this, the drain is removed and the site where it was placed oversewn if necessary.

SINGLE, LARGE LIVER ABSCESS

It has been reported that a single, large liver abscess can cause very similar signs to those described for perireticular abscess formation (see Figure 14-157). The major difference found at surgery in cattle affected with liver abscess was the absence of adhesions to the forestomach compartments, making drainage into the forestomach compartment impossible. These liver abscesses are usually diagnosed on rumenotomy when a mass adjacent to the omasum is felt through the rumen wall. Palpation of the reticular wall shows no adhesions to the mass. These cows must be closed and approached in a different manner. The abscesses are on the right side of the abdomen, usually associated with the left lobe of the liver. Access to them can be gained by a cranial right-paramedian approach with the cow in dorsal recumbency, a right-paracostal approach with the cow in the left-lateral recumbency, or a ventral midline approach with the cow in dorsal recumbency. A celiotomy is made and the abscess is identified. A small 3-cm incision is made adjacent to the original incision; a large (20-24 French) chest trocar[12] is placed through the body wall and fed through any omental adhesions available into the abscess cavity. The catheter is aspirated to ensure that infected material exists within the cavity before it is sutured into place. The cattle are allowed to stand up and the abscess is drained. It may be helpful to gently lavage the abscess cavity over the next few days to drain out any infected material. An approximate 30% recurrence rate has been reported in cattle infected with these single, large liver abscesses. Because of the recurrence problem, a number of modifications have been tried, including lavaging the abscess during surgery and placing more than one drain. Anecdotally, results with these other treatment scenarios have not proven to be much more rewarding. Therefore we still place one large-bore catheter to provide drainage and warn the client that recurrence is a possibility. We have tried placing a percutaneous catheter directly into the abscess of one cow with ultrasound guidance. Peritonitis ensued because the catheter was not passed through adhesions, which allowed purulent exudate to leak into the abdomen at the site of the drain placement.

If the abscess recurs, a partial resection of the left lobe of the liver and its associated abscess can be attempted under general anesthesia through a right-paramedian or right-paracostal approach. This should be reserved for very valuable cows that suffer a recurrence because of the difficulty associated with the procedure and the possibility of severe intraoperative hemorrhage.

[13]Pleur-Evac Thoracic Catheter, Teleflex Medical, Research Triangle Park, NC, USA.

RETROPERITONEAL ABSCESSES

Infected material can localize in the retroperitoneal space secondary to pyelonephritis, previous surgery, or intraperitoneal treatments.

Affected cattle present with nonspecific clinical signs that may include fever, inappetence, distention at the site of the infection, a drop in milk production, elevated total protein levels, and a leukocytosis. Transabdominal ultrasound and rectal examination are useful in determining the nature and size of the retroperitoneal fluid accumulation. Accumulations of fluid and exudate in the retroperitoneal space can be quite large. The large fluid pocket should be aspirated to confirm that exudate is present. The abscessed cavity wall can be very thick, necessitating aspiration with a 14-gauge, 14-cm (5½-inch) intravenous catheter. Once the pocket is identified and infection confirmed, aggressive ventral drainage is required. This means identifying the infected area, approaching it with sharp dissection, and continuing to use a combination of sharp and blunt dissection until adequate drainage is achieved. In some instances, it is necessary to follow the infected tracts along fascial planes until the full extent of the contamination is identified. An outlet for drainage at the most ventral part of the pocket is required to prevent pooling of exudate and lavage fluids. The defect must heal from the inside out and should be lavaged carefully (a risk of creating peritonitis by rupturing the wall surrounding the fluid accumulation exists) on a daily basis. If the abdominal cavity is not involved, nonsterile fluids can be used for lavage. If there is a risk that deeper tissues are involved, sterile fluids should be used. With appropriate wound care, the outcome can be favorable.

INCISIONAL INFECTION

One often can detect a fluid pocket around the ventral aspect of surgical incisions in the first postoperative week; these are usually seromas that should be monitored for 10 to 14 days. The incisional fluid pocket should be aspirated only if the animal is one or more weeks postsurgery and is showing signs consistent with infection, such as inappetence, fever, a drop in milk production, or a large retroperitoneal pocket detected on rectal or ultrasound examination.

If an incisional infection is apparent, waiting until it localizes and matures into a discrete pocket before draining it is ideal. This is best determined by ultrasound. It may be possible to simply remove the most ventral skin sutures and establish drainage, especially for flank incisions. This usually requires some blunt dissection with a sterile, long hemostat and sterile gloves.

As mentioned in the retroperitoneal abscess section, some of the infected pockets can be huge, requiring some bold, blunt dissection to achieve adequate drainage. However, ultrasound is the best guide for this critical task to avoid lacerating large vessels or other vital structures or entering a body cavity inadvertently.

As with any infection, adequate ventral drainage is the treatment mainstay. At the clinicians' discretion, parenteral antibiotics may be indicated, especially with involvement of deeper tissues. Lavage of the infected cavity is appropriate as discussed in the retroperitoneal section.

More invasive surgery may be necessary for complicated incisional infections, such as an abomasal fistula after right-paramedian abomasopexy.

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SURGERY AND THE PERITONEUM

Ava M. Trent

Disorders of the peritoneum are only occasionally recognized as a primary reason for surgery of the abdomen in cattle. However, veterinarians depend on the healing properties and host defense mechanisms of the peritoneum for success in every abdominal surgery performed. Despite the apparently simple nature of the peritoneum, mishandling during surgery can result in a negative treatment outcome regardless of the nature of the surgery.

BASIC STRUCTURE AND FUNCTION

Anatomy

Gross Anatomy

The peritoneum is a continuous serosal layer that lines the internal surface of the abdominal cavity. A parietal layer covers the body walls and diaphragm, and a visceral layer is associated directly with the surface of organs. The parietal and visceral layers are continuous through a double layer of suspending peritoneum that sandwiches neurovascular

structures coursing to and from the organs and the dorsal body wall. The potential space between parietal and visceral layers of peritoneum forms the peritoneal cavity. This space is normally filled with a small volume of fluid transudate that contains a limited number of mature cells and protein. The visceral and parietal surfaces normally lie in close apposition within the abdominal cavity and glide easily along each other to allow viscera to reposition in the abdomen with peristaltic contractions and changes in visceral volume. Nondependent structures that are broadly attached to the body wall, such as the right kidney, are only covered by parietal peritoneum and are called *retroperitoneal*. Caudally, parietal peritoneum reflections extend caudal to the pelvic inlet, creating the pelvic cavity. The reflection of the parietal peritoneum onto the organs transversing the pelvis (rectum, bladder, uterus) creates peritoneal pouches or outpocketings and leaves the caudal portion of these organs to travel through connective tissue with no serosal covering. Similarly, at the diaphragm, peritoneal folds reflect upon the esophagus at the esophageal hiatus and aorta at the aortal hiatus. A further peritoneal extension occurs caudally at a point of reflection called the vaginal ring. This peritoneal extension is the vaginal process. The process becomes surrounded by body wall muscles and connective tissues that form the inguinal canal between the deep and superficial inguinal rings. In the female the vaginal process is accompanied by the round ligament of the uterus whereas in the male the vaginal process partially surrounds the ductus deferens, vessels, and nerves of the testis as well as the testes, creating a visceral layer over these structures that is continuous with an outer parietal layer surrounding the contents of the spermatic cord.

Histology

The peritoneum is a serosal membrane that consists of a single layer of mesothelial cells and is supported by a basement membrane. The mesothelial cells are normally squamous in shape and have cilia that trap cellular products to help maintain the necessary gliding surfaces. The layer is attached to the body wall and viscera by a glycosaminoglycan matrix that contains collagen fibers, vessels, nerves, macrophages, and fat cells. The parietal submesothelial layer varies in thickness and cell concentrations among species and has a moderate thickness in the cow. The visceral submesothelial layer is thin, and the visceral peritoneum (serosa) closely adheres to the underlying viscera. The parietal peritoneum can be grossly separated from the underlying muscle and fascia. Except for the peritoneum that covers omentum, the visceral peritoneum cannot be manually separated intact from the underlying viscera.

Histologic studies in laboratory animals show that junctures between peritoneal cells are tight and passive diffusion limits bidirectional passage to relatively small molecules, including water, glucose, and electrolytes. Distinct openings (stomata) up to 12 µm in diameter are present in the parietal peritoneum that covers the diaphragm. These stomata are adequately sized to allow passage of large molecules and cells, primarily to remove cells, bacteria, particles, and molecules less than 10 µm in diameter. Similar openings occur in the peritoneum that covers both sides of the omentum over focal aggregates of lymphoid tissue called milk spots. Lymphoid and myeloid originating cells move into the peritoneal cavity through these openings, and cells and particulate matter move out of the peritoneal cavity through these openings.

Blood and Lymphatic Supply

The peritoneal cells receive oxygen and other nutrients by passive diffusion along a concentration gradient from vessels in the submesothelium. A low–molecular weight transudate from these submesothelial vessels is the source of the small amount of fluid found in the healthy peritoneal cavity. The omental milk spots appear to be the primary source of phagocytes in the peritoneal cavity. The volume of fluid and often the protein concentration increase as an apparently normal physiologic process in late pregnancy. The volume, protein, and cellular content of this fluid increase dramatically in the presence of inflammatory stimuli.

Lymphatic vessels accompany the arteries and veins in the submesothelium, with specialized accumulations in sites corresponding to peritoneal stomata. Peritoneal fluid may enter lymphatic vessels that carry the now lymph through the caudal and then cranial sternal lymph nodes and from there into the right lymphatic duct. Other diaphragmatic lymphatics drain in the caudal mediastinal lymph node and from there into the thoracic duct. A final passage may involve uptake across the peritoneal surface and entrance into visceral lymphatics to the cysterna chili and into its continuation, the thoracic duct, and this into the general circulation. Lymphatic fluid can also drain via the wall of the omental bursa to the specialized lymphatic vessels in the diaphragm.

Innervation

The parietal peritoneum is supplied by fibers from spinal nerves able to detect sharp and deep pain stimuli. Standard nerve blocks used for incisional analgesia (paravertebral, line, inverted L) do not provide analgesia for the parietal peritoneum during a standing flank incision. The surgeon should expect a painful and accurately localized response to the incision through the peritoneal layer and be prepared to work quickly through this layer to minimize discomfort. Inflammatory processes that originate in or extend to the parietal peritoneum also stimulate a localizable painful sensation at the contact site.

The visceral peritoneum is innervated by the same afferent (sensory) nerves that supply the underlying viscera. These nerves are primarily type C pain fibers that pass along visceral sympathetic nerves into the spinal cord. The viscera and visceral peritoneum can detect stimuli that trigger the deep burning pain sensation characteristic of Type C fibers, including stretch, chemical irritation, and anoxia, but cannot detect sharp pain or touch. The most severe visceral pain results from rapid distention of the smaller diameter bowel or tension on the mesentery, both of which produce rapid stretching of the visceral peritoneum. Distention of larger diameter viscera such as the rumen and abomasum is less likely to create the rapid peritoneal stretch that produces pain. Unlike spinal nerve fibers, stimulation of visceral afferent pain fibers does not result in accurate localization of the pain source. Consequently, the animal's behavior (posture, kicking, etc.) is unlikely to accurately reflect the pathology location, unless an inflammatory stimulus has extended to the parietal peritoneum. This occurs commonly in cases of traumatic reticuloperitonitis and abomasal ulceration and allows localization of pain to the cranioventral abdomen by manual pressure on the ventral body wall. Lack of sharp pain sensation allows the surgeon to manipulate and incise viscera without any analgesia beyond the local block for the approach.

Physiology and Function

Several peritoneal functions are critical to the health of all abdominal structures, including production of peritoneal fluid, maintenance of a gliding surface, removal of waste products, and repair of tissue defects. These functions are usually adversely affected by surgical invasion of the peritoneal cavity. A surgeon's ability to minimize the adverse

effects of surgery and disease and to maximize desirable effects is critical for surgical success.

Peritoneal Fluid Production

Peritoneal fluid is produced by transudation from submesothelial vessels across the peritoneal membrane. The amount of fluid is normally small (less than 50 mL in humans) and contains neutrophils, mononuclear cells, eosinophils, macrophages, lymphocytes, desquamated mesothelial cells, and an average of 3.0 g/mL of protein. The volume often increases during late pregnancy. A significant increase in volume without notably abnormal changes in cellularity or protein concentration can occur in animals with heart failure and ascites or in early uroperitoneum.

Electrolytes and other small molecules enter the peritoneal cavity by diffusion along a concentration gradient and remain in equilibrium with the extracellular fluid of the body. As a result, the concentration of electrolytes in peritoneal fluid is normally similar to that in serum.

Gliding Surface

The peritoneum maintains a gliding surface for peritoneal surfaces in the abdomen through several mechanisms. Peritoneal cells secrete a mixture of phospholipids with lubricating and surfactant properties. These lipids and glycoproteins form a 2- to 15-µm-thick glycocalyx that is trapped against the mesothelial surface and provides very efficient boundary lubrication. The small amount of free fluid in the peritoneal cavity plays a limited role in supporting this gliding surface. In addition, peritoneal cells in most species produce a baseline level of tissue plasminogen activator (tPA), a substance that converts plasminogen to a potent fibrinolytic agent called plasmin. The baseline level of peritoneal tPA production does vary by species, and the cow appears to have one of the lowest levels. Bovine peritoneum also produces relatively large amounts of fibrinolytic inhibitors. As a result, the cow peritoneum may be predisposed to allow formation of fibrinous adhesions, which is a potential advantage for controlling the relatively common problems of forestomach perforation from traumatic reticuloperitonitis and abomasal ulcers. This process will be discussed further in Peritoneal Repair and Peritoneal Adhesions.

Host Defenses

The peritoneum and peritoneal cavity are protected from contaminants and tissue damage by three main mechanisms: phagocytosis as part of the inflammatory response, physical removal through openings in the peritoneal membranes, and functional localization by omentum and fibrin.

Inflammatory Response and Phagocytosis. The inflammatory response in the peritoneal cavity is similar to that in other tissues, although most of the responding cells and mediators must be brought into the cavity across the peritoneal membrane. Initial degranulation of mast cells with release of vasoactive agents results in submesothelial vessel dilation and a large volume of fluid influx into the peritoneal cavity. The initial fluid contains inflammatory mediators, including complement, opsonins, immunoglobulins, chemotaxins, and protein precursors of fibrin and proteases. A cascade of cytokines is also initiated with the inflammatory process. These cytokines, which are produced by mesothelial and other cells, help regulate the inflammatory response, phagocytosis, and wound healing. Mesothelial cells express adhesion molecules that promote adherence of both inflammatory cells and bacteria to the surface.

Thrombin conversion of soluble fibrinogen in the inflammatory fluid to insoluble fibrin begins within minutes of fluid entry into the peritoneal cavity. Neutrophils enter the peritoneal cavity in large numbers within 2 hours of contamination and peak at 24 hours. This is followed by a gradual decline. The first wave of neutrophils is followed by macrophages that peak by the second day after contamination. In a study of peritoneal fluid changes after a clean abdominal surgical procedure in adult cattle, the average neutrophil and mononuclear cell counts rose from 1312 and 770 cells/µL averages, respectively, before surgery to 10,619 and 1216 cells/µL averages at 6 days after surgery. Mesothelial cells are able to ingest bacteria but do not efficiently kill the ingested pathogens. The ability of phagocytes to efficiently locate, engulf, and kill pathogens depends on the presence of complement and opsonins in the peritoneal cavity. Phagocytes are most efficient when both the phagocytes and bacteria are surface bound. The effectiveness of phagocytosis can be impaired by the presence of adjuvants. Adjuvants are agents that promote pathogen survival by a variety of mechanisms—including impeding host responses and improving the local environment for pathogen survival. Large volumes of fluid, including those associated with the initial inflammatory response, serve an adjuvant role by decreasing the ability of phagocytes to find and engulf suspended pathogens. Pathogens trapped in fibrin are less accessible to phagocytes and systemic or locally administered antibiotics and antiseptics. The antimicrobial agents capable of penetrating the fibrin are not always active in the local environment. Fibrin prevents physical transport of entrapped pathogens to exit portals in the peritoneal membrane for physical removal.

Physical Removal. Waste and breakdown products can be physically removed from the peritoneal cavity by either diffusing across the peritoneal membrane or traversing stomata in the diaphragmatic and omental peritoneum. Diffusion is limited to water, electrolytes, and smaller molecules such as urea nitrogen. Larger molecules and cells can only leave the peritoneal cavity intact by way of the stomata. In laboratory species and man, a normal circulation of peritoneal fluid carries material in a general route from the dorsal direction, caudoventrally, and then cranially along the ventral abdomen to the diaphragm. Once through the diaphragmatic stomata, waste is picked up by lymphatic vessels in the diaphragm and carried dorsally via substernal and thoracic lymph nodes into the thoracic duct. Bacterial contaminants not filtered by lymph nodes along the route can appear in the systemic circulation within 12 minutes of introduction into the peritoneal cavity. Clearance through the diaphragmatic stomata can be impaired by accumulations of fibrin or fibrosis in the cranioventral abdomen.

Peritoneal circulation also carries waste products past the omentum, where they can pass through areas of discontinuity into underlying capillaries and lymphatic vessels. The extensive surface area of the omentum potentially increases its role in waste clearance in cattle.

Functional Isolation of Waste by Omentum and Fibrin. Complete physical removal of peritoneal contaminants is not always possible. A third form of host defense functionally isolates pathogens and contaminants from peritoneal tissues by localization in either fibrin or omentum.

The rapid accumulations of fibrin in the peritoneal cavity are capable of trapping local contaminants in their matrix. The efficiency of trapping varies with the specific bacteria, degree of fibrin organization, and presence of other factors in serum. Once there, pathogens are partially isolated from peritoneal tissues as well as other host defenses. Over time, the fibrin can be organized into a fibrous capsule or abscess cavity. The healthy peritoneum of most species possesses an intrinsic control mechanism to help remove fibrin deposits before they can be organized into fibrous tissue and

persistent adhesions or abscesses (see Peritoneal Repair and Peritoneal Adhesions). The cow's ability to produce extensive volumes of fibrin and its relative lack of peritoneal fibrinolytic activity suggest a greater role for fibrin trapping in this species.

The omentum commonly migrates to sites of waste production or accumulation, either incidentally as part of its normal movement pattern or actively through as yet undefined mechanisms. It is often the first tissue to adhere to or surround the initial site of contamination. An angiogenic factor identified in the lipid fraction of omentum is believed to play a role in the omentum's ability to adhere to sites of tissue damage and serve as a source of rapid neovascularization. As a result, omental attachments become stable very rapidly. In addition to enhancing omental contact for waste removal and functional isolation, these attributes have been applied in the therapeutic use of omentum to seal and provide initial vascular supply for damaged tissue inside and outside of the abdominal cavity.

Peritoneal Repair

Peritoneal damage occurs whenever natural disease or invasive diagnostic or surgical procedures traumatize the parietal or visceral peritoneum. If the trauma is sufficient, mesothelial cells will be lost or physically removed. Successful recovery requires restoration of a functional peritoneal surface. The surgeon makes a number of diagnostic and therapeutic choices that can either facilitate or impede peritoneal healing.

The first step in appropriate peritoneal management is to recognize that the peritoneum does not heal like other tissues. Rather than following the skin's contraction and epithelialization processes of healing, peritoneal defects heal diffusely across the defect area. Sharply excised experimental defects, irrespective of size, are diffusely filled by fibrin, cellular debris, and neutrophils within 12 hours of resection. By 24 to 36 hours, the number of cells on the wound surface has increased, and macrophages have become the predominant cell type. Macrophages supported by fibrin cover the wound surface by the second day after injury. In the absence of other adhesion stimuli, this initial inflammatory exudate will begin to resolve and the first immature mesothelial cells will appear within 48 to 72 hours. Islands of mesothelial cells proliferate into connecting sheets. A functionally mature mesothelial surface with a smooth juncture with adjacent mesothelium is evident within 4 to 6 days after resection. By 7 to 10 days after resection both surface cells and submesothelial tissues are histologically and functionally mature. Whether these immature cells are seeded from submesothelial tissues or cells in the peritoneal fluid has been a topic of debate. Injuries such as abrasion, drying, and ischemia, which do not directly remove mesothelial tissue, result in mesothelial cell death and defoliation. The process of healing following defoliation is similar, although often less successful.

Peritoneal healing requires the coordination of fibrin and phagocyte deposition, mesothelial cell colonization and proliferation, and fibrin removal (lysis). Removal of the fibrin after it has served the functions of initial wound seal and matrix for cell deposition and migration is a critical step for wound healing without adhesion formation. Plasmin is the primary agent responsible for fibrin lysis in the peritoneal cavity and is activated primarily by tPA. The mesothelium is considered responsible for 95% of peritoneal tPA activity in man. Macrophages also produce tPA. A urokinase-type plasminogen activator, prevalent in urine but also found in other tissues, and nonspecific proteolytic enzymes may also play minor roles in fibrin removal in peritoneal wounds. Agents that either inhibit fibrin formation or fibrin lysis help balance the process of fibrinolysis. Antithrombin III and protein C impede fibrin formation. Several fibrinolytic inhibitors are produced by mesothelial cells as well as by other tissues in the body. Plasminogen activator inhibitor-1 is considered the most important fibrinolytic inhibitor in the peritoneal cavity in man and laboratory animals.

Under optimal circumstances with mild and transient peritoneal trauma, the peritoneal environment supports temporary involvement of fibrin in wound repair. Mesothelial cell production of tPA decreases or ceases entirely immediately after wounding and remains low until new mesothelial cells enter the wound site. Fibrinolytic inhibitor levels do not usually decrease during this early stage and in some cases may actually increase. This allows fibrin to enter and temporarily seal the wound so that it serves as a scaffold for new cell deposition. The local tPA levels begin to increase 3 to 4 days after wounding and will increase above baseline by 7 to 10 days after injury when the wound is covered with new and metabolically active mesothelial cells. The increasing tPA levels support lysis of the now unnecessary fibrin.

Factors that interfere with initial deposition of fibrin can prevent wound closure, whereas factors that interfere with—or overwhelm—the process of fibrinolysis promote the development of fibrous adhesions (see Peritoneal Adhesions). However, failures in peritoneal healing under clinical conditions typically reflect a persistent inflammatory stimulus (visceral leakage or fistulation) rather than an imbalance in intrinsic tPA and fibrinolytic inhibitor activity. Surgical procedures can also interfere with peritoneal healing by this mechanism. Incomplete visceral closure with leakage or accidental incorporation of omentum in a body wall incision can prevent complete peritoneal healing. Attempts to control undesirable adhesions by artificially enhancing fibrinolysis can also interfere with necessary incisional healing (see Peritoneal Adhesions).

Species variation is recognized in mesothelial production of tPA. Bovine mesothelium does not produce tPA either before or within 10 days of wounding but does produce fibrinolytic inhibitors before and after injury. Although this is consistent with the observation of large quantities of fibrin in the peritoneal cavities of cattle with inflammatory lesions, it does not explain the equally valid observation that many peritoneal lesions heal successfully without persistent fibrin or fibrous tissue.

Diagnostic Procedures

Physical Examination

The primary clinical signs of peritoneal disease detectable by physical examination are signs of abdominal pain, altered visceral position or motility, abnormal gas accumulation, and fibrin accumulation.

Pain occurs as a result of stretching of the visceral peritoneum or inflammation of parietal or visceral peritoneum. Common signs of both visceral and peritoneal pain include elevated pulse and respiratory rate, ileus, and anorexia. Visceral pain may also cause agitation, occasional kicking at the abdomen, or frequent changes in position. Discomfort may be more evident during palpation per rectum. These signs are usually more marked in calves than in adult cattle and can include violent rolling and kicking. Inflammation of parietal peritoneum typically causes a decrease in movements that would stretch the parietal inflamed region. Adult cattle with inflammation of the ventral parietal peritoneum may be reluctant to lie down and will resist arching their backs when pinched on their dorsal spinous processes caudal to the withers, occasionally producing an audible or auscultable grunt. The site of parietal inflammation can be localized in some cattle by pushing a fist or blunt object of similar width firmly into the abdomen in an organized pattern along the

body wall. Pain is indicated by the cow's effort—often subtle—to shift away from pressure in affected areas. The process of applying focal abdominal pressure is helpful in differentiating between inflammatory foci concentrated in the caudal, central, or cranial abdomen or between the right and left sides.

The presence of adhesions may be suggested by several additional findings. Nonreducible or partially reducible umbilical, inguinal, or traumatic body wall hernias generally indicate the presence of adhesions. Immobile structures or sheets of adhesions may be detectable on palpation per rectum. A roughened surface on viscera or the body wall from fibrin deposits may also be palpable. Detection of pneumoperitoneum by auscultation or palpation per rectum without a history of recent abdominal surgery would indicate loss of normal barriers and/or peritoneal infection. Abscesses adjacent to the body wall can produce a tympanic sound on simultaneous auscultation and percussion similar to that produced by an obstructed abomasum or intestinal segment. An example of this situation is the uncommon development of a large right-sided abscess following omentopexy or pyloropexy.

Peritoneal Imaging

Transabdominal ultrasonography can be used to evaluate the structural integrity of the body wall, identify fluid or fibrin adjacent to the body wall, and evaluate motility in viscera adjacent to the body wall in calves and adult cattle. Transrectal ultrasonography can provide similar information on the pelvic and caudal abdominal cavity in adults. Transabdominal ultrasonography is particularly useful in characterizing the contents of intraabdominal umbilical remnants and the nature of adhered structures in calves with umbilical infections. Ultrasound also allows differentiation between umbilical infection and herniation, edema, hemorrhage, or free-fluid accumulation (including urine) in calves with swelling of the abdominal wall. Ultrasonography can also be used to help guide fluid collection from the peritoneal cavity or from abscess cavities adjacent to the body wall. Ultrasound is used effectively to follow the resolution of abscesses after transcutaneous or transreticular drainage in adult cattle.

Radiography can provide valuable information about the structural and functional integrity of the peritoneum in the neonate and adult. Radiographs can help characterize structures in body wall defects and may identify accumulations of peritoneal fluid, abscesses, or abnormally positioned structures in the neonatal calf. The increase in body size and the extensive development of the forestomach compartments and greater omentum limit the value of radiography in adult cattle. It has been used most extensively for evaluation of the cranioventral abdomen, in which accumulations of fibrin or multiple small gas pockets and persistent dorsal displacement of the reticulum indicate peritonitis.

Peritoneal Fluid

Fluid Collection. The unique development of the ruminant stomach, expansive omentum, and the species' propensity for fibrin deposition place some constraints on collection of peritoneal fluid in cattle. Ideally, abdominocentesis is done under ultrasonographic control at or near the disease process. Otherwise, there are four abdominal sites that can be used. These include 3 to 6 cm to the right and left of the caudal midline, 3 to 6 cm cranial to the mammary gland in the female, or 3 to 6 cm caudal to the preputial opening in the male. Two cranial sites 3 to 6 cm to the right and left of the cranial midline at the most dependent site of the abdomen, usually 5 to 6 cm caudal to the xiphoid process, can be alternative sites. In general, one of the two recommended caudal sites in the standing adult is preferred. Using all four sites has been suggested to provide better localization of the lesion.

Samples can be collected with an 18-gauge, 1½-inch needle in most adult cattle. Longer needles are occasionally indicated for highly conditioned beef cows and adult bulls. In young calves, a 20-gauge, 1-inch needle is more appropriate. A teat cannula may be used instead of a needle if preferred. All penetration should be performed in the center of a clipped and aseptically prepared area.

Fluid is normally limited in volume and a small (3 mL) ethylenediaminetetraacetic acid (EDTA) tube and sterile 3-cm^3 syringe should be immediately available to collect fluid by gravity. Attempts to aspirate fluid are typically not successful, presumably because the negative pressure created is sufficient to plug the needle or cannula with the omentum. Excessive amounts of EDTA will cause cell lysis, a false depression of the packed cell volume and total protein, and altered serum electrolyte values.

Fluid Evaluation. The fluid should be evaluated grossly for clarity, color, opacity, and odor. A centrifuged anticoagulated sample (EDTA or heparin) can be used to determine packed cell value and plasma protein concentration. An anticoagulated sample should also be stained and evaluated microscopically for cell characteristics and the presence of intracellular or extracellular bacteria or parasites. If initial evaluation indicates that bacteria are present, a Gram stain should be performed to differentiate between gram-negative and gram-positive organisms for selection of initial antibiotic therapy. Sterile samples should be submitted for aerobic and anaerobic cultures if possible.

Cytology. Normal peritoneal fluid is clear to slightly turbid and clear to light yellow in color, with a potential slight pink tinge normal in late gestation. The specific gravity should be less than 1.016, and the pH should be between 6 and 8. A pH of less than 4 would suggest accidental abomasocentesis. The total protein is typically less than 3 g/dL. Fibrinogen in normal bovine peritoneal fluid may be sufficient to clot on exposure to air.

The cell count in peritoneal fluid is normally less than 10,000 white blood cells/µL. Mature neutrophils and monocytes are the predominant cells and are fairly equal in number. Up to 60% mature neutrophils with a total cell count of <10,000 cells/µL would be considered within normal parameters. Greater than 60% neutrophils, particularly with an elevated total cell count, would be abnormal and suggests contamination, infection, or trauma. The presence of degenerating neutrophils is abnormal and suggests infectious or toxic changes. Eosinophils are commonly detected in peritoneal fluid of cattle in some geographic areas. Other than the potential implication of parasite migration or other antigenic stimulation, eosinophils are not considered indicative of peritoneal pathology. Lymphocytes, macrophages, and desquamated mesothelial cells may also be present in normal fluid. Platelets are not normal components of peritoneal fluid, and their presence suggests the sample has been contaminated with blood.

Special Chemistry Evaluation. The concentration of common serum enzymes in normal peritoneal fluid is determined by their molecular weight, with smaller molecules such as urea nitrogen in equilibrium with serum. The relative elevation of electrolytes and enzymes that are concentrated in urine in the peritoneal fluid are useful aids in diagnosing urinary tract rupture (see Chapter 16).

Disorders of the Peritoneum

Peritoneal Infection

Peritonitis, or peritoneal inflammation, is a common finding in both adult cattle and calves. Inflammation without infection can occur from mechanical trauma during surgery or from chemical irritation caused by urine leakage or poorly balanced or caustic lavage solutions. Peritonitis from infectious agents is more common.

Categories of Infectious Peritonitis. Primary peritonitis refers to peritoneal infection without an evident intraabdominal source of infection. Primary peritonitis is relatively rare in cattle compared with secondary peritonitis. The fibrinous peritonitis associated with sporadic bovine encephalomyelitis (*Chlamydia psittaci*) and septicemia caused by *Haemophilus* spp. are examples. Contamination by passive diffusion or forced flow of organisms from the uterus through patent oviducts in the postparturient period has also been recognized as a source of peritonitis in cattle.

Secondary peritonitis. Secondary peritonitis is the most common source of peritonitis in cattle. Secondary peritonitis includes cases of bacterial peritonitis secondary to intraabdominal lesions. In cattle, sources of bacterial peritonitis include lesions that disrupt normal barriers between a visceral lumen and the peritoneal cavity (foreign-body perforations, ulcers, ischemia) and extension of preexisting infection through the peritoneal membrane (umbilical remnant infection, liver or renal abscesses, retroperitoneal infections, body wall infections).

Tertiary peritonitis. Tertiary peritonitis is defined as a recurrent peritoneal infection after an appropriately managed episode of primary or secondary peritonitis. A single organism or a limited number of synergistic organisms are typically involved. This category clearly exists in cattle, although differentiation between cases of recurrent peritonitis after appropriate management of secondary peritonitis versus unresolved cases of secondary peritonitis would be difficult.

Pathophysiology. Regardless of the source of contamination, peritoneal infection occurs when the number and virulence of contaminating organisms exceeds the ability of available host defenses to control or eliminate the organisms before they are able to multiply and invade tissue to cause tissue damage. The number of organisms necessary to cause peritonitis appears to depend on a variety of factors, including the nature of the organism, method of introduction, local environment, and available defenses.

The number of organisms necessary to cause infection can be decreased by the presence of adjuvants—agents that either decrease the availability or efficacy of host defenses or increase the survivability of invading pathogens. A number of specific adjuvants have been identified in the peritoneal cavity, including increased fluid levels, blood, hemoglobin, and foreign bodies. Inadequate hemostasis, incomplete removal of lavage fluid, inadequate debridement, traumatic surgical technique, and use of excessive or reactive suture material or surgical mesh by the surgeon all act as adjuvants in the peritoneal cavity and increase the risk of infection. Some organisms act synergistically in the peritoneum, and their concurrent presence increases the survival of both. The frequency of polymicrobial infections with *Escherichia coli*, *Truperella pyogenes*, and *Fusobacterium necrophorum* suggests that a synergistic relationship may exist.

Once contaminants have entered the peritoneal cavity, they can move through one of several stages based on the nature of contamination, the available host defenses, and the nature and timing of therapeutic intervention. The first contamination stage (Stage 1, "golden period") represents a delay of 4 to 6 hours between the introduction of bacteria into a tissue and establishment of infection. All surgical abdominal procedures initiate this stage unless infection has already developed from a previous source of contamination.

Stage 1 is characterized by a rapid inflammatory response with fluid influx that contains complement, opsonins, chemotaxins, fibrinogen, and thrombin. Physical removal is the primary host defense mechanism against bacteria and inert contaminants during this period, with the greatest rates of removal during the first 3 hours after contamination. Neutrophil influx and phagocytosis become significant within hours of initial contamination and remain high throughout this stage. Soluble fibrinogen is rapidly converted to insoluble fibrin, thus allowing fibrin entrapment of contaminants. The presence of adjuvants can interfere with one or more of the available waste-removal methods and decrease the ability of the host to eliminate contaminants before infection can develop.

Mortality is very low during the contamination phase of peritonitis. Clean surgeries (elective, no invasion of a lumen) in generally healthy animals without breaks in technique would normally introduce so few organisms that host defenses alone are sufficient to control the contaminants. Addition of therapeutic assistance in the form of antimicrobial therapy and removal of adjuvants can help host defenses eliminate more extensive contaminant loads. However, if bacteria are not physically removed or effectively neutralized by the combination of host defenses and therapeutic intervention, infection will develop and enter Stage 2.

Stage 2 (acute generalized peritonitis) occurs between 3 and 4 hours and 4 and 5 days after initial contamination. The peritoneal circulation has distributed at least some contaminants away from the original site of inoculation en route to the diaphragmatic stomata. Active infection may be present throughout the peritoneal cavity if the number of contaminating organisms is high. When contamination occurs outside of the supraomental bursa in adult cattle, the extensive omentum may help decrease the concentration of organisms carried into the bursa by physical separation. This is consistent with the clinical observation that contamination originating in the bovine cranioventral or craniolateral abdomen (traumatic reticuloperitonitis, liver abscesses, some abomasal ulcers) tends to spare the viscera within the supraomental bursa, whereas sources that originate in the caudal region or within the supraomental bursa are more commonly associated with generalized peritonitis.

Physical removal of contaminants is still the predominant host defense mechanism in early Stage 2, but the volume of material removed decreases later because fibrin deposits limit fluid flow. Functional trapping by omentum and fragile, easily disrupted fibrin strands and clots begin to play a role. Phagocytosis is active, with neutrophils peaking 24 hours after infection and decreasing slowly afterward. Macrophages begin to play a significant role the second day after contamination. The process of selective reduction begins during this stage, but the flora from polymicrobial contamination remains. Mortality is high during this stage and accounts for the majority of deaths attributed to peritonitis. The primary cause of death in Stage 2 is bacteremia that results from the rapid transfer of specific pathogens from the peritoneal cavity into the general circulation. Gram-negative aerobes/facultative anaerobes such as *E. coli* are by far the most common agents identified in the circulation in humans and the laboratory species for which this information is available. Adjuvants in the peritoneal cavity typically increase the

mortality rate. The presence of anaerobes in the peritoneal cavity at this stage appears to be necessary for abscess formation in Stages 3 and 4 and also improves the environment for survival of synergistic organisms. Experimental inoculation of contaminants in a fibrin clot decreases acute mortality in laboratory animals, although it also increases the incidence of abscess formation in later stages. The cow's ability to rapidly deposit large volumes of fibrin in response to contaminants may contribute to its apparent success in surviving the early stages of peritonitis.

Once this stage has been entered, three possible outcomes are the following: 1) host defenses may still overcome pathogens, thus leading to complete resolution of infection (typically in animals with good host defenses, relatively small numbers of contaminating organisms, and few adjuvants) but often leaving residual changes in the peritoneal cavity such as adhesions; 2) pathogens may clearly overwhelm host defenses, thus leading to fulminant peritonitis and death (typically from bacteremia); or 3) pathogens and host defenses may achieve a standoff, thus leading to the third stage of peritonitis.

Stage 3 (acute localizing peritonitis) is a transitional period for cases that have survived Stage 2 but were incapable of completely eliminating organisms from the peritoneal cavity. This stage occurs between 4 and 10 days after contamination in laboratory animals and humans, although the propensity for fibrin formation may shift the schedule forward or shorten its duration in cattle. Selective reduction is complete, and the number of initial contaminants has been typically reduced to one or two organisms capable of long-term survival in the peritoneal environment. Single organisms or a combination of two to three synergistic organisms are most common.

The predominant method of waste control is functional removal by fibrin and omental entrapment. Regional differences may occur in the distribution of fibrin based on the concentration of organisms distributed in Stage 2 as well as the location of necrotic tissue or persistent inflammatory stimuli, such as foreign materials. Physical removal of contaminants continues at a reduced level, which is limited by obstruction of stomata and interference with contaminant mobility by fibrin accumulations. However, fibrin also impedes access of phagocytic cells to entrapped organisms.

Mortality is lower in this stage than in Stage 2 and is more sporadic. Cows that survive Stage 3 will either move on to Stage 4 or effectively resolve the infection with persistent adhesions and/or sterile abscesses. If pathogenic organisms are effectively eliminated, the potential for return to full health will depend on the location and nature of persistent adhesions (see Peritoneal Adhesions).

Cases that survive Stage 3 by localizing persistent pathogens into organized abscesses enter Stage 4 (chronic abscessing peritonitis). This stage begins anytime at or after the eighth day following contamination. The propensity of the bovine abdomen for fibrin deposition may increase the likelihood of encountering this stage in cattle. Selective reduction is complete, and a relatively small number of organisms capable of abscess formation can be found, typically anaerobes (obligate or facultative). In some cases, organisms will be eliminated, thus leaving a sterile abscess. Mortality is low in this stage, but the persistent infection can create a continued strain on the animal's system evidenced by poor weight gain, suboptimal food consumption, and decreased milk production. Intermittent escape of bacteria from abscesses can occur and cause episodes of pyrexia, neutrophilia, and depression. Depending on location, abscesses and adhesions may suddenly produce complete obstruction or serve as a focus for intestinal volvulus, resulting in more acute and severe clinical signs. In humans, death in this stage is commonly attributed to multiple organ failure. Although not commonly acknowledged in cattle, bacterial endocarditis and pyelonephritis have been recognized in association with peritonitis at postmortem evaluation.

Clinical Signs and Diagnosis. The clinical presentation of cattle with peritonitis depends largely on the source and magnitude of contamination and the stage of infection.

Clinical signs during Stage 1 are primarily associated with the initiating lesion rather than the peritoneal insult. Identification of the specific onset of this stage in naturally occurring cases is usually impossible unless the animal was being monitored for progression of a suspected visceral lesion by serial peritoneocentesis. Sudden relief of severe abdominal pain consistent with visceral distention/obstruction followed by gradual signs of depression and shock may mark the time of visceral rupture and peritoneal contamination. Cases initiated by surgical intervention have a more reliable identification of the initial time of contamination, although recognition of excessive contamination is not always immediate. By the end of this stage, peritoneocentesis would typically demonstrate neutrophilia and hyperfibrinogenemia.

Cows in Stage 2 usually demonstrate both systemic and abdominal signs. Systemic signs include depression, anorexia, dehydration, elevation or depression of temperature and pulse rate, and signs of systemic shock. Feces are usually decreased in volume and may vary from loose to pasty in consistency. Rumen motility is often depressed, and rumen distention may be present. Pain from peritoneal inflammation may be detectable. Surgical exploration would often reveal large volumes of fluid with loose disorganized accumulations of fragile fibrin clots and erythematous surfaces.

Systemic neutrophilia with or without a left shift or neutropenia is common. However, hematological changes are variable, and normal neutrophil counts do not rule out peritonitis. Plasma fibrinogen is typically elevated. Serum chemistry changes parallel the cow's lactation cycle and intestinal ileus. These changes include hypocalcemia, hypochloremia, and hypokalemia. Serum urea nitrogen and creatinine are commonly increased because of dehydration and prerenal azotemia. Serum protein may be increased or decreased in this stage, depending on the rapidity with which protein is lost into the peritoneal cavity balanced by inflammatory increases in serum fibrinogen and globulins. A marked increase in peritoneal total white blood cell and neutrophil counts is typical during this stage; however, care should be taken not to overinterpret an increased count as a definite sign of infection. In a study of peritoneal fluid after clean surgical exploratory celiotomy and omentopexy in adult cattle, total nucleated white blood cell and neutrophil counts rose as high as 17,800 and 11,125 cells/μL, respectively, at 1 day after surgery and as high as 65,000 and 46,800 cells/μL 2 days after surgery.

Clinical signs in Stages 3 and 4 are similar and vary in severity based on the location of infection and its duration. Depression, anorexia, dehydration, changes in fecal consistency, depressed ruminal motility, depressed milk production, and weight loss may be intermittently present. Temperature, pulse rate, and respiratory rate vary from above to below normal limits. If the process involves the parietal peritoneum, localized pain may be detectable on physical examination. If the normal motility patterns of viscera are disturbed, the resulting tension on bowel can produce signs of visceral pain.

Intermittent seeding of organisms into the circulation may produce fluctuating fever or signs of septic shock consistent with Stage 2.

Hyperfibrinogenemia is the most consistent hematological finding. Systemic cytology and serum chemistries will

often be within normal limits, although changes seen in earlier stages may be present. The results of peritoneocentesis may vary greatly by location. Cytology for fluid collected from areas of active inflammation will be consistent with an active or sterile abscess (degenerative neutrophils, occasional bacteria), whereas cytology of adjacent sites may be normal or may reflect mild inflammation.

Grossly, accumulations of fibrin are becoming more localized and more organized in Stage 3, but some may still be disrupted manually. By Stage 4, adhesions and abscess walls are primarily fibrous and distinctly localized. Intermittent disturbance of adhesions or abscesses may reinitiate an inflammatory reaction with some less organized fibrin interspersed among the fibrous adhesions.

Common Organisms in Cattle. An accurate description of pathogens involved in peritonitis in cattle is hampered by lack of consistent culture procedures in clinical cases of peritonitis, particularly for anaerobes. Without regard for the source of contamination and methods of culture, the most common agents identified in peritonitis of adult cattle are *Truperella pyogenes* (previously identified as *Corynebacterium/Actinomyces pyogenes*), *Fusobacterium necrophorum*, *E. coli*, and—less commonly—*Staphylococcus* spp. and *Streptococcus* spp. Less information is available about the organisms associated with specific sources of contamination; therefore prediction of probable contaminants for prophylaxis and initial therapy is often based on knowledge of normal local flora.

The flora of the gastrointestinal tract varies greatly based on distance aborad. The ruminoreticulum contains a large number of potentially pathogenic obligate and facultative anaerobes necessary for the digestion process—and relatively few viable pathogenic aerobes. Cases of peritonitis resulting from traumatic reticuloperitonitis are typically attributed to *T. pyogenes*, *F. necrophorum*, and *E. coli*. The acidic environment of the healthy abomasum maintains an essentially sterile environment, although lesions such as ulcers can be colonized by a variety of organisms. Moving from proximal to distal in the intestinal tract, the flora shifts from low numbers of gram-positive aerobes to increasing numbers of gram-negative aerobes (Enterobacteriaceae) in the ileum and very large numbers of gram-negative aerobes and anaerobes in the cecum and colon. Similar flora are present in the urogenital viscera, with the additional consideration of *Moraxella* spp., *Proteus* spp., *Pasteurella multocida*, and *Bacteroides* spp. in the uterus and *Corynebacterium renale* and *Pseudomonas aeruginosa* in the urinary tract. Organisms associated with persistent infection of the umbilical remnants of calves include *T. pyogenes*, *E. coli*, and less commonly, *Proteus* spp. and *Enterococcus* spp. Several nematodes migrate through the peritoneal cavity, including *Setaria* spp. These nematodes typically cause a mild and transient fibrinous peritonitis and may be associated with an increase in peritoneal eosinophils.

Treatment

The four goals of peritonitis treatment are to 1) eliminate sources of contamination; 2) eliminate infectious agents; 3) minimize detrimental effects of the host defense process; and 4) provide systemic support. The relative importance of each and appropriate therapeutic steps vary with the three stages of infection.

Contamination—Stage 1. Therapy in Stage 1 is directed at preventing the development of infection from recently introduced organisms. Prophylactic antibiotics—if not on board already—can be of some benefit but should be given intravenously to achieve high serum and tissue levels as soon as possible. If a source of contamination first develops intraoperatively, rapid steps to minimize the amount and distribution of contamination are indicated. Gross contamination should be localized whenever possible by exteriorizing the site of leakage or packing it off with laparotomy sponges, physically removing all accessible contaminants, and avoiding palpation unless absolutely necessary so that contaminants are not physically transported from the site of leakage to other sites in the abdomen. If the site can be adequately exteriorized to allow external drainage, localized lavage with a sterile isotonic fluid can help remove contaminants. However, generalized lavage is more likely to distribute high concentrations of organisms to potentially clean areas and is only recommended if the site cannot be exteriorized or dissemination has already occurred. Effective removal of lavage fluid is very difficult in the adult cow, and any remaining fluid will interfere with host defenses after closure. There is no proven benefit to adding antibiotics to the lavage fluid if appropriate systemic antibiotics have been administered.

Acute Diffuse Peritonitis—Stage 2 (for example, Traumatic Reticuloperitonitis). Intervention during this stage should focus on preventing death from potential gram-negative bacteremia and eliminating continuing sources of contamination and adjuvants. Systemic antibiotics should have good efficacy against the gram-negative aerobes that are most likely to enter and survive in the general circulation and, if consistent with the source of contamination, against anaerobes. Intraperitoneal organisms have not yet been fully localized by fibrin or omentum and are accessible to systemic antibiotics. Nonsteroidal antiinflammatory drugs should be considered to help manage possible endotoxemia. The use of peritoneal lavage appears to be of limited or no value during this stage and carries the risk of adding adjuvant fluid to the cavity. Surgical exploration is not indicated at this stage unless it is necessary to identify and eliminate a persistent source of contamination.

Acute Adhesive Peritonitis—Stage 3 (for example, LDA with Perforating Ulcer). This stage presents a number of challenges to the surgeon. Systemic antibiotics protect against sporadic shedding of organisms into the systemic circulation, although the developing fibrin accumulations will interfere with access to entrapped bacteria for either systemically or locally administered drugs. Cattle that have survived to this point will have established some seal over sites of contamination to minimize or eliminate further contamination. However, the seal is tentative and may be disrupted by surgical exploration, peritoneal lavage, or normal activities of the cow, potentially sending the peritonitis back into Stage 2 with an increased risk of septicemia and related risks. Unless the cow's condition takes a sudden turn for the worse, surgical intervention is not usually recommended.

Chronic Abscessing Peritonitis—Stage 4. At this point a distinct abscess (or abscesses) has formed, and the goal is to either remove or marsupialize the infection before multiple organ failure occurs. Cranial abdominal abscesses (in the liver or caused by traumatic reticuloperitonitis) that are directly or indirectly (by way of a solid sheet of adhesions) connected to the ventral body wall may be drained transcutaneously using a large-gauge (28-32 French) drain. Ultrasound can be used to guide drain placement in the standing animal, or the drain may be placed during ventral midline celiotomy. Perireticular abscesses that are firmly attached to the reticulum are located at or above the ventral floor of the reticulum and that are caused by traumatic reticuloperitonitis may be effectively drained into the reticulum by an

incision through the reticular wall from the luminal side using a rumenotomy approach. Intestinal resection and/or bypass may be necessary if viscera are obstructed. Antibiotic access to organisms is poor in this stage, and antibiotic use may even be contraindicated if it obscures clinical signs or results in a delay of definitive surgical treatment. Nonetheless, abscesses not amenable to either resection or marsupialization have been managed in other species by long-term therapy (4-6 weeks) with antibiotics that have good penetration into and efficacy in the environment of an abscess. This option is seldom possible in cows for economic and antibiotic regulation reasons. Clinically, it would appear that organisms may be eliminated from some abscesses by the host, and if the abscess wall itself does not interfere with other critical structures, no further action is required.

Prognosis

The prognosis for cases of peritonitis that reach Stage 2 or 3 is fairly low, whereas for Stage 4 it is approximately 30%. Mortality is highest in the early, acute diffuse stage of peritonitis, primarily because of gram-negative septicemia.

Noninfectious Diseases of the Peritoneum

Nonseptic Peritonitis

Chemical peritonitis can be initiated by any body fluid or exogenous fluid that contains toxic elements or has a pH significantly different from relatively neutral peritoneal fluid. Many therapeutic agents that can be administered safely by intravenous or other parenteral routes will induce some degree of inflammatory reaction in the peritoneal cavity, including nonaqueous and many acidic or basic aqueous antibiotics, concentrated fluids such as hypertonic calcium and dextrose, and antiseptic solutions such as povidone iodine solution. Lavage fluids that are either more basic or acidic than peritoneal fluid can also induce chemical peritonitis. Introduction of normally separate body fluids, such as bile, can initiate a marked inflammatory reaction. Chemical peritonitis as a result of urine contamination is the most common form of mild chemical peritonitis in cattle.

Uroperitoneum

Uroperitoneum is discussed in Chapter 16.

Peritoneal Adhesions

Peritoneal adhesions are physical connections between normally separate peritoneal surfaces caused by bridging fibrinous or fibrous tissue. Peritoneal adhesions form as an extension of the healing process in response to damaged tissue that cannot be rapidly replaced or restored to normal function.

Significance

Peritoneal adhesions can have both beneficial and detrimental effects, although the detrimental sequelae are more commonly acknowledged. Intestinal obstruction is the most commonly recognized detrimental effect. Neonates are considered to be at particularly high risk of obstruction. Other undesirable effects of peritoneal adhesions include abdominal pain caused by traction on mobile viscera, infertility from extraluminal compression of the oviducts, and urinary dysfunction caused by extraluminal compression of ureters or traction on the bladder.

It is important to remember that the process of adhesion formation is an extension of the normal healing process. Although the location and extent of adhesions can interfere with visceral function, they also can provide a seal for breaks in continuity of viscera and the body wall, thus serving a potential life-saving function. Adhesions, particularly to omentum, provide a route of neovascularization to areas of ischemia. Adhesions around a site of contamination can help seal the site and limit dissemination of material throughout the abdominal cavity. The surgeon can also intentionally create adhesions to stabilize large-diameter viscera in functional positions (i.e., abomasopexy).

The incidence of peritoneal adhesions in cattle is unknown, but the ability of adhesions to help localize contamination from foreign-body perforation of the reticulum and abomasal ulcers in cattle is well recognized. The extensive omentum in cattle helps separate these common sites of contamination in the cranioventral abdomen from the small and large intestines within the supraomental bursa. This anatomic variation probably accounts for the relatively rare event of intestinal obstruction from adhesions in cattle. Intestinal obstruction is a greater risk with lesions that originate within the supraomental bursa or pelvic region, although these are less common sites of contamination. Infertility associated with adhesions in the region of the ovary and oviducts has been recognized in cows. Dysuria and pollakiuria have been recognized as a result of bladder or urachal adhesions, most commonly in calves.

The cow may be uniquely designed to benefit from the positive effects of peritoneal adhesions. The relatively low fibrinolytic activity of bovine mesothelium would promote adhesion development, whereas the extensive omentum helps separate the most common sites of contamination from viscera more sensitive to their detrimental effects. As surgeons, we use adhesions intentionally to stabilize the abomasum with a variety of abomasopexy and omentopexy techniques. These procedures form stable adhesions by suturing the target structure to the body wall. Preexisting adhesions provide a protective wall that allows us to marsupialize cranial abdominal abscesses into the reticulum or through the ventral body wall. Rapid formation of localized adhesions also serves a protective function during transabdominal bladder catheterization for urinary tract obstruction in steers. The extensive omentum can also be used to help revascularize ischemic tissues that cannot be removed and limit leakage and prevent formation of more detrimental adhesions at the same time.

Pathophysiology

Fibrin deposition is part of the initial response to peritoneal injury or contamination. When the stimulus is localized and transient, fibrin deposits are typically limited to the wound surface and are resolved as new mesothelial cells fill the wound (see Peritoneal Repair). When more extensive areas of tissue damage occur, fibrin deposition is more extensive. If two damaged peritoneal surfaces covered by fibrin matrix come into contact during the early healing period, the matrices can connect, thus forming a fibrinous adhesion. If this fibrin scaffold persists, fibroblast invasion will begin within 3 to 4 days. Collagen deposition by fibroblasts and subsequent infiltration of capillaries create the more solid and potentially detrimental fibrous adhesion, usually within 7 to 14 days after injury. Once a fibrous adhesion is formed, it is considered relatively stable aside from maturation of the collagen and remodeling along principal lines of force. Lysis may be possible through collagenase activity, although the process would be very slow (many months to years).

Control and Treatment

Promotion. Promotion of adhesions may be necessary to help stabilize a mobile viscus, provide a source of neovascularization for damaged tissue, or help seal potential leaks from areas of contamination. Abomasal displacements are the most common reason to promote adhesions in cattle. The surgeon can increase the likelihood of establishing a stable, long-lasting, localized adhesion between the body wall and

either the abomasum or omentum by using a nonabsorbable suture material and incorporating parietal peritoneum in the incision line.

The extensive omentum can be used effectively to create potentially beneficial adhesions in a variety of situations in the cow. By suturing omentum over sites of questionable viability, the surgeon can provide a source of vascularization, help prevent leakage through ischemic visceral walls or poorly sealed anastomotic sites, and block adhesion to other viscera. Care should be taken to avoid interposing sections of omentum between incision edges because this can interfere with incisional healing, thus leading to partial or complete dehiscence.

Prevention. Adhesion prevention may be approached at a number of levels, including the following: 1) decreasing trauma to peritoneal surfaces; 2) decreasing the inflammatory response; 3) decreasing conversion of soluble fibrinogen to fibrin; 4) decreasing contact between traumatized surfaces; 5) controlling the nature of traumatized surface contact; 6) enhancing natural fibrinolytic activity; 7) decreasing fibrinolytic inhibitor activity; 8) decreasing fibroblast invasion and collagen deposition; and 9) enhancing collagenase activity. Specific preventative measures may act at one or more levels and generally fall into the following six categories: 1) surgical techniques; 2) antiinflammatory agents; 3) anticoagulants; 4) fibrinolytic agents; 5) coating solutions; and 6) solid barriers. Some measures are practical and appropriate for adhesion control under all surgical conditions. Others are limited by cost or feasibility to situations of increased risk in animals of significant value to the owner.

Routine preventative measures. A number of practical measures are available to decrease the risk of undesirable adhesions and should be applied routinely. These include limiting serosal trauma, avoiding stimuli that promote inflammation, and controlling contact between traumatized surfaces. Gentle tissue handling and prevention of tissue drying, abrasion, or ischemia are all important steps that decrease peritoneal trauma. Leaving parietal peritoneum unsutured will decrease serosal ischemia and the risk of adhesion without decreasing wound strength or the rate of healing. Minimizing the amount of fluid, blood, ischemic tissue, and foreign material left in the abdomen will also decrease the stimulus for adhesions. When it is necessary to leave surgical foreign material such as sutures in the abdomen, absorbable materials are less likely than nonabsorbable materials to lead to fibrous adhesions. Nonsteroidal antiinflammatory agents decrease a number of factors that promote adhesion formation (including vascular permeability, plasmin inhibitor, platelet aggregation, and coagulation) and reduce adhesion formation in some animal models. Steps to prevent infection are indicated as part of inflammation control and include prophylactic antibiotics, good aseptic technique, minimizing the presence of adjuvants, and avoiding elective abdominal surgery until remote infections can be eliminated.

The extensive omentum and the compartmental nature of the adult bovine abdomen are perhaps the greatest potential tools in protecting against detrimental adhesions. Efforts to limit serosal trauma and contamination to areas outside of the supraomental bursa are indicated whenever possible. Particular care should be taken to avoid inadvertently tracking contaminants from sites of poorly localized infection into the caudal abdomen or supraomental bursa. If lesions exist that cannot be resolved without fully removing ischemic tissue, an omental patch should be considered. If the omentum can be easily mobilized to the site of ischemia, suturing the omentum to the site may seal potential sites of leakage and provide a source of neovascularization. Although omental adhesions are not without potential complications, they are less likely to cause physical or functional problems than adhesions to other serosal surfaces are.

Increased adhesion risk and value. Although the routine precautions described earlier are sufficient in most conditions, some situations merit further preventative measures because the risk of deleterious adhesions is high and the value of extra prophylactic measures is economically warranted for that animal in the owner's opinion. Adult cattle with potentially increased risk include those with lesions in the supraomental bursa or pelvic canal, particularly those in both genders involving the small intestine or spiral colon, or the uterus or pelvic canal in females with high reproductive potential. Calves younger than 3 months of age may have increased risk regardless of the location of the lesion because of their limited omental development and minimal compartmentalization. The relative value of the animal is determined by the owner's assessment of its potential future value. The decision of which options to use should be based on cost and relative benefit in consultation with the owner.

Coating solutions used as a dip or wash for surgical gloves and sponges—or as a local lavage—have been used with some frequency in human surgery and less frequently in equine abdominal surgery. Coating agents decrease serosal trauma primarily by reducing the friction between gloves, sponges, and tissues through mechanical lubrication. The most commonly used coating agent in veterinary practice is 1% sodium carboxymethylcellulose, a high–molecular weight substitute polysaccharide. It is relatively inexpensive in its powder form but must be converted to a sterile solution for application. Coating agents have been of some benefit in decreasing adhesions in man and horse but can make viscera slippery and difficult to handle. Their use may be indicated when surgical manipulation of viscera in a controlled environment such as the supraomental bursa is necessary. A precipitate has been found in the blood of horses and cows in which carboxymethylcellulose was administered as a peritoneal infusion at a dose of 0.96 to 11.7 mL/kg. A direct correlation between the concentration of precipitate and the concentration of solution administered was found. No specific pathologic effect was identified. Solid barrier agents (see Potential Tools) may also be beneficial in preventing adhesions in selected cases but, with the exception of omentum, have not yet been tested in cattle.

Potential tools. A variety of techniques have been explored in human surgery or experimentally in laboratory species and may prove either detrimental or beneficial for future use in cattle. Other coating solutions tested in laboratory animals and humans with variable success include chondroitin sulfate, 32% dextran 70, poloxamer solutions, hyaluronic acid, hyaluronic acid with phosphate-buffered saline, and polyvinylpyrrolidone. In addition to natural barrier agents such as omentum, a number of natural and synthetic solid barrier agents such as fat, amnion, Gelfilm and Gelfoam,[14] Surgicel,[15] polytetrafluoroethylene mesh,[16] oxidized regenerated cellulose,[17] and a chemically derived sodium hyaluronate and carboxymethylcellulose bioresorbable membrane (Seprafilm; Genzyme) have had limited use in cattle.

Recombinant forms of tPA have reached second (Alteplase, Activase; Genentech) and third (Reteplase,

[14]Upjohn, Kalamazoo, MI, USA.
[15]Johnson & Johnson, New Brunswick, NJ, USA.
[16]PTFE, Gore-Tex®, Gore & Associates, Flagstaff, AZ, USA.
[17]ORC, Interceed, Johnson & Johnson, New Brunswick, NJ, USA.

Retevase; Boehringer Mannheim) generations and have shown particular promise in adhesion prevention in human and laboratory animal studies. These agents have significant advantages over earlier fibrinolytic agents such as urokinase and streptokinase. They are absorbed specifically into fibrin clots and show few or no effects on hemostasis if absorbed into the general circulation. They are not antigenic and do not induce an inflammatory response. Although not currently tested for use in bovine abdominal surgery, these may emerge as potentially useful agents in the future, despite the differences in baseline plasminogen activator activity in cattle. Emerging areas of adhesion prevention include prevention of collagen deposition, inhibition of angiogenesis, use of gene therapy, and use of antitransforming growth factor-β and antitumor necrosis factor-α.

Treatment. Treatment of peritoneal adhesions typically involves separating detrimental adhesions and may involve additional procedures to restore the function of affected viscera. Perhaps the most difficult aspect of treating existing adhesions is preventing recurrence. Separation, or *lysis*, of adhesions can be performed bluntly, by sharp incision, or by other methods of incision—including electrocautery and laser. The risk of adhesion recurrence is high regardless of the method of lysis, and preventative measures described previously should be considered if the recurrence of adhesions is a concern. This is more likely to be the case for adhesions in the supraomental bursa or pelvic canal. Lysis of adhesions to the abomasum may be of less concern if the abomasum is secured in a functional position, in which case new adhesions may be beneficial.

Blunt dissection, usually manual, is commonly used to lyse fibrinous and early fibrous adhesions in cattle, particularly when adhesions cannot be exteriorized or well exposed. Particular care must be taken to protect connected viscera. As the adhesion matures, it will be intimately integrated into the wall of connected viscera. A distinct line of separation between fibrous tissue and visceral wall may not be apparent, and the fibrous adhesion often has greater tensile strength than the visceral wall. Uncontrolled tension on a mature adhesion is more likely to pull a hole in the visceral wall than to break the adhesion. To safely break a maturing fibrous adhesion, the surgeon should firmly hold the site of adhesion attachment to a viscus and use his or her thumb and first fingers of both hands to break the adhesion as close to its center and as far from attached viscera as possible. It is often necessary to manually split the adhesion longitudinally into bands with smaller cross-sectional areas that are easier to break. Sharp incision will be necessary for mature fibrous adhesions not amenable to manual disruption and may be advisable for less mature thick adhesions that can be safely exposed. Although laparoscopic laser lysis has shown lower recurrence rates in comparison to other methods in many studies of human and laboratory species, it is seldom a practical option in food animals. Electrocautery carries similar practical limitations.

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CHAPTER 15

Surgery of the Bovine Musculoskeletal System

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MUSCULOSKELETAL EXAMINATION IN CATTLE

André Desrochers

Musculoskeletal examination of cattle lacks uniformity, and many techniques for lameness examination have been described. Veterinarians most often subjectively evaluate the animal to determine which limb or region is affected and then rely on physical examination to determine the diagnosis. This system is useful in identifying lameness sites in most cases. The temperament and lack of halter training of cattle prevent a thorough lameness examination and necessitate consideration of other information such as most commonly affected sites, diseases more common to a given age group, and historical data. In horses, flexion and extension tests, selective perineural anesthesia, and intraarticular anesthesia are used to isolate a focal area of pain. These techniques can be adapted to use in cattle, but they have not become commonplace because cattle are infrequently halter trained, often do not tolerate limb handling followed by controlled walking and trotting, and commonly are housed on surfaces that have a higher risk of falling (e.g., wet concrete). Further, cattle are less commonly presented to the veterinarian for examination of subtle diseases that cause mild or intermittent lameness (e.g., osteochondrosis, bowed tendons, stress fracture). Thorough history, observation of stance and stride, and physical examination are critical to the diagnosis of lameness in cattle. The clinician should remember that 80% to 90% of lameness in cattle originates distal to the fetlock and more specifically the hind feet. For this particular reason, unless there is an obvious lesion on the limb, such as a swollen joint or fracture, examination of the claws should always be performed.

HISTORY

Historical data for the affected individual and of the farm are important to refine differential diagnosis of lameness. The veterinarian should obtain a detailed knowledge of production levels, nutrition programs, vaccination regimens, origin of the animal and length of residence at the facility, any changes in management, and occurrence of other diseases on the farm. Questions more specific to the affected animals should be posed to determine the duration of lameness, when the first clinical signs were observed, what the initial signs were, how the animal's condition has progressed, what medications have been administered—at what dose, by what route, and for how long—and what response was noted after giving medications.

LAMENESS EXAMINATION

Observation

Significant information can be gained by taking a few minutes to look at the animal quietly in its stall or in its normal environment. Look for angular abnormalities, swollen joints, weight bearing, weight shifting, favoring one leg, dropped fetlocks, and muscle atrophy. Lameness most easily can be assessed when the cow is observed in motion. Certain types of walking surfaces may exacerbate some lameness (e.g., grass vs. dirt vs. gravel vs. concrete). A cow with a sole lesion may experience more pain to walk on concrete or gravel rather than grass because concussion is more pronounced.

Posture

Many lamenesses are obvious by observing the cow's stance. Attention should be paid to the posture of the cow—including the back, shoulders, pelvis, and major limb joints. Back posture was a primary factor in a lameness scoring system proposed by Sprecher et al. (Table 15-1). Observations with the animal standing should include the general stance and position of each limb and digit. Compare one region to the opposite side, and determine whether obvious swelling, wounds, shifting of weight, and foot posture such as toe touching or displacement of weight bearing onto the medial or lateral claw are present. A cow with heel lesions (Figure 15-1*A* and *B*) will have a tendency to relieve its pain by standing on the toes. A cow with laminitis will tend to place the feet such that weight is shifted to the heels. Cows with sole lesions of the medial digits of the front limbs tend to place their feet such that weight is shifted to the lateral digit. Animals in which bilateral sole lesions are present may cross their forelimbs (Figure 15-2).

If only one of the digits is affected and the disease is not severe, the animal will bear weight on the sound digit of the same foot. Examination of the foot reveals excess wear of the wall and sole of the healthy digit. In long-standing diseases with severe lameness, the heels are taller and the wall longer on the affected digit in comparison to that of the healthy claw. A dropped fetlock (e.g., hyperextension of the fetlock joint) may be noticed on the contralateral limb because of excessive load on the flexor tendons and suspensory ligament (Figure 15-3). In young animals, angular limb deformities secondary to uneven weight bearing occur rapidly with chronic lameness. When chronic lameness occurs in a hind limb, the contralateral tarsus typically will develop varus deformity (the limb is bowed outward so the convex surface occurs in the lateral aspect of the limb; Figure 15-4). When chronic lameness occurs in a forelimb, the carpus in the affected limb typically develops a valgus deformity (the limb is bowed inward so the lateral aspect of the limb has a concave appearance.

Cows with laminitis often stand with the back arched and the feet placed under the body (Figure 15-5*A* and *B*). They are reluctant to walk. Draining tracts above a swollen coronary band associated with a severe lameness is typical of septic arthritis of the distal or proximal interphalangeal joint (see section Foot Including Digit Fractures). Cattle affected with heel erosion or digital dermatitis will tend to keep their heels just on the border of the gutter in a tie stall barn to relieve the pain. They shift weight constantly because of the

Table • 15-1

Lameness Scoring Systems Described for Cattle

ANDERSON DESCRIPTION	GREENOUGH	SPRECHER ET AL., 1997	WELLS DESCRIPTION
0—Normal gait	1—Normal: gait	1—Normal: stands and walks normally, flat back topline	0—Gait abnormality not visible at a walk: not reluctant to walk
1—Mild: walks easily, readily; bears full weight on foot and mild limb but has an observable gait alteration; stands on all four limbs; line of back bone normal	2—Slightly abnormal: stiff uneven gait	2—Mildly lame: stands with flat back topline; arches back during ambulation; slightly abnormal gait	1—Mild variation from normal gait at walk; includes intermittent gait asymmetry of mild bilateral or quadrilateral restriction in free movement
2—Moderate: reluctant to walk and bear weight but does use the limb to ambulate; short weight-bearing phase of stride; rests the affected limb when standing; increased periods of recumbency, may see arching of backbone	3—Slight lameness: moderate and consistent lameness	3—Moderately lame: stands and walks with arched back topline; shortened phase of stride	2—Moderate and consistent gait asymmetry or symmetric gait abnormality but able to walk
3—Severe: reluctant to stand; refuses to walk without stimulus, non–weight bearing on affected limb; "hoops" over limb rather than bears weight; does not use limb when standing and lies down most of the time; backbone arched with caudoventral tip to pelvis	4—Obvious lameness: still weight bearing	4—Lame: arched back topline when standing and walking; obvious diminished weight bearing in one or more limb(s)	3—Marked gait asymmetry or severe symmetric abnormality
4—Catastrophe: recumbent; unable to rise; humane euthanasia often indicated	5—Severe lameness: non-weight-bearing	5—Severely lame: constantly arched back; difficulty moving	4—Recumbent



Figure 15-1 *A*, Sole ulcer of the left hind lateral digit after debridement. *B*, Heel erosion of a hind foot.



Figure 15-2 An adult Angus cow crossing her front limbs, favoring weight bearing on the lateral claws and relieving the medial claws. She had bilateral white line infection of the medial claws.



Figure 15-3 A 6-month-old Holstein heifer suffering from chronic pain of the right front limb. The left front limb is compensating with a drop fetlock and a flexed carpus.

discomfort. On certain occasions, the animals will relieve the pain on the affected claw by bearing weight on the sound claw only. If both front medial claws are affected, they may cross their legs (see Figure 15-2).

Differential diagnoses for non-weight-bearing lameness should always include the following: sole abscess, fracture, joint luxation, weight-bearing ligament or tendon injury, nerve injury (e.g., radial nerve, femoral nerve, and sciatic nerve), septic arthritis, and septic tenosynovitis. An abnormal deviation of the limb is usually related to a fracture, collateral ligament rupture, or joint luxation. The stance and position of the limb are abnormal with nerve damage, tendon rupture, or a severe ligament injury. Cattle affected with a radial nerve paralysis will have a dropped elbow, but this must be differentiated from a humerus fracture or a radius/ulna fracture (Figure 15-6). A rupture of the muscular or



Figure 15-4 *A*, A Guernsey with laminitis in the hind limbs. Laminitis results in underrun heels with the characteristic stance on the toes. *B*, Underrun heels of the same cow. (Courtesy of Thomas J. Divers.)

tendinous portion of the gastrocnemius muscles is shown by hyperflexion of the hock and a dropped calcaneus (e.g., hock is horizontal rather than vertical during weight bearing; Figure 15-7), but this must be differentiated from a fractured calcaneus or sciatic nerve paralysis (Figure 15-8). Careful attention should be paid to muscle atrophy because this may be caused by nerve injury or disuse atrophy. Neurogenic muscle atrophy occurs rapidly and is severe. Muscle atrophy caused by disuse occurs over a longer period of time. Chronic lameness of the front limb will usually bring atrophy of the triceps, biceps, and scapular muscles. The consequence of this atrophy is a more apparent shoulder with joint instability and the animal may be falsely diagnosed with shoulder joint diseases. Similarly, atrophy of the muscles of the rear limb causes pronounced greater trochanter of the femur that may be misdiagnosed as a coxofemoral joint luxation.

Examination in Motion

In certain cases, lameness is subtle, and other procedures are necessary to localize the lesion. The characteristics of the lameness can more easily be assessed with the animal walking. The observer should attempt to describe the severity of the lameness and assess the individual components of the gait including the arc of flight, position of the digit when it touches or leaves the ground, and the relative time spent in each phase of the stride. An example is a sole ulcer of the left front medial digit (see Figure 15-1). This disease may cause a shortened weight-bearing phase of stride and a prolonged non-weight-bearing phase of stride in the affected limb because the cow is reluctant to place the foot down and quick to relieve pressure by picking the foot up off the ground. This animal may place the foot with the limb carried



Figure 15-5 A heifer with secondary varus deformity of the left hind limb from chronic lameness in the contralateral limb (i.e., peroneal nerve injury). Note that this is the same heifer as in Figure 15-8. (Courtesy of Dr. Hayley Lang, Cornell University.)



Figure 15-6 An adult Holstein cow with a dropped elbow and flexed carpus. She was diagnosed with a torn triceps.



Figure 15-7 An adult Guernsey cow with a ruptured Achilles tendon in the left hind limb. (Courtesy of Dr. Norm G. Ducharme, Cornell University.)



Figure 15-8 A Holstein heifer with peroneal nerve damage in the right hind limb. Note that knuckling of the fetlock should alert the examiner of more proximal nerve involvement, such as sciatic nerve injury. (Courtesy of Dr. Hayley Lang, Cornell University.)

further under the body in an attempt to transfer weight to the lateral digit and may place the foot closer to the body, rather than extending the limb in an attempt to spare the pressure on the heel.

When diseases of the proximal limb, such as the hip, stifle, or shoulder, are suspected, the individual structures should be palpated as the animal walks. Bone-on-bone crepitation may be felt if a luxation or fracture is present. Soft tissue crepitation may be felt if tendon or ligament injury is present or simply because of abnormal muscle tension; crepitation can be from a tendon slipping on a bony prominence. Gas crepitation may be felt if emphysema of the tissues is present (e.g., sucking wound, clostridial myositis) (Figure 15-9). It is sometimes difficult to pinpoint the location of the crepitation because it can be felt away from the lesion. Marked bone-on-bone crepitation felt at the stifle might actually be coming from a coxofemoral lesion; it can be difficult to distinguish. Identification of swelling over the greater trochanter and rectal palpation of the hemipelvis and region of the coxofemoral joint during ambulation may help localize the lesion to the coxofemoral joint (Figure 15-10). Alternatively, auscultation of the suspected regions with a stethoscope during walking or manipulation of the limb may help localize the point of maximum intensity of the crepitus.

Conformation is involved in certain types of lameness. Cattle that have a postlegged conformation (e.g., hyperextended joints during weight bearing, usually tarsus and stifle) are more subject to degenerative changes in the joints (Figure 15-11). The animal does not have the same capacity for shock absorption because hyperextension causes excessive load on cartilage and subchondral bone leading to cartilage damage, inflammation, synovitis, progressive joint degeneration, and osteoarthritis. Sickle-hocked (e.g., hyperflexion of the hock during weight bearing) cows endure excessive stress in flexor tendons that may result in a drop in the fetlock and rapid wearing of the heels.



Figure 15-10 A cross Simmental cow with a chronic dorsal left-hip luxation. The gluteus muscles are swollen. (Courtesy of Dr. Michele Ballotin, Miega, VR, Italy.)



Figure 15-9 A Holstein heifer with a severely swollen right hind limb secondary to clostridial myositis.



Figure 15-11 A Holstein cow with abnormally straight hind limbs.

Grading of Lameness

Assessment of the severity of the lameness is helpful to classify lameness and monitor responses to treatment. For this reason, lameness scoring systems have been created. Equine lameness scoring systems have been well standardized. However, these systems are difficult to extrapolate for use in cattle because of the need to control the gait (e.g., walk, trot) and perform various tests (e.g., circling, flexion tests). These tests may be performed in show cattle, but no standardization has been established for cattle. Various scoring systems have been described for use in lameness examination of cattle, and these scoring systems are based more on locomotion rather than responses to specific tests. Greenough et al., Wells et al., Sprecher et al., and Anderson et al. (see Table 15-1) have described lameness scoring systems that use grades of 1 to 5 or 0 to 4, but none has been universally accepted in practice. Multiple variations of lameness scoring have been published. Whatever the system used, veterinarians should be consistent and coherent to evaluate with precision, but agreement and reliability are low, with significant variability. At least, all associates in the same practice should agree on a grading system to facilitate communication within the practice and with the clients.

A stall lameness score has been described to evaluate cows in tie stalls. Four parameters are evaluated: repeated weight shifting, constantly standing on the edge of the stall, uneven weight by lifting the foot off the ground, and uneven movement when the cow is encouraged to move side to side. One point is given for each present parameter. A cow with a score ≥2 had 4.88 times the odds of being lame compared with a cow with a score <2.

Recently, automatic locomotion scoring systems have been used on large farms where manual scoring is difficult to do. The automatic scoring system is based on a kinetic, kinematic, or indirect approach. The kinetic system is based on weight distribution and variability on force plates. Some systems are commercialized and are currently used to detect lame cows. Lameness is detected by weight shifting on force plates and weight distribution. The kinematic approach implies the use of a marker on the animal, a video recording system, and sophisticated software. The indirect approach measures behavior parameters like lying time with an accelerometer attached to a limb or the neck of the cow.

Limb Examination

At this point, the clinician should have an idea of which leg is affected and an estimation of the affected region of the limb. Now the affected limb must be examined carefully. Unless an obvious lesion is apparent, the authors start by a palpation of the limb. The clinician should watch for pain reaction and determine whether swelling, deformation, crepitation, warmth, and wounds are present. A hoof tester may be used to evaluate pain of the claw (Figure 15-12). The hoof tester should be applied where the common lesions of the sole surface are usually situated, including the apical region of the sole, the white line zone, and the prebulbar region. The hoof tester may be used to impact the dorsal and abaxial hoof wall to evaluate for a pain response that suggests laminitis, submural infection, and fracture of the distal phalanx. These manipulations can be performed with the animal standing and by picking up the affected limb for a short time. Alternatively, these procedures may be done with the animal free-standing and rope restraints used on the limb, restrained in a head gate or chute, restrained in a standing hoof-trimming chute, restrained in lateral recumbency on the ground after a casting rope is used, or restrained in lateral recumbency on a tilt table. Sedatives and tranquilizers should be avoided whenever observations of pain responses are desired. After localization of the lesion, local anesthesia or sedation may be required to complete the examination.



Figure 15-12 A hoof tester is applied across the claw. (Courtesy of Dr. Andrew H. Parks, University of Georgia.)

Examination of long bones is performed by applying firm pressure in regions of minimal soft tissue presence (e.g., the medial aspect of the tibia and radius, the greater trochanter of the femur, the greater tubercle of the humerus, etc.). If the animal has an adverse response—as evidenced by withdrawal, avoidance, attempts to kick the evaluator, or muscular flinching—the opposite leg should be palpated for comparison. Most fractures are obvious, but incomplete nondisplaced fractures can be suspected if deep palpation of the limb elicits a pained reaction. Each joint should be palpated separately, and complete flexion, extension, abduction, and adduction of the limb should be done. Isolation of the shoulder and elbow or of the stifle and tarsus is difficult when flexion or extension movements are performed because muscle tendon units unite these joints.

Special techniques are employed when injuries to the coxofemoral joint or cruciate ligaments are suspected. Examination of the coxofemoral joint requires manipulation of the rear limb. These tests can be performed with the animal standing, but they are easier to perform with the animal in lateral recumbency with the affected limb uppermost. The relative position of the greater trochanter to that of the tuber coxae and the tuber ischii should be determined before the animal is laid down. The normal position of the greater trochanter is ventral to both of these bony prominences, and imaginary lines drawn between them will create a triangle (Figure 15-13). Failure to palpate the greater trochanter may suggest a ventral luxation of the coxofemoral joint. Positioning of the greater trochanter in line with the tuber coxae and tuber ischii suggests dorsal luxation of the coxofemoral joint (see Figure 15-13). After the animal is laid down with the affected leg uppermost, the foot or the metatarsus III/IV is grasped and the entire limb rotated while performing repeated abduction and adduction motions. Fracture of the physis of the head of the femur (i.e., capital physeal fracture) should elicit crepitation of the hip that can be felt and occasionally heard. Coxofemoral joint luxation should elicit more crepitation, excessive movement of the greater trochanter, and ease of abduction if the luxation is ventral (Figure 15-14).

Cranial cruciate ligament (CCL) rupture is more difficult to diagnose. Typically, the stifle is swollen and painful to palpation. A "drawer" test can be performed with the animal standing and is easier to perform when the injured limb is



Figure 15-13 Lateral view of a cow with white tape on the greater trochanter, tuber coxae, and tuber ischia. Note that the relative position of the greater trochanter is ventral to the tuber coxae and tuber ischia. (Courtesy of Norm G. Ducharme, Cornell University.)



Figure 15-14 A downer cow is in lateral recumbency for a physical examination. The right hind limb is abducted to evaluate the coxofemoral joint. She had a ventral luxation of the coxofemoral joint.

weight bearing. The examiner should stand immediately behind the affected leg and place both hands on the tibial crest by encircling the limb. Then the examiner's knee is placed on the back of the calcaneus. A drawer test is positive if displacement or crepitation can be felt after firm caudal traction on the tibial crest followed by a sudden release. The anatomy and function of the rear limb of cattle are such that the tibia is already displaced cranial to the femur when the CCL is ruptured. Thus caudal movement of the tibia is a sign of positive drawer. The examiner must be careful when performing this test to avoid being kicked. An alternative technique is for the examiner to stand cranial and lateral to the affected limb and place both hands on the tibial crest. Then a firm, rapid thrust is applied to the proximal tibia, and the limb is observed for displacement and felt for crepitus. Although this test is safer to perform, we have found this technique to be less sensitive for detecting injury to the CCL.

Use of Selective Anesthesia

Selective perineural anesthesia with lidocaine HCl 2% solution is common practice in equines for lameness diagnosis but is uncommon in cattle. Nonetheless, selective perineural anesthesia can be used to isolate regions of lameness. The clinician must be familiar with the anatomy of the nerves of cattle because these are quite different from those of the horse. The authors often employ regional anesthesia by placing intravenous (IV) lidocaine distal to a tourniquet (IV regional anesthesia). The tourniquet is left in place for 10 to 20 minutes, released, and the lameness reevaluated. IV regional anesthesia induces anesthesia for a significantly shorter period of time compared with that of selective perineural anesthesia. Therefore lameness evaluation must be expedited. This technique is useful when the clinician wants to rule out the digits as a source of pain that has failed to be localized by previously mentioned diagnostic tests. With selective perineural anesthesia, each digit can be anesthetized individually, and this procedure aids in more specific isolation of lameness. Occasionally, intraarticular anesthesia is desired to isolate subtle lameness to a specific joint. We have found this to be most useful for diseases that affect the coxofemoral joint, the scapulohumeral joint, femoropatellar and femorotibial joints, and the elbow. In complex joints, the examiner should pay special attention to the frequency of joint communication, depending on which joint is injected (Table 15-2). Recently a femoral nerve block under ultrasound guidance was described to diagnose spastic paresis of the quadriceps.

Examination of the Foot

Adequate restraint is critical to performing a thorough examination of the claw. Fortunately, claw-trimming chutes have become commonplace and facilitate the ease, safety, and efficiency of examination. If a chute is not available, different techniques have been described for restraining the animal. Certain animals require sedation either for restraint or to complete the examination. Xylazine HCl is commonly used because of its rapid onset of action, its short duration, and the availability of reversal drugs. It is preferable to withhold feed from these animals for 12 to 24 hours before sedation to avoid bloating and reduce the risk of regurgitation while in lateral or dorsal recumbency. However, we routinely place cattle in lateral recumbency for short periods of time (e.g., <30 to 45 minutes) without restricting feed. Close monitoring of the patient is required to prevent respiratory compromise or regurgitation. Immediately after application of restraint, the foot is thoroughly cleansed. Thorough examination is difficult to perform when mud, manure, and debris contaminate the foot. The total time the animal is maintained in lateral recumbency should be minimized to reduce the likelihood of development of muscle or nerve

Table • 15-2

Joint Communications in Cattle

JOINT	COMMUNICATION	FREQUENCY
Fetlock	Medial to lateral digit	99%
Stifle	Femoropatellar to medial femorotibial	100%
	Lateral femorotibial to medial femorotibial and femoropatellar	65%
	All three together	57%
Carpus	Antebrachiocarpal—no communications	96%
	Middle carpal to carpometacarpal joint	86%
	Middle carpal joint to antebrachiocarpal and carpometacarpal joints	14%
	Carpometacarpal joint to middle carpal joint	86%
	Carpometacarpal joint to middle carpal and antebrachiocarpal joints	22%
Tarsus	Tibiotarsal to proximal intertarsal	100%
	Proximal intertarsal to distal intertarsal	0%
	Distal intertarsal to tarsometatarsal	21%
	Tarsometatarsal joint to distal intertarsal joint	43%

Adapted from Desrochers A: Characterization of the anatomic communications of the carpus, fetlock, stifle, and tarsus in cattle using intraarticular latex and positive contrast arthrography. Master's thesis. Kansas State University, Manhattan, KS, 1995.
Frequency of communication is based on communication when the first joint listed is injected. The phrase *all three together* indicates that communication did not depend on which joint was injected.

injury. Heavily muscled and obese cattle are at increased risk of developing myopathy or neuropathy after prolonged periods of lateral recumbency. Excessively thin animals are at increased risk of developing nerve injury. These conditions are caused by direct compression injury and by indirect injury resulting from compression of vessels that causes hypoxia to the tissues.

A hoof tester is applied to the different areas of the claw. Firm pressure should be applied, but the examiner must be cautious to apply similar degrees of pressure to each point and—most importantly—on each claw. Without consistency of application, response to hoof pressure tests can be misinterpreted. When hoof testers are applied with consistent pressure, they can be reliable. Corrective trimming may be performed first, followed by detailed inspection of the lesions. Each blackened area (e.g., cavity filled with manure, dirt, debris, or necrotic tissue) should be explored. This is particularly important along the white line or the apical region of the sole. A pinpoint lesion is often similar to the "tip of an iceberg," and further trimming may reveal large defects or an abscess (Figure 15-15*A* and *B*). The interdigital space is inspected for redness, abnormal proliferation, or necrotic tissue. The heel bulbs are closely inspected for the presence of erosions, separation, digital dermatitis, or other

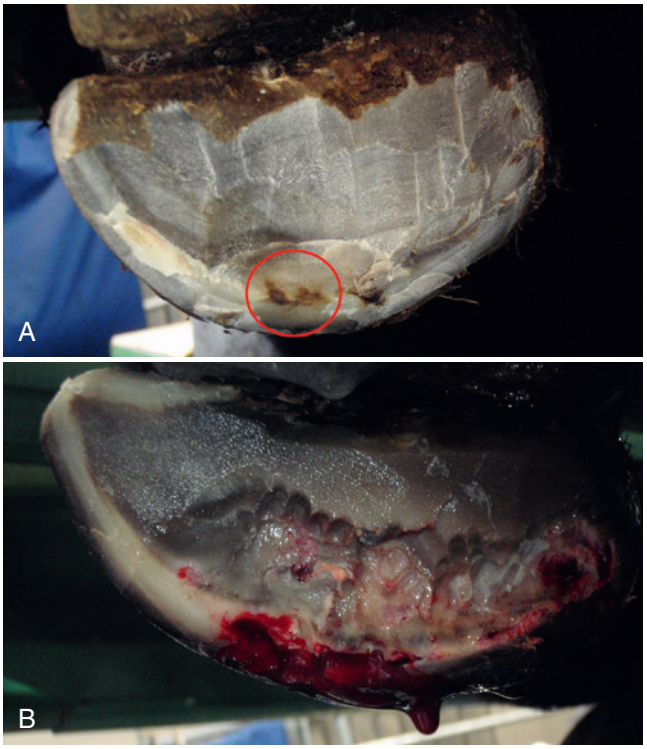


Figure 15-15 *A*, A small dark spot on the white line was hiding a severe infection as shown in *B*.

lesions. Any draining tract should be inspected with a malleable probe or a teat cannula.

SELECTED DIAGNOSTIC TESTS

To eliminate the foot as the lameness cause in difficult cases, a four-point digital block can be easily performed, anesthetizing the two digits. Ancillary diagnostic tests for lameness evaluation in cattle include radiography, arthrocentesis, ultrasonography, computed tomography (CT) scan, scintigraphy, histopathology, microbial culture, and thermography. Each test has specific indications to be performed, but we most commonly perform radiography, ultrasonography, microbial cultures, and arthrocentesis. If a joint or tendon sheath is suspected to be involved, sterile saline may be injected into the joint after aseptic preparation of the skin. The lesion is observed for drainage as evidence that a communication with the wound exists. This must be done aseptically to prevent iatrogenic infection of the joint or tendon sheath. In many areas, nuclear scintigraphy is banned in all food-producing species. This has greatly limited use of scintigraphic bone scans as diagnostic tools to discover bone inflammation or bacterial infection.

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TREATMENT OF PATHOLOGIC DISEASES

FOOT INCLUDING DIGIT FRACTURES

Chuck Guard and Norm G. Ducharme

Digital disease in cattle is common. The hind lateral digit is most commonly involved. Lameness that originates from the digits is a multifactorial disease. General hygiene of the housing environment, parity, stage of lactation, abnormal hoof growth, gait abnormalities, age and weight of the animal, and rear claw angle are all risk factors that can contribute to lameness.

The most common lesions in lameness that originate from the digits are sole ulcer, sole abscess, interdigital necrobacillosis, and digital dermatitis. These lesions can often be treated with local debridement, topical antiseptic on the wound, and if necessary a wooden block applied with polymethylmethacrylate[1] or preferably polyurethrane[2] on the healthy digit of the affected limb to alleviate pain. However, a sole ulcer and abscess can result in deep sepsis of the digits if neglected. This sepsis can spread to the distal sesamoid bone and its synovial bursa and to the distal and proximal interphalangeal joints. A thorough examination of the digits and radiographic evaluation help the clinician choose the appropriate treatment and surgical approach. Age, sex, weight, type of production, and environment of the cattle also should be considered in the choice of therapy.

TOE TIP NECROSIS

This condition is seen secondary to bruising of the corium near the toe tip (Figure 15-16) with secondary necrosis of tissue due to anoxic damage. The internal pressure in the

[1]Technovit, Jorgensen Laboratories, Loveland, CO, USA.
[2]Bovi-Bond, Vettec.com, Oxnard, CA, USA.



Figure 15-16 A Red Holstein cow, 5 years old, with toe tip necrosis (*arrows*) on the lateral claw of a left hind limb with infection of the pedal bone tip after overtrimming. This was seen 10 days after overtrimming (i.e., removing too much horn from the wall and tip) by the owner. (Courtesy of Dr. Karl Nuss, University of Zurich.)



Figure 15-17 Toe tip necrosis treatment. After removal of the affected tip of the hoof, a burr is used to remove the infected distal part of the third phalanx (i.e., pedal bone) (Courtesy of Dr. Karl Nuss, University of Zurich.)



Figure 15-18 Vertical crack in the dorsal wall filled up with polymethylmethacrylate and tightened with wires.

fairly rigid toe tip can increase beyond systolic blood pressure from osmotic movement of fluid into the bruised tissues. The typical case is chronic when seen and may include extensive invasion proximal to the toe tip. Following IV regional anesthesia and clean preparation of the cornified portion of the digit, the apex of the toe is amputated with hoof nippers (Figure 15-17). Slices of tissue are removed until all evidence of sepsis is removed. A hoof block is attached to the sound digit and a pressure bandage applied to the cut surface to control hemorrhage. The bandage may be changed in 2 days. Systemic antibiotics are not routinely used but analgesics are. Regrowth of the digit from the healthy stump usually results in a hoof of normal conformation.

VERTICAL CRACK

This condition is secondary to excessive drying of the superficial layers of the hoof wall and subsequent trauma. The crack starts from the weight-bearing surface of the hoof and extends proximally. If the coronary band is traumatized, the opposite situation is observed; a vertical crack starts from the coronary band and extends distally. The animal will be lame if the sensitive laminae or other deep structures of the hoof are affected.

The first part of treatment is thorough debridement of the crack. This can be done with a curved hoof knife or motorized burr. Debridement should be carefully done so that the intact sensitive lamina is not too traumatized. A 1-cm bar or triangle may be used to make grooves at the end of the crack to redistribute the force and prevent the crack from extending further. Wiring of the crack also prevents further extension and decreases the pain engendered by movement of the wall on the sensitive laminae. If the dermis is not infected, polyurethane can be applied to fill the defect (Figure 15-18). If the sensitive laminae are exposed or infection is present, polyurethane application should be delayed until the infection is controlled and the exposed laminae are covered with keratinized tissue (i.e., dry surface). In severe cases, a wooden block should be applied on the healthy digit and the animal should be rested in a stall. The prognosis is good to excellent if the sensitive laminae are not infected. Hoof ointment may be applied to the hoof to prevent further desiccation.

AMPUTATION OF THE ACCESSORY DIGIT (DEWCLAW)

Amputation of the accessory digit of the hind limb has been described to prevent self-inflicted teat laceration. This is far less commonly done and typically the dewclaws are amputated with a Burdizzo emasculator in the first week of life. In older calves (4-8 weeks old) a surgical technique is performed.

The animal is sedated and kept in lateral recumbency. The area around the accessory digit is prepared aseptically, and a local block is performed around the dewclaw. The dewclaw is pushed proximally to avoid resection of the plantar annular ligament and plantar common digital artery. Either Burdizzo or Sharp dissection with a scalpel is used to remove the dewclaw. Hemostasis is performed, and a bandage with antiseptic ointment is placed on the wound. If the surgery is performed on older cattle, a tourniquet around the distal metatarsus may be used to control hemorrhage.

INTERDIGITAL HYPERPLASIA (CORN)

Interdigital hyperplasia is a proliferative reaction of the interdigital skin. The incidence of lameness caused by interdigital hyperplasia is between 1% and 4.8%. Excessive outward spreading of the digits secondary to an underdeveloped ligamentous structure overstretches the interdigital skin and causes hyperplasia. There is a heritable component to interdigital hyperplasia, with Hereford cattle most commonly affected. The continuous mechanical stimulation of the interdigital skin due to splaying of the toes when walking induces the skin proliferation. Males are affected more often than females. The animal affected by this disease is usually not lame unless the growth is traumatized while walking or standing. A foul odor may be present during physical examination because of erosive lesions and secondary infection. The proliferative mass is hairless, ulcerated secondary to



Figure 15-19 Interdigital hyperplasia lesion with a vertical crack on the lateral digit.

pressure trauma, and painless to palpation (Figure 15-19). The lesions can be found on one or all four limbs. Treatments with either en bloc resection of the growth, cryosurgery, and electrocautery have been successful. The procedures should be performed after administration of IV regional anesthesia. If en bloc resection is chosen, an Allis tissue forceps is used to grasp the interdigital corn. A wedge-shaped excision is made on each side of the mass. All hyperplastic tissues should be removed to minimize the risk of recurrence. The interdigital fat should also be removed to avoid its interposition between the incised skin edges. Hemorrhage is controlled and a bandage is applied. The toes are wired together by drilling two holes through the hoof wall at the point of the toes. The bandage is left in place for 5 days, and the animal is kept in a small, clean stall.

A second type of interdigital hyperplasia is caused by skin reaction to chronic superficial infection with *Bacteriodes nodosus*. Interdigital dermatitis due to *B. nodosus* is very common in housed dairy cattle. The degree of hyperplasia and heel erosion associated with this infection is directly related to hygiene of the feet and preventive foot-bathing practices. Skin hyperplasia may be minor to extensive and includes multiple 2- to 3-mm-diameter erosions. There is usually a distinct odor associated with the dermatitis. Cattle with interdigital hyperplasia are at greater risk of both interdigital necrobacillosis and digital dermatitis. Treatment of individual cases of interdigital dermatitis is usually not done, but the secondary infections are treated either systemically for foot rot or topically for digital dermatitis.

FRACTURE OF THE DISTAL PHALANX

Fracture of the distal phalanx is secondary to trauma or very rarely fluorine intoxication. Pathologic fracture secondary to osteitis of the distal phalanx has also been reported. Cattle show a sudden onset of severe lameness and a typical stance: bearing weight on the healthy digit of the affected leg. The lateral hind digit or medial front digit often is affected. In the authors' experience, the front digits are affected more commonly. Examination is important to rule out sole abscess, white line abscessation, or distal interphalangeal (DIP) joint abnormalities that cause similar clinical signs.

Radiographic images of the affected digit are important to diagnose this condition. Radiographs usually show a

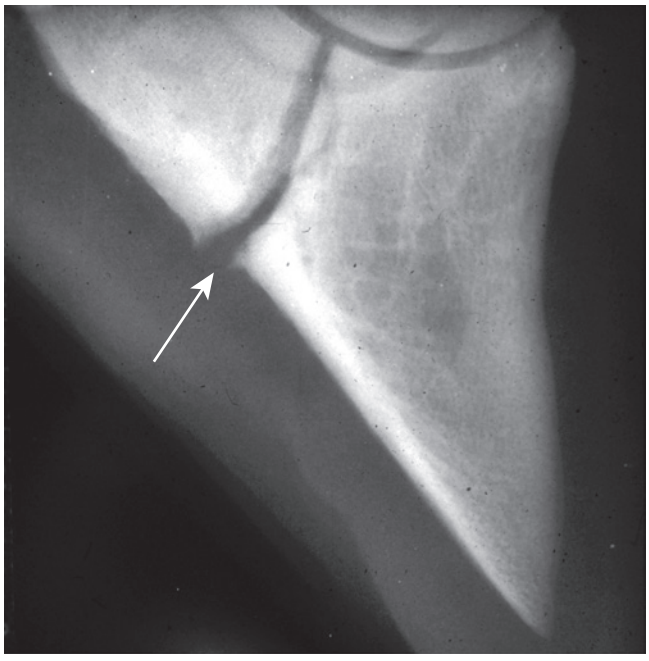


Figure 15-20 Interdigital radiograph of a digit. There is a displaced articular fracture of the distal phalanx (*arrow*) extending from the solar surface to the coffin joint.

fracture that extends vertically from the middle aspect of the distal interphalangeal joint to the solar surface with a fracture gap superior at the solar aspect of the distal phalanx (Figure 15-20). The palmar or plantar fragment may rotate because of the pull of the deep digital flexor (DDF) tendon. Treatment consists of immobilizing the affected digit by putting a wooden block on the healthy digit of the affected limb. The affected digit is wired in slight flexion to the wooden block to prevent separation of the palmar or plantar fragment from the parent bone caused by tension from the DDF tendon on the flexor process of the distal phalanx. The wooden block should be left in place for 6 to 8 weeks, with the animal confined to a small well-bedded stall. After 6 weeks, the block is removed and the animal is reassessed. Determination of improvement should be based upon clinical signs, not on radiographic evaluation. The fracture gap can take 4 to 5 months to heal and sometimes 8 months. The prognosis for return to normal function is good if the cattle are treated promptly. If bony proliferation and signs of degenerative joint disease are visible on radiographs or a septic process caused the fracture, facilitated ankylosis of the DIP joint or digit amputation should be considered.

PEDAL OSTEITIS

Pedal osteitis in cattle is generally a septic process of the distal phalanx. The infection originates from solar trauma (such as a puncture wound or severe abrasion at the toe) or extension of an existing infection around the distal phalanx. The incidence could be high in feedlot cattle on a concrete floor. Cattle recently placed in a feedlot will fight around a feed bunk, and their hind digits will slip on the concrete floor, thus causing severe abrasion at the toe region and secondary infection.

A preoperative radiograph is helpful to evaluate the extent of the infection (Figure 15-21*A* and *B*). The sole and infected corium are debrided first (Figure 15-22). The

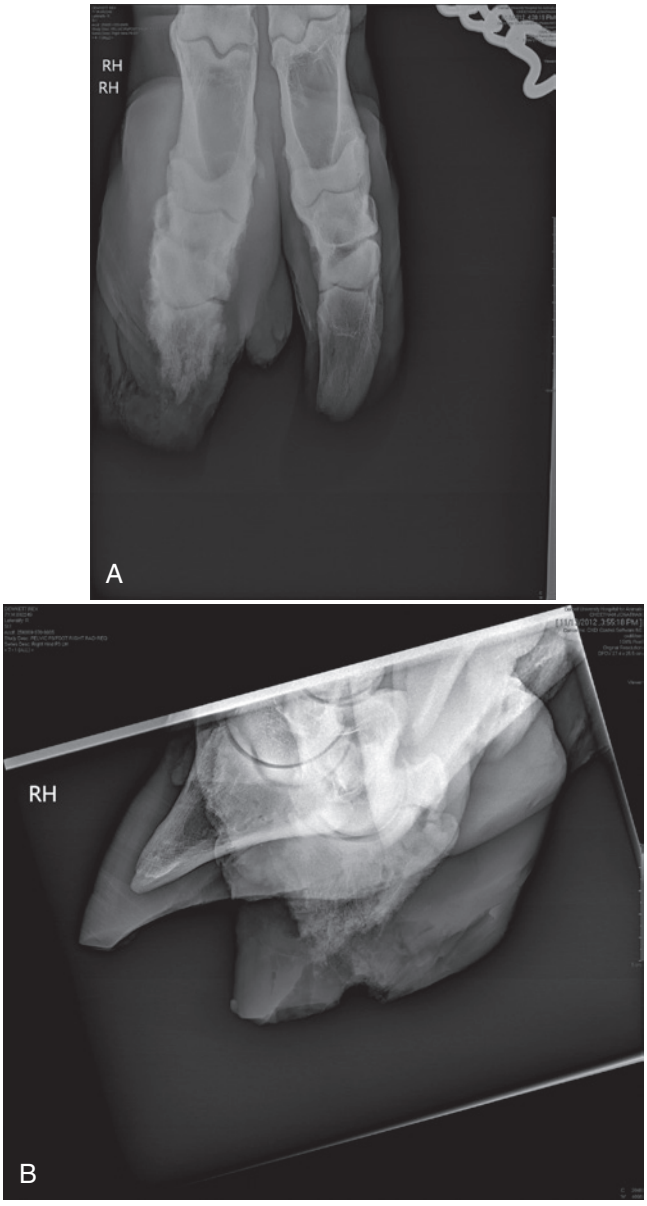


Figure 15-21 *A*, 60-degree dorsoplantar radiographs of a 2-year-old steer with septic osteitis of the lateral claw. *B*, Lateral scissor view of the same hoof. Note that bone lysis is moderate to severe at the distal aspect of the distal phalanx.



Figure 15-22 Severe pedal osteitis of the lateral digit treated with partial amputation.

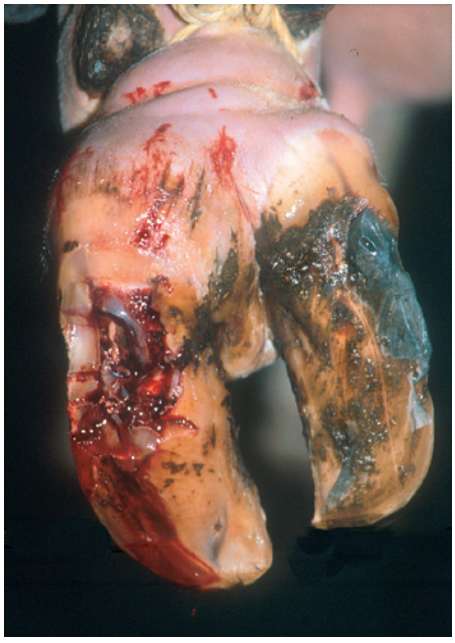


Figure 15-23 The lateral digit has a chronic sole ulcer. The heel and the coronary band are swollen, which is compatible with septic arthritis of the distal interphalangeal joint.

infected part of the distal phalanx is curetted. Lavage is performed and the wound is bandaged. A wooden block is applied on the healthy digit of the affected limb. Bandaging and lavage should be continued until the infection is controlled and granulation tissue covers the distal phalanx. Amputation could be performed for economic reasons or if the infection is extensive.

Septic Arthritis of the DIP Joint

Cattle affected with DIP joint sepsis have a history of chronic lameness and often have been previously treated. The clinical signs vary with the function of the structure involved in the process and the chronicity of the disease. Sepsis of the DIP joint is caused mainly by extension of sole disease, such as pododermatitis circumscripta or traumatica and white line disease (Figure 15-23). A penetrating foreign body in the interdigital space or interdigital phlegmon is also often implicated in sepsis of the DIP joint. The distal sesamoid bone and its bursa, the tendinous portion of the DDF muscle, the tendon sheath of the DDF muscle, and the superficial digital flexor (SDF) muscles are in close relationship; uncontrolled solar infection may affect these structures.

Cattle with DIP joint sepsis usually are very lame. The coronary band is swollen and red, and the adjacent horn is of poor quality. A fistula tract may be present on the dorsal palmar or plantar aspect of the abaxial collateral ligament of the middle and distal phalanx. Another fistula tract may be seen dorsoproximally to the coronary band and axial to the tendinous portion of the common or long digital extensor muscle. Examination of the hooves and interdigital spaces may show the origin of the septic arthritis. A swollen heel

suggests infection of the distal sesamoid bone and its bursa and the digital cushion pad, and a fistula tract may be present at the heel–skin junction. Cattle with deep sepsis of the digit show signs of pain when the heel is palpated or the digit is extended. Severe necrotic process may extend into the tendinous portion of the DDF tendon so it ruptures and causes the affected digit to tilt upward.

Radiographic evaluation of the DIP joint is helpful in determining the extent and duration of the process. Septic arthritis is apparent on radiographs 10 days after onset of the infection. Widening of the joint space from increased intrasynovial pressure, soft tissue swelling, and the presence of gas may be the only abnormalities seen on radiography of acute septic arthritis. Radiographic views of a DIP joint with chronic septic arthritis first show a decreased joint space because of cartilaginous degeneration followed by an increased joint space because of subchondral bone lysis. Distal and proximal periosteal proliferation is present (Figure 15-24). The distal sesamoid bone may show lysis of its articular surface or may be destroyed completely. The proximal interphalangeal (PIP) joint also might be involved in the process. If a fistula tract is present, communication with the DIP joint is confirmed by inserting a sterile probe into the tract or with positive arthrography.

Acute septic arthritis of the DIP joint is rare but possible. Arthrocentesis is indicated, and synovial fluid may be submitted for cytologic examination and bacterial culture. Treatment consists of systemic and local antibiotics and thorough joint lavage. A 14-gauge 5-cm needle is inserted dorsoproximal to the coronary band, axial or abaxial to the tendinous portion of the extensor muscle and at a 60-degree angle to the coronary band. The joint is distended with 10 mL of 0.9% NaCl solution. A second needle is then inserted plantar or palmar to the abaxial collateral ligament of the DIP joint, above the coronary band, at a 45-degree angle. Lavage of the joint is performed until the synovial fluid is clear and without fibrin clots.

Five hundred milliliters of 0.9% NaCl solution under pressure usually is enough to lavage the joint. Arthrotomy should be considered if fibrin is abundant and lavage difficult.

Joint lavage is performed a minimum of 3 days subsequently or longer if needed. Joint lavage is discontinued based on clinical improvement, clarity of the synovial fluid, or negative bacterial culture. In the authors' experience *Trueperella pyogenes*, *Escherichia coli*, and *Staphylococcus* spp. are the most common bacteria isolated from an infected DIP joint. Systemic antibiotics should be administered for 1 to 2 weeks after disappearance of clinical signs.

Chronic presentation of septic arthritis of the DIP joint is a more common situation (Figure 15-25). Surgery is the treatment of choice to provide debridement and drainage of the DIP joint. The two surgical options are digit amputation and facilitated ankylosis of the joint.

Digit Amputation

Digit amputation has been used successfully to treat pedal osteitis, luxation, or fracture of the distal phalanx, deep sepsis of the digit, and septic arthritis of the DIP or PIP joint. The advantages are that it is a rapid and inexpensive procedure, all the infected/affected tissues are resected, and cattle usually return rapidly to their previous level of production. The disadvantages are that expected production life is reduced, heavy animals do poorly, and cosmetic result is poor. The production life of cattle that have a digit amputated depends on which digit was removed, weight of the animal, and type of housing. Cattle that weigh more than 680 kg and have a digit amputated will have a short production life. The site of amputation should be chosen based on the extent of the infection. Digit amputation through the distal aspect of the proximal phalanx is the most common technique. It is a rapid and simple procedure and usually provides a wide resection and effective drainage of the affected digit (Figure 15-26).



Figure 15-24 Radiograph of the distal hind limb, dorsoplantar view. There is subchondral bone lysis, widening of the distal interphalangeal joint (*black arrows*), and new bone formation (*white arrows*). This is compatible with a chronic septic arthritis of the distal interphalangeal joint.



Figure 15-25 Chronic septic arthritis of the medial distal interphalangeal joint in a cow. Note that there is fibrous enlargement proximal to the coronary band compared with the lateral claw. (Courtesy of Norm G. Ducharme, Cornell University.)



Figure 15-26 Digit amputation, a few days after the surgery was performed.

The distal limb is prepared aseptically, and IV regional anesthesia is administered. The interdigital skin is incised to the level of the distal aspect of the proximal phalanx axially, with a 45-degree angle to the proximal digit abaxially. An assistant can hold the digit to provide more stability when the osteotomy is performed in the same plane. A bandage is applied and left in place for 5 days. The bandage then should be replaced and the new bandage left in place for another 5 days. A broad-spectrum, systemic antibiotic is administered for 3 to 5 days after the surgery.

A skin flap could be preserved to cover the stump by continuing the interdigital incision distal and abaxial at the palmar and dorsal aspect of the digit and along the proximal aspect of the coronary band. Although this technique provides a superior cosmetic result and decreases subsequent care of the stump, it may prevent adequate drainage and extension of the infection. The authors therefore recommend this technique for a nonseptic process of the digit (pedal fracture, digit luxation) or distal sepsis without extensive soft tissue infection (pedal osteitis).

Arthrodesis of the DIP Joint

The techniques for arthrodesis of the DIP joint differ by surgical approach. Choice of a technique should be based on the anatomic structure infected and the location of existing draining tracts. Intact ligaments and tendons should be preserved when possible to keep the affected digit stable during the ankylosis procedure.

The advantages of ankylosis of the DIP joint compared with digit amputation are that cattle have a longer production life, the outcome is superior for a heavy animal or when the hind lateral or front medial digit is affected, and the healing result is more cosmetic and mechanically more stable. The disadvantages are that it is more expensive and technically demanding, more postoperative care is needed, and cattle have a slower return to previous production because of the pain engendered by the procedure and the long process of ankylosis.

Arthrodesis of the DIP Joint by the Solar Approach

The surgery is performed under sedation and IV regional anesthesia. Cattle are restrained in a foot-trimming chute or in lateral recumbency with the affected leg uppermost. The plantar or palmar portion of the sole and the heel should be pared away until the sole can be indented easily. In severe and extensive infection of the DIP joint that originates from a solar lesion, the distal sesamoid bone and the joint can be felt through the wound and the sole already can be indented easily. The distal limb is prepared aseptically. A horizontal incision that starts 2 cm proximal to the coronary band is made along the plantar or palmar aspect of the second phalanx (Figure 15-27*A*). The tendinous portion of DDF muscle is cut from its insertion on the distal phalanx and resected proximally at about 5 to 7 cm from its insertion. The distal sesamoid bone is removed, exposing the interphalangeal joint (Figure 15-27*B*). If necrotic, it is removed easily with a rongeur. If not, the two collateral ligaments and the distal ligaments are resected with a scalpel blade. The DIP joint then is exposed. Debridement of the joint from the solar wound through the dorsal hoof wall, 1 cm distal to the coronary band, is performed with a 1.3-cm drill bit (Figure 15-28). The joint is curetted and copious lavage is performed with isotonic solution. If the tendon sheath or the tendinous portion of the superficial digital flexor muscle is infected and necrotic, the incision is extended 2 to 3 cm proximally to the accessory digit to allow debridement and drainage. Any necrotic tissue at the heel and sole junction is removed. A wooden block is applied with appropriate adhesive on the healthy digit of the affected limb (Figure 15-27C), and the claws are wired together with the affected digit in slight flexion. The wound is bandaged and lavage is performed every other day, if possible. Systemic antibiotics are given for 2 to 3 weeks, and flunixin meglumine is given as needed for the first 2 weeks.

Kostlin has reported a success rate of 85% for 281 cattle with this technique. This technique provides good visualization of the DIP joint, excellent drainage, and a good long-term prognosis. However, the approach to the joint is difficult. Even if not affected by the septic process, the tendinous portion of the DDF muscle and the distal sesamoid bone—as well as the tendon sheath—must be resected, which can create instability of the joints.

Arthrodesis of the DIP Joint by a Dorsal Approach

Surgery is performed with the cattle sedated and restrained in lateral recumbency. IV regional anesthesia is administered. The surgical site is prepared aseptically. Two arthrotomies are performed either with a trephine that is 5.56 to 14 mm in diameter or by making a circular incision with a scalpel blade. The first arthrotomy is made into the DIP joint on the dorsal aspect of the digit, 0.5 cm proximal to the coronary band, abaxial or axial to the tendinous portion of the common (forelimb) or long (hind-limb) digital extensor muscles. The second arthrotomy is made 0.5 cm proximal to the coronary band caudal to the abaxial ligament of the DIP joint (Figure 15-29). When a draining tract communicates with the joint, the tract is enlarged with a trephine if needed, and a second arthrotomy is performed dorsal or palmar at the previously mentioned sides. Cartilage and necrotic bone are curetted through the arthrotomy sites. A wooden block is placed on the healthy digit of the affected limb (see Figure 15-27C). Joint lavage is performed through the arthrotomies daily for 1 week or until the infection is controlled and the swelling is decreased. From the experience of the authors, cattle were slightly lame postoperatively for 4 months.

This technique is indicated if the distal sesamoid bone and the tendinous portion of the DDF tendon are not affected. The approach to the joint is easy to perform and less invasive. This technique also provides more stability

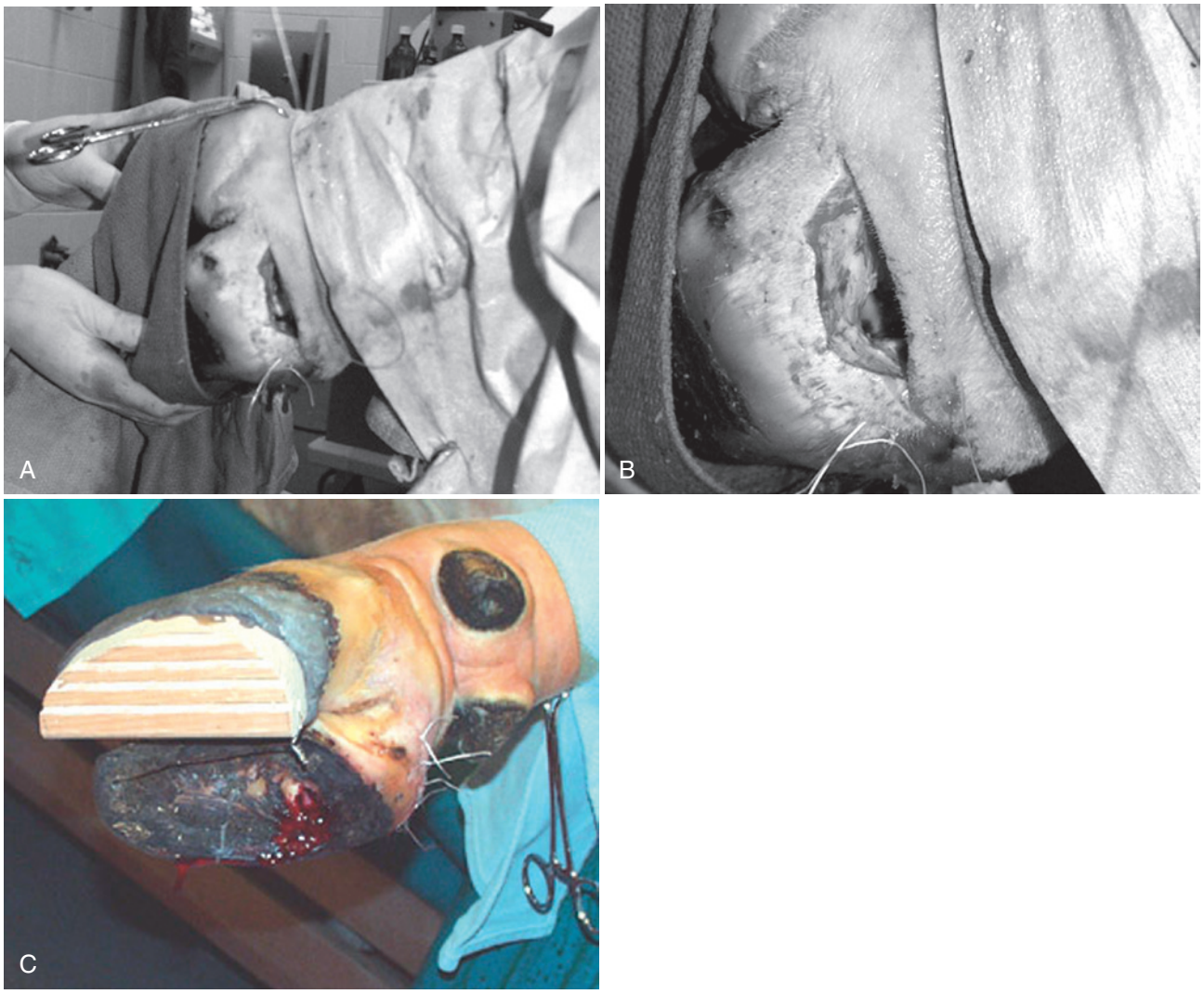


Figure 15-27 *A*, Plantar approach to the distal interphalangeal joint. *B*, Close-up view of the distal interphalangeal joint after removal of infected navicular bone. *C*, During placement of wooden block on intact lateral claw. Note the curettage and removal of solar abscess on the medial claw. (Courtesy of Norm G. Ducharme, Cornell University.)

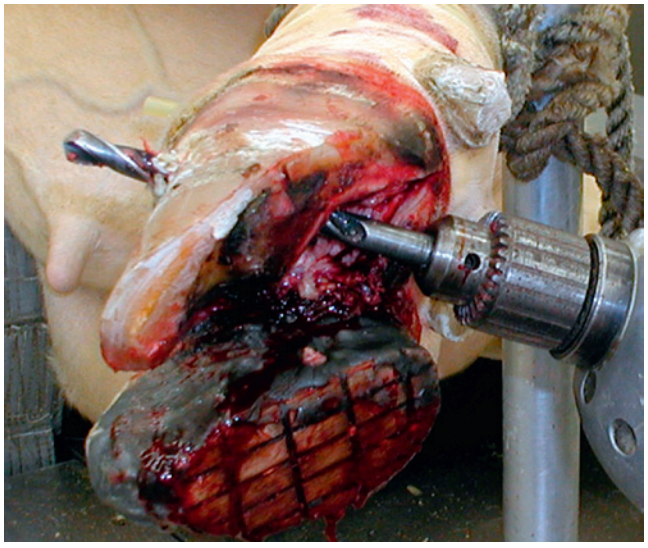


Figure 15-28 Facilitated ankylosis of the distal interphalangeal joint—solar approach.

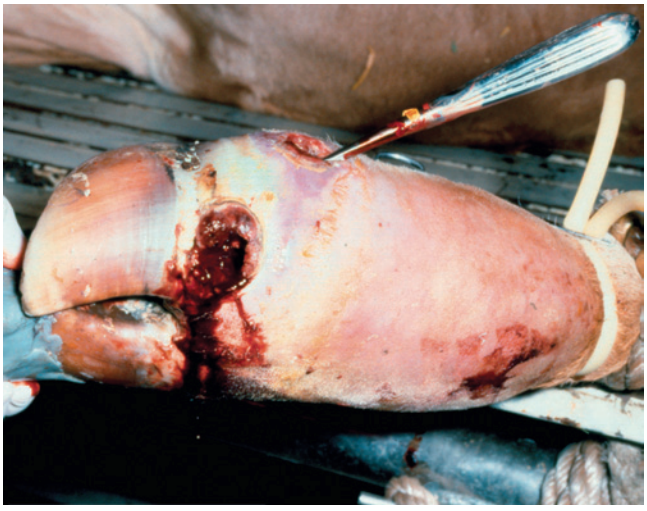


Figure 15-29 Facilitated ankylosis of the distal interphalangeal joint—dorsal approach.

to the joint, because the tendinous portion of the DDF muscle is not disrupted. Limited visibility of the DIP joint surfaces is attained with this surgical approach; therefore adequate removal of cartilage and necrotic bone is difficult to assess. Drainage is less efficient than with a solar approach.

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SEPSIS OF THE COMMON DIGITAL FLEXOR TENDON SHEATH

Adrian Steiner

Sepsis of the common digital flexor tendon sheath (CDFTS) typically occurs by direct inoculation (via penetrating wounds, foreign bodies, or iatrogenic trauma from farm implements such as a pitchfork or front-end loader) or as a result of extension of local sepsis, such as with sole ulcer, a septic DIP joint, a septic navicular bursa, or a heel bulb abscess. Septic tenosynovitis caused by hematogenous translocation of bacteria (septicemia) is rare. Each digital branch of the SDF and DDF tendon has its own tendon sheath, and the two sheaths rarely communicate near their proximal extent. Clinical signs include lameness (moderate to non-weight-bearing with a shortened second phase of the stride), recumbency, decreased milk production, and decreased feed intake. When standing, affected cattle may be reluctant to walk or may walk with the limb abducted or adducted to shift weight to the unaffected digit. Effusion of the tendon sheath results in swelling proximal to the dewclaws. Swelling in the pastern region is limited by the annular ligament of the fetlock, the digital annular ligament, and the proximal interdigital ligament. The lateral portion of the hind-limb tendon sheath is the most frequently affected. Diagnosis of septic tenosynovitis includes a thorough orthopedic and ultrasonographic examination (Figure 15-30) and collection of synovial fluid for cytologic evaluation, culture, and total protein analysis. Temporary fixation of a wooden block to the unaffected partner claw usually elicits marked pain relief.

Treatment of septic tenosynovitis of the CDFTS should include management of the inciting disease and of the

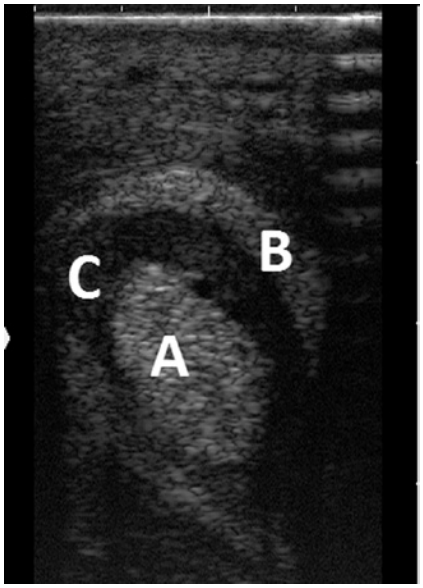


Figure 15-30 Ultrasonsographic view of a septic tenosynovitis of the common digital flexor tendon sheath of an adult cow. *A*, deep digital flexor tendon; *B*, manica flexoria of the superficial digital flexor tendon; C, synovial space with increased amount of synovial fluid.

infected tendon sheath. Medical management alone (systemic antibiotics, hydrotherapy, nonsteroidal antiinflammatory drugs [NSAIDs]) is unlikely to be effective because of the severity of the inciting disease and the excessive fibrin deposition within the tendon sheath. Antibiotics cannot effectively penetrate fibrin foci to achieve therapeutic concentrations. Effective treatment options of septic tenosynovitis include tenoscopic lavage, tenosynoviotomy with surgical debridement, resection of affected tissue and passive ventral drainage, or digit amputation (see Digit Amputation). Selection of the most appropriate treatment option depends on economic constraints and on the severity of the septic process, ranging from the least invasive technique (arthroscopic lavage), adequate for treatment of serofibrinous tenosynovitis, to the most invasive technique (tenosynoviotomy and debridement with ventral drainage) in chronic cases with severe septic involvement of the tendons. Amputation may be classified as a salvage procedure.

Tenosynovioscopic Lavage

Tenosynovioscopic lavage, combining through-and-through and distention-irrigation lavage, was described for successful treatment of septic serofibrinous tenosynovitis with minor tendon involvement in four adult cattle. A 1-cm skin incision is made 4 to 5 cm proximal to the dewclaws in the midline of the respective CDFTS. The sleeve with a blunt trocar is introduced into the proximal pouch of the CDFTS, just proximal to the palmar/plantar annular ligament and advanced along the whole of its length in a distal direction, plantar or palmar to the SDF tendon (Figure 15-31). The arthroscope is then introduced into the sleeve and the CDFTS examined and thoroughly flushed using 3 to 6 L of physiologic Ringer's solution. Care has to be taken to also explore the dorsal aspect of the synovial sheath. At the end of the procedure, 12×10^6 IU of sodium benzylpenicillin and 10 mL of 2% lidocaine were injected into the CDFTS. Aftercare includes 30,000 IU/kg sodium benzylpenicillin every 8 hours IV through an indwelling catheter in the jugular vein for 7 days, while 4 mg/kg ketoprofen was administered orally once a day for 3 to 5 days. Recommendations for further care after discharge from the clinic are daily intramuscular administration of benzylpenicillin procaine (30,000 IU/kg) until day 10 after surgery, removal of the skin sutures on day 11, removal of the wooden block on day 30, and stall confinement until day 60 after surgery. In cases of fibrinous tenosynovitis with minor tendon involvement, removal of fibrin clots may be achieved with a Ferris-Smith forceps under arthroscopic control (Figure 15-32).

Tenosynoviotomy with Resection of Affected Tissue

If purulent tenosynovitis is present, tenosynoviotomy with surgical debridement and passive ventral drainage is indicated. Surgical exploration provides optimal access for thorough debridement of the tendon sheath and tendons. Exploration is performed by incising the sheath beginning at its origin proximal to the accessory digits and extending in a curvilinear fashion distally between the dewclaws to the coronary band. Thorough debridement and lavage of the tendons and the sheath are performed. If the tendons are necrotic, affected aspects are rigorously resected (Figure 15-33). Thereafter, an indwelling Penrose drain exiting distally is introduced to facilitate drainage after surgery, and the proximal four-fifths of the sheath and the skin are sutured. The Penrose drain is removed at 3 to 5 days after surgery (Figure 15-34), and a bandage is maintained until suture removal at day 11. Antibiotic and antiinflammatory medication should be administered for at least 10 days after surgery. Dehiscence of the surgical wound is a potential complication because of the high motion occurring in the palmar/plantar aspect of the fetlock. In our experience, the prognosis of this procedure is favorable if the involved tissues were removed rigorously.

Affected cows are to be kept separate from the herd in a box with adequate dry straw bedding. A wooden block is applied to the healthy digit to improve comfort and ambulation during the convalescent period.

Digit amputation proximal to the middle phalanx provides ventral drainage of purulent material and fibrin from the tendon sheath (see Digit Amputation). Immediate relief



Figure 15-31 Position of the arthroscope sleeve for tenosynovioscopy of the common digital flexor tendon sheath.

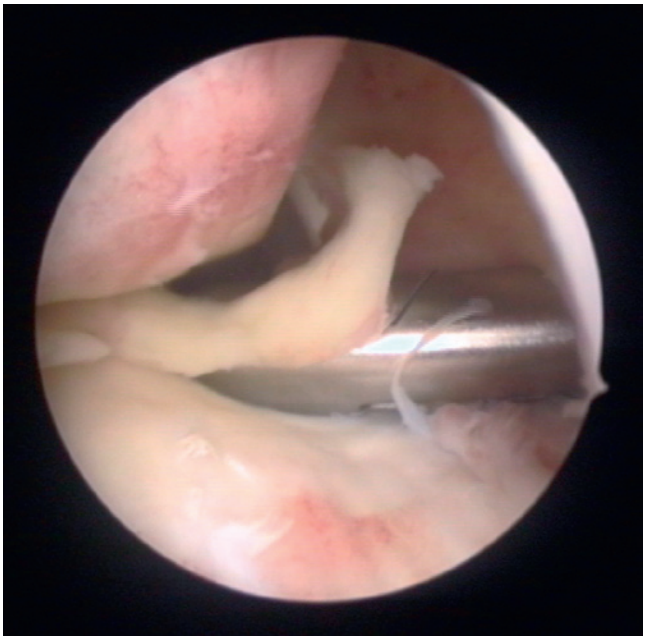


Figure 15-32 Removal of fibrin clots from the common digital flexor tendon sheath, using Ferris-Smith forceps under arthroscopic control.

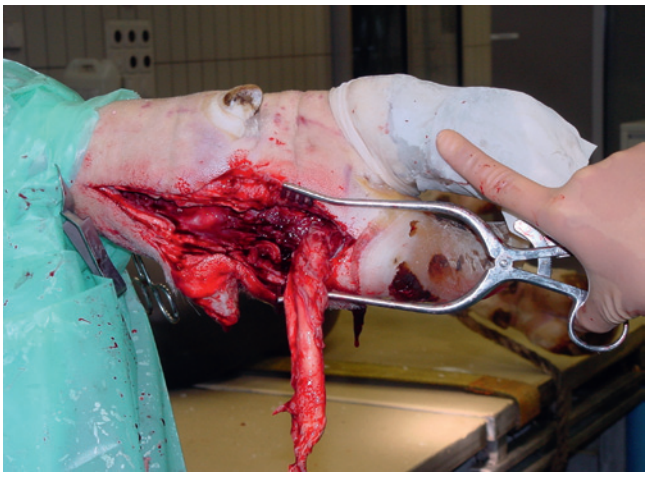


Figure 15-33 Tenosynoviotomy of the common digital flexor tendon sheath, allowing for resection and thorough debridement of necrotic tissues.



Figure 15-34 Three days after tenosynoviotomy of the common digital flexor tendon sheath. The proximal four fifths of the sheath and the skin were sutured. The Penrose drain is still in place.

from pain and swelling may be noted after surgery. Antibiotics should be administered for 7 to 10 days after surgery but may be omitted if early salvage is performed.

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SEPTIC ARTHRITIS (EXCLUDING DIGIT)

André Desrochers

Septic arthritis is the most common condition that affects the joints in cattle. Indeed 47% to 72.2% of all lameness other than from the foot is located in the joints and ligaments. Few data are available on the importance of septic arthritis in cattle. In Israel, arthritis counts for 13.8% of lameness cases. Although not as common as claw diseases, the consequences of septic arthritis are dramatic if left untreated, with potential irreversible joint dysfunction. Regardless of the incidence or prevalence of septic arthritis in a herd, it is always potentially serious and detrimental to the productive life of the individual animal. Septic arthritis needs to be addressed quickly with aggressive treatment to control the infection and limit its degenerative action on articular cartilage. It can also be the first sign of a contagious disease like *Histophilus somni* or *Mycoplasma bovis*.

PATHOPHYSIOLOGY

Septic arthritis in cattle is predominantly of bacterial origin, causing a lot of damage to the joint. The origin of the bacteria is variable. It can be caused by direct trauma to the articulation (primary), an adjacent infection to the articulation (secondary), or a systemic infection (tertiary). Direct trauma is a common cause of septic arthritis in adult cattle. Trauma does not have to go through the joint; periarticular infection that results from trauma may progress and extend to the joint at a later time. The distal limb, being less protected by soft tissue, is more susceptible to infection from external trauma, especially if it occurs in a heavily contaminated environment. A good example of a secondary septic arthritis in adults is a foot lesion (abscess/ulcer), which often extends directly into the coffin joint. Calves with umbilical infections or adults with endocarditis are at risk for polyarthritis from a remote site. The most common bacterial organisms isolated from septic arthritis in adult cattle are *Trueperella pyogenes*, *Escherichia coli*, and other environmental bacteria. Cattle affected by *Histophilus somnus* and *Mycoplasma* spp. usually have more than one articulation infected. If only one cow is polyarthritic in a herd, endocarditis has to be included in the differential. Cardiac murmur upon auscultation, enlarged jugulars, ventral edema, and a history of recurrent fever should alert the clinician to the diagnosis of endocarditis. Lyme disease, pneumonia, and mastitis can also be a source of septic arthritis.

Even though the synovial membrane is somewhat effective in eliminating bacterial contamination (up to 100 colonies of *Staphylococcus aureus*), villi inflammation allows microorganisms to attach and establish themselves. Toxins from bacteria, specifically *S. aureus*, can cause direct chondrocyte death. Although bacteria directly damage cartilage and synovial membrane and fluid, the animal's immunologic response is often the most serious cause of articular degeneration. Microorganisms are destroyed first by neutrophils and their enzymes (elastase, cathepsin, gelatinase, and collagenase). These enzymes destroy cartilage and its components as well as bacteria. Moreover, neutrophils and inflamed tissues release free radicals, which have the same harmful effects on articulation. Furthermore the diverse bacterial pathogens trigger activation of multiple inflammasomes (NLRP1, NLRP3, NLRC4, AIM2, and pyrin) at the synovial mucosa. The inflammation increases capillary permeability and lets other mediators (kinin, factor of coagulation, cascade of the complement, fibrinolytic system) including inflammatory cytokines (interleukin [IL]-1β and IL-18) arrive at the site of infection. These mediators stimulate the synoviocytes and chondrocytes. The chondrocytes release mediators as matrix metalloproteinase, which decreases proteoglycan production. The reduced production and increased degradation of proteoglycans deteriorates the physical properties of cartilage, thus decreasing its compressive potential and making it more susceptible to trauma. The presence of fibrin on cartilage and synovial membrane decreases the nutritive effectiveness of synovial fluid and inhibits diffusion of antibiotics used to treat septic arthritis. If left untreated, this

fibrin will form a pannus covering all surfaces of the joint cavity.

DIAGNOSIS

Differential diagnosis for swollen joint should include septic arthritis, osteochondrosis, osteoarthritis, ligament injury, idiopathic arthritis, and articular fracture. Cattle affected with septic arthritis are severely lame. Direct trauma to the joint is the principal cause of septic arthritis in adult cattle. Infection may result from external trauma; a wound over a swollen joint should arouse suspicion of septic arthritis. On closer examination, one may detect synovial fluid flowing freely from the laceration. A wound should be cautiously investigated to avoid contaminating the joint if the synovial membrane is still intact. A malleable probe can be used to evaluate a draining tract.

Arthrocentesis is performed in the area away from the wound to avoid contamination (Figure 15-35). After surgical preparation of the site, synovial fluid is withdrawn and conserved for further analysis. The existence of communication from a wound adjacent to the joint is verified by injecting 10 to 20 mL of a sterile solution into the joint. Arthrocentesis can be easily performed by placing the needle into the area with maximum joint distention (Figure 15-36). Unsuccessful aspiration is rather rare but possible. It can be caused by inadequate technique, low volume of fluid, or needle obstruction with fibrin or plica of synovial membrane or fat pads (stifle). If the synovial fluid is purulent, thick, or contains a lot of fibrin, a 14-gauge needle can be used but only if septic arthritis is highly suspected based on ultrasound or radiographic images. The synovial fluid is collected by passive flow or by using a 10-mL syringe. The synovial fluid should be placed in a purple top tube for cytologic analysis and in a milk culture tube for bacteriologic culture. Macroscopic examination of synovial fluid is often diagnostic (increased turbidity, decreased viscosity, fibrin). If macroscopic changes are subtle, the sample should be submitted for cellular counts and differential. Nuclear cell counts greater than 25,000/µL, polymorphonuclear cell counts greater than 20,000/µL or a proportion higher than 80%, and total protein greater than 4.5 g/dL indicate septic arthritis.

Microorganisms are not always seen on cytology. Ideally, routine, aerobic, and specific anaerobic and mycoplasma cultures must be requested in all cases of septic arthritis. Samples should be submitted as soon as possible and should be transported refrigerated when a delay between sampling and culture is expected. Contacting the bacteriology laboratory is strongly recommended to confirm the ideal shipping procedure and to specify the culture of bacteria, such as *Mycoplasma* spp. or *H. somni*, which require specific media. A positive synovial fluid culture provides important information for choosing appropriate antibiotics. Bacterial isolation and identification are obtained in 50% to 60% of the samples submitted of known septic arthritis. A blood culture medium reportedly increases the likelihood of a positive culture. Affected animals already on antibiotics have a decreased chance of in vitro bacterial growth. Recently developed sensitive molecular techniques such as polymerase chain reaction increase the identification rate of microorganisms. Swabbing an open joint through a wound results in multiple bacteria being isolated because of severe environmental contamination and will not be diagnostic.

Radiographic examination helps a clinician specify a diagnosis and establish a prognosis. A portable radiographic machine can be used for the distal limbs, but its power is limited for more proximal articulations such as the stifle and coxofemoral joints. It is imperative to take two radiographic views: a craniocaudal and lateromedial. Chronic presentation is common in food animals. For this reason, radiographic lesions are often obvious (Figure 15-37). When interpreting radiographic views, the clinician must remember that osseous lesions can only be seen when the disease process is 10 to 14 days old. Therefore an infection can be present but obvious



Figure 15-35 Open joint laceration at the dorsal aspect of the fetlock. The plantar aspect of the joint is surgically prepared for arthrocentesis, avoiding the contaminated area.



Figure 15-36 *A*, A puncture (*arrow*) was the entry point of this septic swollen fetlock. *B*, Arthrocentesis is performed away from the entry point in the palmar pouch of the fetlock joint. The synovial fluid is opaque and dusky.



Figure 15-37 Radiographic image of a septic fetlock, dorsoplantar view. There is soft tissue swelling, and increased joint space of the medial compartment from subchondral bone lysis. Bone proliferation is present at the distal aspect of the metatarsi. A wooden block was glued to the lateral digit, relieving weight from the infected medial digit.

radiographic lesions will be seen later. Bone tissues must undergo a demineralization greater than 50% to be visible on radiographs. Cartilage is not visible on radiographs. Soft tissue swelling with gas present can be seen in certain cases, and increased articular space will be observed in acute conditions. Chronic lesions such as subchondral bone lysis, decreased joint space from articular destruction, osteomyelitis, periosteal reaction, and bony proliferation are more visible. These lesions can be focal or multicentric. With chronic septic arthritis, severe bone neoformation is observed more frequently in adults than in calves where bone lysis is more typical (Figure 15-38).

Soft tissues are better evaluated with ultrasound examination. Synovial fluid and membrane, joint surface, and surrounding connective tissues are easily seen within certain limits when one uses the proper equipment and technique, depending on the joint being given the ultrasound (see Chapter 2). In acute septic arthritis, the synovial fluid volume increases, and echoic (gray) material (fibrin) can be seen floating in the joint (Figure 15-39*A*). Cartilage is anechoic (black) because of its high water content. Subchondral bone is hyperechoic (white), and lysis or a defect will change its contour. If a laceration is present, structures surrounding the joint (tendons, ligament, and joint capsule) are evaluated and may help the clinician make a more precise prognosis and apply the appropriate treatment. Ultrasound can also be used to access underguidance deep structures like the coxofemoral joint (Figure 15-40).



Figure 15-38 Dorsoplantar radiographic image of a septic foot on a 900-kg Charolais bull. Multiple joints were infected. The extent of bone proliferation in heavy animals is shown. Stents were applied to protect the arthrotomy incisions of the stifle (cow in lateral recumbency).

TREATMENT

Before starting any treatment, the owner must be fully aware of the consequences from the condition and the short- and long-term prognoses. A good clinical assessment of the joint is essential in choosing the appropriate treatment. Multiple treatment possibilities exist for septic arthritis, but the following basic principles must be followed: 1) control the infection; 2) remove abnormal joint fluid; 3) control inflammation; and 4) restore joint function. In all case, the primary cause should be treated.

Antimicrobial Uses

In cattle, bacterial infection is the major cause of septic arthritis; therefore antibiotics are immediately used if a joint is swollen and the animal severely lame. Choosing the appropriate antibiotic is based on the suspected microorganism involved, the antibiotic's ability to work in the presence of fibrin and an acidic environment, the route of administration, the cost of treatment, and the withdrawal time for meat and milk (see appropriate governmental regulations). Penicillin procaine is the first-choice antibiotic for treating *T. pyogenes*, the most common microorganism isolated in cattle. Antibiotics effective against gram-negative *Bacteroides* should be considered to treat a severely contaminated wound. In general, all antibiotics penetrate and diffuse well into an acute septic joint. The presence of fibrin or necrotic tissue decreases the effectiveness of most antibiotics; therefore adjunct treatments such as joint lavage or drainage (as described in the section on Joint Lavage/Drainage) should be an essential part of the treatment plan. Antimicrobial treatment should be continued 2 to 3 weeks after an animal begins to clinically improve. The standard systemic routes of administration are IV, intramuscular, and subcutaneous. Oral medication does not achieve sufficient concentration to treat joint infections adequately. The clinician should be conscious that any extended treatment duration may change withdrawal time. Other routes should be considered:

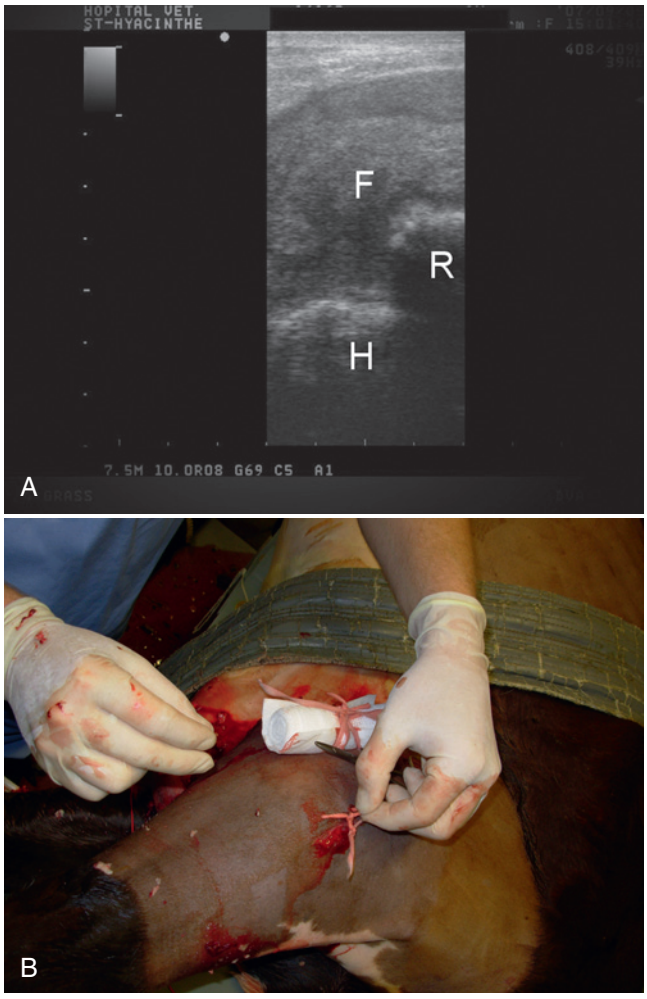


Figure 15-39 *A*, Ultrasound image with a 7.5-MHz linear probe of a septic elbow. The probe is applied laterally. H, humerus; R, radius; F, fibrin. *B*, Arthrotomy sites are covered with stents that can be easily removed daily to lavage the joint if needed.



Figure 15-40 A 5-MHz curvilinear ultrasound probe is positioned between the greater trochanter and the coxofemoral joint for guided arthrocentesis with a spinal needle.

intraarticular injection, IV injection under a tourniquet, and antibiotics incorporated into a slow-release medium.

The main advantage of intraarticular injection is a higher minimal inhibitory concentration at the site for a longer time period. Gentamycin injected intraarticularly in horses has shown an antibiotic concentration superior to minimal inhibitory concentration for 24 hours, but this antimicrobial should never be used in cattle in North America. In cattle, intraarticular injections have been used empirically based on extrapolation from scientific data in other species. Clinicians must respect the principles of extralabel use of antibiotics when they choose this and other routes of administration.

IV injection of cephalosporin has been well investigated in cattle. Regional IV perfusion of antimicrobials has many advantages: it reaches infected tissue by diffusion at a far greater concentration (tenfold) than after IV administration. In addition, the local tissue concentrations remain higher than after IV administration; thus a lower dose may be effective. The main disadvantages are the need to apply and maintain a good tourniquet and injection site morbidity. Regional perfusion is performed as follows. A catheter is applied proximal to the joint to medicate and is placed into a local distended vein. Using an aseptic technique, the clinician should place a catheter after considering the best protection obtainable. Therefore place the catheter where a bandage can be easily applied and maintained. Alternatively, repeated regional IV injections can be given. Appropriate antibiotics are diluted to a 30- to 60-mL volume and administered slowly via a catheter.

Implantation of nonabsorbable or absorbable, slow-releasing molecules combined with antibiotics has shown promise. Polymethylmethacrylate (PMMA) in different combinations with antibiotics has been used in horses and humans to treat chronic osteomyelitis. Without a doubt, the slow release of antibiotics for 1 to 2 months at concentrations superior to minimal inhibitory concentration is an advantage for conditions that necessitate long-term antibiotics. Although PMMA beads are not commercially available in North America, they are easy to make. The antimicrobials are added to the polymer powder and thoroughly mixed before adding the liquid monomer. After the liquid polymer is added, the preparation is mixed until it is uniform. Elongated beads approximately 2 cm long by 5 mm wide are made in a line around a No. 2 nonabsorbable monofilament suture (polypropylene or nylon) to facilitate later removal. Recovery of antibiotics in PMMA beads for years after implantation has been documented, thus necessitating bead removal in farm animals. Unlike PMMA beads, absorbable preparations don't have to be removed. Gentamycin-impregnated (not allowed in North America) collagen sponges were used successfully to treat chronic septic arthritis in cattle.

Antiinflammatory drugs are useful for pain management and control of the inflammatory process. As mentioned previously, the inflammatory response is as much, if not more, deleterious by itself for the joint than the presence of bacteria alone. One must be aware of potential negative secondary effects of administration of NSAIDs, particularly when prolonged treatment may be necessary. NSAIDs have gastrointestinal and renal toxicity. They must be used with caution in cattle with decreased appetite or those that are dehydrated. To our knowledge, there are no published studies on the efficacy of NSAIDs in cattle for the control of inflammation with septic arthritis. However, flunixin meglumine was reported to be effective in controlling pain in dairy steers with induced synovitis. The analgesic effect of meloxicam also was demonstrated in cows with resection of the DIP joint. Phenylbutazone cannot be recommended anymore in North America in dairy cattle for food safety and legal

considerations. Finally, sodium iodide 20% IV is occasionally used to treat chronic nonresponding septic arthritis at a recommended dosage of 15 mL/kg. Although its exact mechanism of action is unknown, it seems particularly effective when inflammation is chronic and granulomatous (*T. pyogenes*).

Joint Lavage/Drainage

Because infected joints are painful, adequate analgesia, anesthesia, and immobilization are necessary for joint lavage and drainage. Most joint lavages are performed under sedation, and the animal should be immobilized in lateral recumbency. If arthroscopy is used to treat septic arthritis, the procedure should be performed under general anesthesia. If available, a trimming chute with the animal standing or in lateral recumbency works very well. Removal of infected tissue, debris, and inflammatory mediators in the joint is essential for normal return to previous function. The goals of joint lavage are to remove debris and dilute the abnormal constituents in the joint with a large volume of sterile fluids. Joint lavage is performed in different ways: tidal, through-and-through, and arthroscopy. Aspiration and irrigation are performed through the same needle in a tidal lavage, which creates a lot of turbulence and dislodges the debris (Figure 15-41). With this technique, the volume of fluids injected is limited because the tendency is to use the same fluid in the syringe for a long period of time. The author often combines this technique with a through-and-through lavage. The size of the needle used by the author in adult cattle is 16 to 14 gauge. Using large volumes of fluids is easy with through-and-through lavage. A good knowledge of anatomy and communication between articulation compartments is essential for efficient treatment. Two needles are necessary for this technique (see Figure 18-18). One needle is inserted for ingress and the other for egress. The needles have to be far from each other to avoid direct communication and exit of the fluids without adequate irrigation of the cavity. Intermittently blocking the egress needle distends the joint, thus improving lavage. The volume injected depends on the joint itself and severity of the infection. For example, the DIP joint needs 250 mL in comparison to a large articulation like the stifle, with which 3 L is necessary. If fibrin is present, needles have a tendency to clog; therefore arthroscopy or arthrotomy has to be considered. The author has used 5-mm trocar and cannula arthroscopic units to perform through-and-through lavage when fibrin is obstructing a 14-gauge needle. The fluids used have to be isosmotic and isotonic and have a pH close to 7.4. Sterile Ringer's solution, balanced physiologic solution, and physiologic saline are types of fluids that are used commonly for joint irrigation. Adding disinfectant or antibiotics to fluids has been debated, but the total volume of the solution injected is more important. Joint lavage is repeated every day or every other day two to three times, depending on the facility and character of the animal. More articular lavages are often necessary in fibrinous septic arthritis. Macroscopically, the synovial fluids should be clearer with increased viscosity. Leukocyte count and total protein concentration will decrease if the infection is controlled. More importantly, clinical signs should improve 24 to 48 hours after treatment initiation.



Figure 15-41 The medial femorotibial joint is distended with fluids before reinserting a needle into the femoropatellar joint.

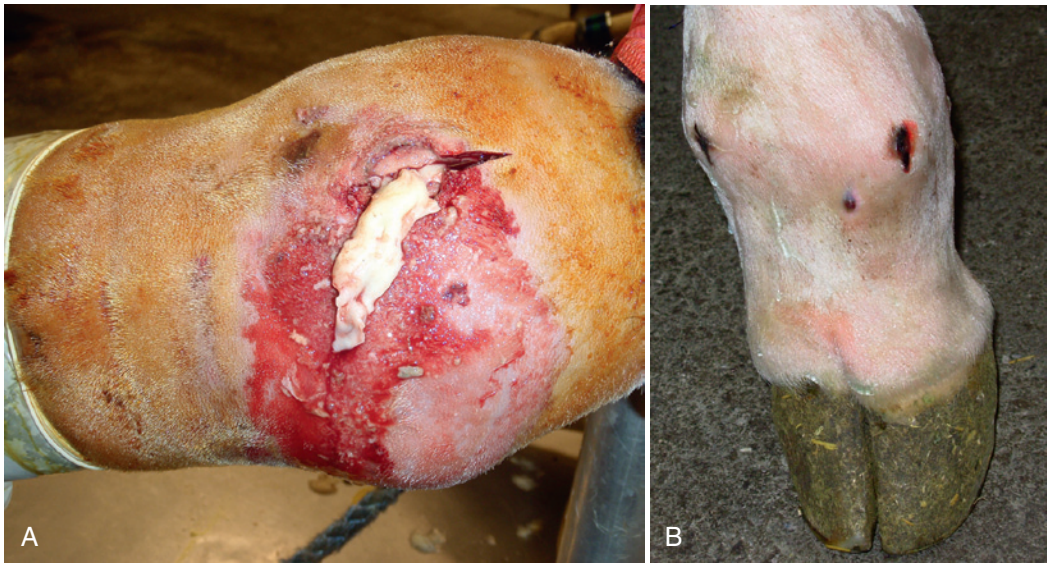


Figure 15-42 Chronic septic arthritis of a fetlock joint drained by two dorsal arthrotomies. *A*, Fibrin is pulled out of the joint. *B*, 10 days later the swelling is down and the arthrotomy site is healing well.

Arthroscopy provides a good lavage and drainage of the joint but also helps the clinician visualize the joint for a more precise prognosis. Because athletic performance is not an issue in farm animals, arthroscopy is not routinely performed in cattle for economic reasons.

Arthrotomy is performed if medical treatment has failed (within a few days) or if the joint is full of fibrin or pus so that a through-and-through lavage is impossible. Arthrotomy sites are the same as those for an arthrocentesis. The incision should be long enough to allow adequate drainage and introduction of forceps to remove fibrin (Figure 15-42). More than one incision per joint is necessary to access the joint compartments completely and improve debridement. To prevent ascending infection, the incisions are covered with a regular bandage or suture stent bandage (see Figure 15-39*B*), and additional lavages are performed if needed, usually two to four times. After 24 to 48 hours, the incision often has to be reopened to access the joint cavity because of its tendency to seal with fibrin or from swollen adjacent tissues. Joint lavage is performed until synovial fluids are clear and the fibrin removed from the cavity is negligible.

Arthrodesis of the carpus has been performed successfully by the author although we do not recommend it for tibiotarsal and proximal intertarsal joints in adult cow. Facilitated ankylosis can be achieved in the low range of motion distal rows of the tarsus. For more detail please refer to the section on septic arthritis in calves in Chapter 18.

PROGNOSIS

In cattle, the prognosis is generally good for a return to previous function and productivity. The prognosis depends on the time of presentation, the amount of bone lysis and proliferation (radiographic evaluation), and the degree of extracapsular ankylosis. Two studies assess the success rate for treatment of septic arthritis at between 72% and 85%. Cattle with septic tarsi have less chance of recovery. In another study, arthroscopic lavage and implantation of antimicrobial-impregnated collagen sponges were successful in 12 out of 14 animals treated.

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LIGAMENTOUS DAMAGE

LACERATIONS TO OR ADJACENT TO THE JOINTS

Norm G. Ducharme

Puncture wounds to the joints may result from machinery or cleaning tools, fencing materials, or sticks and horns, all of which carry high levels of environmental bacteria. These wounds need to be assessed to determine whether joints have been penetrated or neurovascular tissues injured. Knowledge of the relevant periarticular anatomy is necessary to explore adjacent structures such as tendon sheath, neurovascular bundle, or joint penetration. For example, in the stifle joint, the lateral femorotibial joint compartment extends distally around the origins of the peroneus tertius and long digital extensor muscles. Therefore deep wounds to the dorsolateral limb in the area of the proximal tibia should be evaluated for involvement of these structures.

The affected joint should be examined to see whether collateral (or patellar ligaments and cruciate ligaments in the stifle joint) have been injured. Radiographs and ultrasound are useful in determining the involvement of joints or ligaments in a deep wound.

The treatment of periarticular and/or articular wounds requires the application of sound principles of wound management. Debridement of traumatized, devitalized, contaminated, and ischemic tissue is indicated. If the wound is contaminated and adequate debridement and lavage is conducted, complete closure of the wound may be indicated. However, if the wound is greater than 12 hours' duration and untreated, it is likely that bacterial contamination will have progressed to an infection. Under these circumstances,

wound culture, debridement, and lavage need to be conducted. A provision for wound drainage must be made, and in most cases complete wound closure is not indicated. Instead partial closure and packing of the periarticular component of the wound with betadine solution–soaked Kerlix roll gauze is done. Broad-spectrum antibiotics are indicated for deep wounds. The antibiotics may need to be changed to target-specific antibiotics after wound culture and sensitivity results are obtained. If the joint spaces have been invaded by a traumatic incident, large-volume joint lavage is used to flush the joints. For example, adequate lavage of a mature cow stifle requires a minimum volume of 5 L of isotonic electrolyte solution. Appropriate antibiotics may be added to the lavage solution.

In cases where heavy contamination of the joint exists, arthroscopy provides the best examination of the joint and allows for direct joint lavage, fibrin removal, and debridement. If arthroscopic equipment is not available, or not affordable, an arthrotomy has a better chance for successful debridement and lavage than the use of ingress and egress needles alone (see section on Joint Lavage/Drainage). To prevent dehiscence, a dorsal (with or without palmar/plantar) lateral (or medial) arthrotomy approach would give good drainage of the joint. In the stifle joint, only dorsal arthrotomies are used, but they should not extend beyond the patellar attachment of the lateral (or medial) patellar ligament.

If heavy contamination or septic arthritis is present, the arthroscopy or arthrotomy incision(s) should be left open (or partially open) to allow drainage. The incision sites in the joints should be protected from the environment either by a bandage or, if not possible, by placing suture loops around the wound, so a stent bandage (see Figure 15-39*B*) can be applied and changed as needed until the joint no longer communicates with the environment.

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CRANIAL CRUCIATE RUPTURE

André Desrochers and Norm G. Ducharme

CRANIAL CRUCIATE LIGAMENT INJURY

Dairy and beef breeds incur injuries to the CCL in males and females. Cattle may present with a complete or a partial tear of the CCL. The injury is often related to a single traumatic event, but chronic injury may occur in bulls as a result of mounting and thrusting. The instability caused by CCL tears leads to osteoarthritis. However, the reverse is also possible: osteoarthritis leads to synovitis and chronic joint inflammation, which may precede CCL injury.

Cattle with acute CCL rupture are usually non-weight bearing or partially weight bearing but some weight-bearing function is reached as the injury becomes chronic. Instability between the femur and tibia may be observed in weight-bearing patients; a snapping action occurs when the tibia slips forward relative to the femur that can be heard or felt in some animals. If the tibia is displaced cranially relative to the femur, a drawer sign may be elicited as follows: the examiner's knee is placed on the caudal aspect of the hock and the tibia is retracted caudally by placing both hands over the tibial crest (Figure 15-43). An alternative drawer test can be done on bulls if standing behind the animal is unsecured: the examiner is standing in front of the affected limb with both hands pushing on the tibial crest. A drawer test is positive if displacement or a crepitation can be felt after sudden release of the tibia (Figure 15-44). In addition, internal



Figure 15-43 Drawer test in cattle. The examiner's knee is placed on the caudal aspect of the hock, and the tibia is retracted caudally by placing both hands over the tibial crest. Increased laxity and crepitus can be detected with this test.



Figure 15-44 Alternate drawer test in cattle. The examiner's hands are placed on the tibial crest to push the tibia caudally. Increased laxity and crepitus can be detected upon sudden release of the tibia.



Figure 15-45 External rotation of the stifle to be followed by internal rotation; this identifies increased range of rotation (because of increased internal rotation) and crepitus in cattle with cranial cruciate tears.



Figure 15-46 Mature Holstein-Friesian bull with a cranial cruciate tear of 3 weeks' duration. The right tibia is displaced cranially as evidenced by the cranial position of the intercondylar eminence relative to the middle third of the femoral condyle. Extensive irregular new bone formation associated with the intercondylar eminence and tibial plateau is present. (Courtesy of Dr. Peter Scrivani, Cornell University.)

rotation of the tibia relative to the femur is greater than normal in stifles with CCL rupture. This can be evaluated by having the hock and stifle slightly flexed while the examiner applies outward rotational force to the distal limb (Figure 15-45).

Joint effusion is usually present with CCL injury. In acute injuries, there is usually marked distention of the joint because of hemorrhage and increased synovial effusion. In more chronic cases, fibrosis of the periarticular soft tissue may make synovial distention difficult to appreciate.

In a lateral-to-medial radiograph of a normal stifle in a standing animal, the tibial intercondylar eminence is completely overlapped by the femoral condyles. In CCL injuries, the tibia is displaced forward, so the intercondylar eminence will be located cranial to the femoral condyles (Figure 15-46). Additionally, radiographs may provide evidence of fractures of the intercondylar eminence, avulsion fractures at the insertion sites of the CCL, or medial collateral ligaments (MCLs), mineralization of the CCL, or other evidence of degenerative joint disease (see Figure 15-46). Joint instability caused by CCL injury often results in tearing or crushing of the meniscus, which may lead to calcification and/or decreased joint space in the medial femorotibial joint. The caudal-to-cranial radiographic view on a weight-bearing leg provides an evaluation of the meniscal integrity.

Arthrocentesis is unnecessary if the drawer test is positive and the radiographs are diagnostic unless septic arthritis hasn't been ruled out.

Conservative management of CCL disruption is usually unsatisfactory because of the secondary changes that result from joint instability. A degenerative progression occurs, starting with maceration of the medial meniscus, followed by subsequent loss of articular hyaline cartilage, and finally erosion of the subchondral bone of the femoral condyles. Box stall confinement and antiinflammatory medication may be beneficial only in partial rupture of the CCL.

Two surgical procedures are used to provide stability to the femorotibial joint and reduce the progression of osteoarthritis. The simplest procedure is an extraarticular plication of the dorsomedial and dorsolateral retinacular tissues. The second procedure provides intraarticular stabilization of the femorotibial joint.

Preoperative and Operative Preparation

Food is withheld for 36 to 48 hours and water for 12 hours before anesthetic induction. An NSAID and broad-spectrum antibiotics (such as cephalosporins) are administered before the procedure. The animal is induced and prepared for general anesthesia. General anesthesia with halothane, isoflurane, or sevoflurane is recommended with a closed-circuit positive-pressure ventilation system (see Chapter 5). The animal is placed in lateral recumbency with the affected limb uppermost and elevated at 30 degrees from the horizontal plane (Figure 15-47). The limb is aseptically prepared from the hock to 10 cm rostral to the tuber coxae and extending to the dorsal midline (see Figure 15-47).

Stifle Joint Imbrication

Surgical Procedure

After appropriate draping, an S-shaped incision that starts 5 cm proximal to the patella and extends first medially is made on the cranial aspect of the stifle joint until 5 cm distal to the tibial crest (Figure 15-48). The incision is extended with scissors through the loosened areolar subcutaneous tissue and superficial fascia until the strong periarticular fascia is encountered. Synovial fluid must be removed from the stifle joint to achieve maximal imbrication because it interferes with imbrication (Figure 15-49). With the limb in nearly full extension, a first row of imbricating suture pattern (Lembert) with a nonabsorbable suture material (No. 5 polyester[3] or polyblend[4]) is placed at the level of the lateral femoropatellar ligament and extended from the dorsal aspect of

[3]Ethibon, Ethicon Inc., Johnson & Johnson, Piscataway, NJ, USA.
[4]Fiberwire, Arthrex, Naples, FL, USA.



Figure 15-47 The animal is placed in lateral recumbency with the affected limb uppermost and elevated at 30 degrees from the horizontal. The limb is aseptically prepared from the hock to 10 cm rostral to the tuber coxae and extending to the dorsal midline.

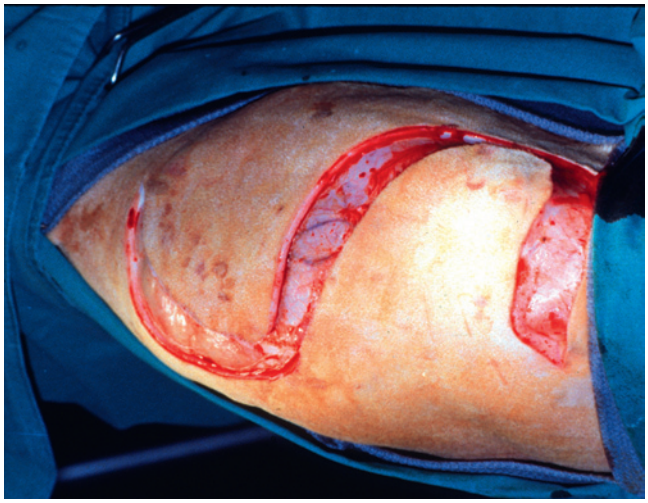


Figure 15-48 S-shaped incision used for the approach for a stifle imbrication.

the patella distally to the tibial crest (Figure 15-50). The procedure is also performed on the medial aspect of the stifle joint centered over the medial femoropatellar ligament (see Figure 15-50). A second row is placed over the first row, and a third row is placed if the fascia is strong enough to hold. The number of overlapping rows of imbricating sutures is limited by the strength of the periarticular tissue. If the sutures start tearing the fascia, no further sutures are placed. Placement of an antirotating suture from the lateral attachment of the gastrocnemius muscle on the femoral condyle to the fascia near the tibial crest has been described. Because the common peroneal nerve is located close to the lateral collateral ligament, inadvertent encroachment of the common peroneal nerve can occur; therefore the authors do not recommend placing an antirotating suture.

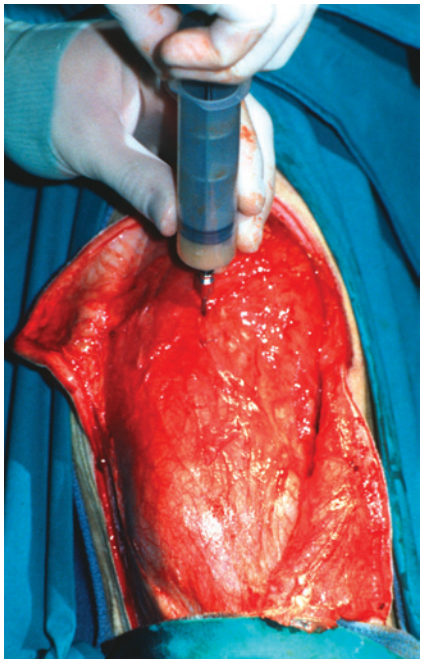


Figure 15-49 Exposure of periarticular fascia immediately after skin incision and extending the incision through the superficial fascia. Synovial fluid is being removed before imbrication.

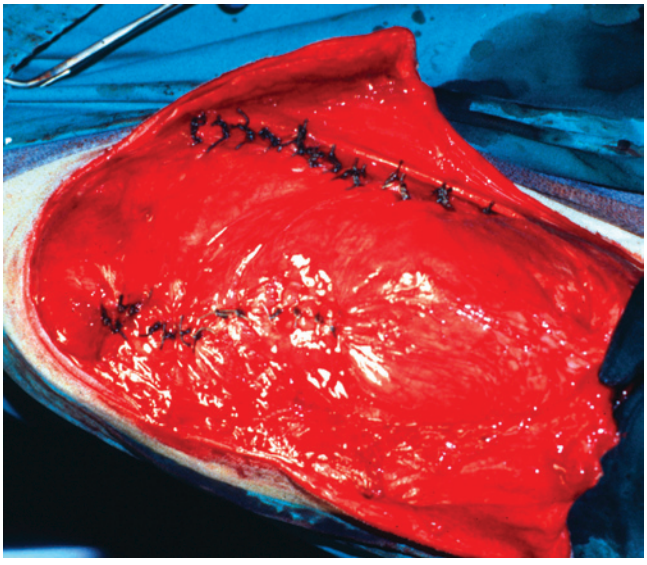


Figure 15-50 Intraoperative view after placement of imbrication sutures on the medial and lateral aspect of the stifle joint.

The superficial fascia is closed with No. 2 absorbable suture material in a simple interrupted or cruciate pattern. The subcutaneous tissue is closed with a simple continuous pattern (No. 1 absorbable suture material), whereas the skin is closed using a Ford interlocking pattern or a simple cruciate pattern (No. 1 nonabsorbable suture material). A stent is then sutured on to relieve the tension on the incision. The stent bandage is kept in place as long as it is dry, up to a maximum of 7 days.

Replacement of the CCL

Two procedures have been described for replacing the CCL, the first using the gluteobiceps tendon as the replacement material and the second using synthetic suture materials.

Gluteobiceps Tendon as Replacement for the CCL

The following technique was originally described from independent studies by Moss and Crawford, with modifications suggested by the author and Dr. R. Eggleston (College of Veterinary Medicine, University of Georgia). In cattle, the superficial gluteal and biceps femoris muscles are continuous and form the gluteobiceps muscle. The medial fascia of the gluteobiceps muscle is 5 to 7 mm thick and approximately 7 cm wide. Distally, the fibers of this fascia are continuous with the fibers of the lateral patellar ligament. A strip of tissue harvested from the medial fascia of the gluteobiceps muscle and the lateral patellar ligament can form a graft. Using a modification of the over-the-top technique, the clinician forms an intraarticular replacement for the disrupted CCL.

After aseptic preparation and draping, a skin incision is made from the major trochanter to the lateral aspect of the patella. The incision is then curved so it is parallel to the lateral distal patellar ligament and extended to the tibial crest. The fascia lata is incised over and parallel to the plane between the vastus lateralis and gluteobiceps muscles. A full-thickness strip of fascia 2 cm wide is sharply dissected from the cranial margin of the medial gluteobiceps muscle. The dissection is continued distally through the fibrocartilaginous thickening over the lateral epicondylar bursa. The graft is extended farther distally by dividing the lateral patellar ligament (in a craniocaudal plane) parallel to its fibers down to the tibial crest though maintaining 50% of the lateral distal patellar ligament. A continuous graft is thereby formed, attached distally to the tibial crest, that contains the lateral half of the lateral patellar ligament, a portion of the suprabursal fibrocartilage, and approximately 20 cm of the gluteobiceps fascia (Figure 15-51*A* and *B*). The femorotibial joint is approached by an arthrotomy between the lateral and middle patellar ligaments. The patellar fat pad is reflected and the insertion of the CCL inspected digitally. Because of the depth of the insertion of the CCL on the tibial eminence, meaningful visual assessment of the joint and ligament damage is often difficult (Figure 15-52). The cranial segments of the menisci may be evaluated. Bone fragments and crushed or torn segments of menisci should be removed if they are accessible. A custom-manufactured, curved graft passer[5] (Figure 15-53*A*) is passed through the intercondylar space in a cranial-to-caudal direction and is directed through the caudal joint capsule and popliteus muscles to exit through the fibers of origin of the lateral gastrocnemius muscle at the lateral epicondyle (Figure 15-53*B*). A 120-cm length of 8-mm-wide umbilical tape is threaded into the eye of the graft passer and brought out through the arthrotomy incision by retracting the graft passer. Cutting umbilical tape at the graft passer eye leaves two 60-cm lengths of tape in the route taken by the graft passer; one length is designated as a spare in case the first attempt to pull the graft through the tissue tunnel fails. Pulling the graft through the tissues can be difficult. Because of these difficulties, the following steps are done. First, a length of sterile gauze (soaked in 1% carboxymethyl cellulose) is tied to the umbilical tape leader and pulled through the intercondylar space. With the joint held in 100 degrees of flexion, the gauze is drawn back and forth to enlarge and

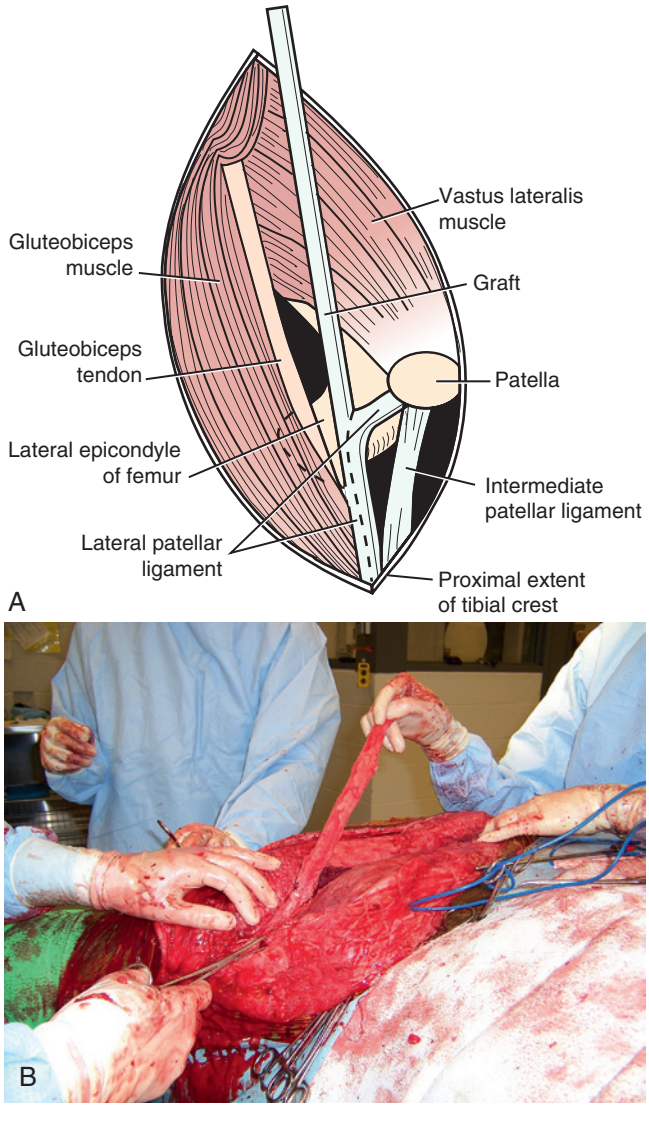


Figure 15-51 *A*, Schematic representation of the lateral view of the right stifle, which shows the autogenous graft formed from the right gluteobiceps fascia and the lateral patellar ligament. *B*, Intraoperative view of a full-thickness, 20-cm-long strip of fascia 2 cm wide from the cranial margin of the medial gluteobiceps muscle. The graft is extended distally by dividing the lateral patellar ligament (in a craniocaudal plane) parallel to its fibers down to the tibial crest. (*A*, Redrawn from Crawford WH: Intraarticular replacement of bovine cranial cruciate ligaments with an autogenous fascial graft, *Vet Surg* 19:380–388, 1990.)

lubricate the passageway. The graft is then inserted approximately 7.5 cm within the lumen of a 10-mm-diameter sterile braided nylon rope (length, 2 ft [60 cm]) and is secured to the edge of the graft by using interrupted sutures of No. 1 suture material. The other end of the rope is secured to the gauze. The rope and graft are lubricated with sterile 1% carboxymethyl cellulose water-soluble lubricant jelly and, with the stifle in 100 degrees of flexion, the rope leader and attached graft are pulled through the passageway. The graft enters the intertrochlear space best with the joint in 100-degree flexion whereas it exits the space best in partial extension. Therefore the stifle is placed in approximately 100 degrees of flexion until it appears to wedge and then is

[5]Messer Innovative Products; Cottage Grove, WI, USA.

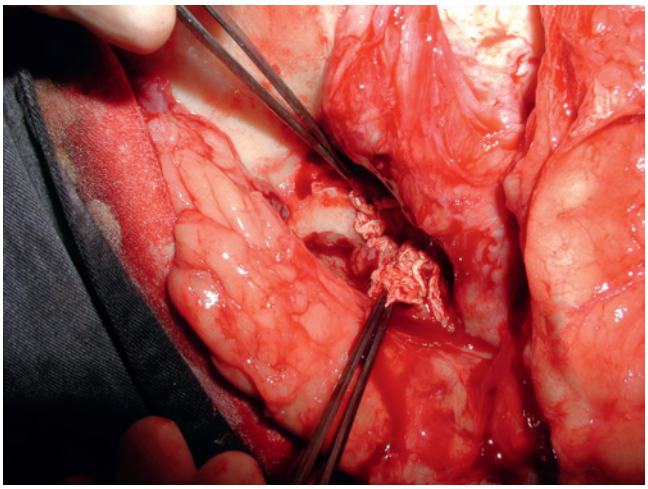


Figure 15-52 Intraoperative view of the femorotibial joint. The forceps are holding the torn cranial cruciate ligament.

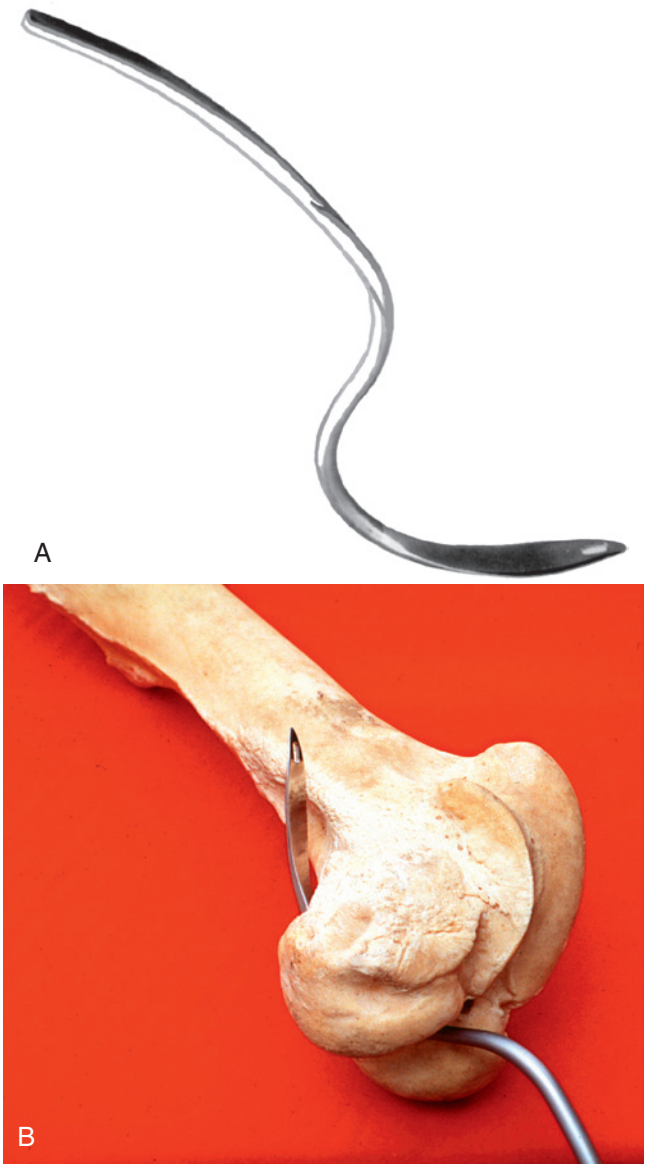


Figure 15-53 *A*, Graft passer manufactured by Messer Innovative Products, Cottage Grove, WI. The overall length is 30 cm and the blade width is 12 mm. The radius of curvature in the instruments varies from 6.5 to 10 cm, depending on the size of the patient. *B*, Anatomic specimen that shows path of the graft passer. The instrument enters between the middle and lateral patellar ligaments and exits through the muscle fibers of the lateral head of the gastrocnemius muscle at the lateral epicondyle.

extended 20 degrees as traction is applied simultaneously. Cycling the joint through the range of motion described earlier with continuous traction facilitates graft passing. In this fashion, a 20-mm-wide fascial strip can be pulled through the tissue tunnel. One should evaluate how much of the lateral belly of the gastrocnemius muscle is present between the caudal aspect of the femur and graft. If the graft has exited the caudal aspect of the joint too far from the caudal aspect of the femur, the lateral belly of the gastrocnemius muscle can be partially incised so the graft can be placed against the femur and therefore under greater tension. An attachment site for the proximal segment of the graft is prepared by elevating a 6-cm-wide section of periosteum from the lateral epicondyle. With the stifle placed in approximately 140 degrees of flexion and the tibia slightly externally rotated, the fascial strip is pulled tightly so it lays just proximal to the lateral epicondyle. An assistant holds the graft under tension as it is stapled to the prepared area of the epicondyle with a 1.75-cm bone staple.[6] The free end of the strip is folded caudal over the stapled attachment, and a second staple is placed to include a double thickness of the strip. Alternatively, a three-hole narrow dynamic compression plate[7] can be placed over the strip to anchor it to the epicondylar bone by using two 44-mm-long, 4.5-mm-diameter cortical bone screws[8] to compress the fascial strip between the bone and plate (Figure 15-54). The free end of the strip is then folded back on itself and sutured in place with[5] nonabsorbable suture material.[7,8]

The most common postoperative complication is seroma formation and subsequent wound breakdown. A multilayer closure with heavy surgical materials is required to prevent synovial leakage and fascial disruption. The gluteobiceps and vastus lateralis muscles are reapposed by using No. 2 absorbable sutures (polyglactin 910[9]) in a simple continuous pattern. The joint capsule is closed with similar material placed in a simple cruciate pattern. The transected lateral femoropatellar ligament is reapposed with three interrupted horizontal mattress or interrupted cruciate sutures with No. 3 polyglactin 910. The distal deep fascia, from the lateral femoropatellar ligament to the tibial crest, is closed with interrupted cruciate sutures of No. 2 polyglactin 910, and the proximal segment of the deep fascia incision is closed with the same material in a simple continuous pattern. The superficial fascia is apposed with No. 1 polyglactin 910 in a simple continuous pattern. Skin closure is with No. 2 polypropylene[10] placed in simple interrupted sutures in the distal

[6]Fixation staple, Smith and Nephew, Memphis, TN, USA.
[7]Synthes, Paoli, A.
[8]Innovative Animal Products, 6256 34th Avenue NW, Rochester, MN, USA.
[9]Vicryl, Inc., Somerville, NJ, USA.
[10]Prolene, Ethicon Inc., Somerville, NJ, USA.

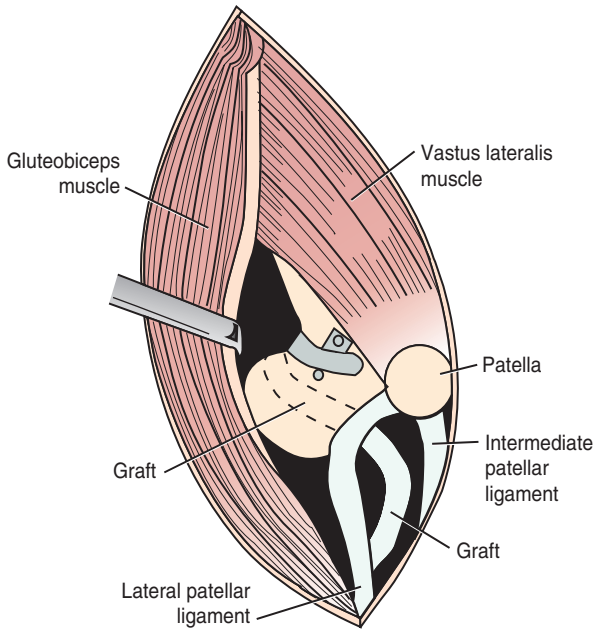


Figure 15-54 Schematic drawing demonstrating the placement of the autograft before application of tension and stapling. Graft is continuous behind the femur and up and over to be fastened by plate. (Redrawn from Crawford WH: Intraarticular replacement of bovine cranial cruciate ligaments with an autogenous fascial graft, *Vet Surg* 19:380-388, 1990.)

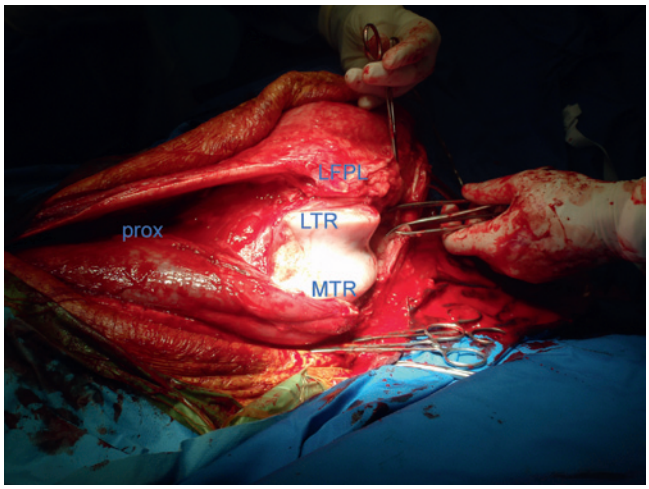


Figure 15-55 Intraoperative view of the surgical exposure after medial luxation of the patella. LFPL, lateral femoropatelar ligament; LTR, lateral trochlear ridge; MTR, medial trochlear ridge.

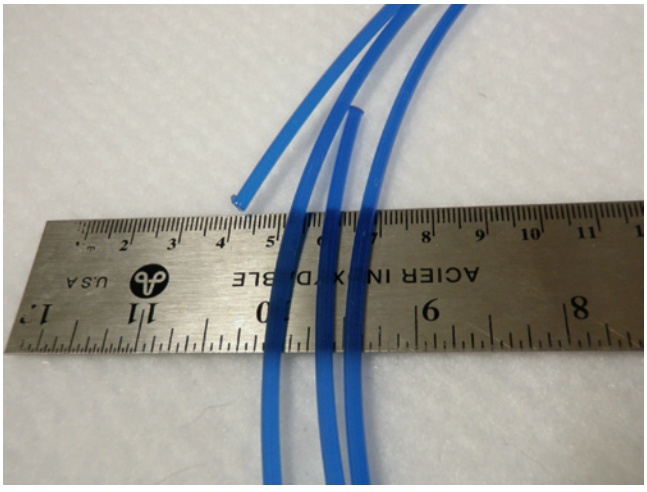


Figure 15-56 Nylon cable used for artificial prosthetic ligament. (Courtesy of Dr. David E. Anderson, University of Tennessee.)

one-third of the incision and a Ford interlocking pattern in the proximal two-thirds. A stent bandage is sutured over the closed incision line and kept in place for 7 days if it remains dry. Perioperative penicillin and cephalosporins are administered for 5 days, with NSAIDs as needed for the first week after the procedure.

Synthetic Cranial Cruciate Ligament

Hamilton and Adams described a surgical technique involving the use of synthetic material. As described previously, the procedure is performed under general anesthesia with the animal in lateral recumbency and the affected limb uppermost (see Figure 15-47). A 40-cm linear incision is performed starting mid femur, following its shaft distally, lateral to the patella, along the tibial crest ending distal to it. The approach to gain access to the joint is similar to the previous technique by incising the fascial lata and cutting the lateral femoropatellar joint and medial luxation of the patella (Figure 15-55). Three bone tunnels are performed with a 6.2-mm drill bit with repeated passage to increase the diameter and avoid sharp edges at the tunnel's extremities. The first tunnel is drilled just proximal to the lateral femoral epicondyle and aims toward the intercondylar space approximately where the cranial cruciate ligament originates. At this point the stifle is in flexion. The second bone tunnel is drilled from the medial aspect of the tibial crest and exiting at the insertion site of the cranial cruciate ligament. Finally, from the previous medial tibial crest bone hole, the drill bit is aimed laterally. Many synthetic materials have been used: from threaded caprolactam or polyester to fishing lines or custom-made nylon cable (David E. Anderson, University of Tennessee, personal communication) (Figure 15-56). The synthetic implant is passed through the tunnels similarly to what was described with the graft. It is a difficult process that may extend surgery time significantly, which can be detrimental to heavy animals like mature bulls. The implant is passed through the femoral tunnel first, then through the tibia from proximal to distal, and finally from medial to lateral through the tibial crest tunnel (Figure 15-57). The distal portion of the implant is then tunneled underneath the muscles proximally (Figure 15-58*A*) to be tightened on the lateral epicondylar area (Figure 15-58*B*). If heavy-duty nylon cables (500-1000 lb) are used, knot making is impossible (Figure 15-59). Therefore a 5-hole stainless steel plate has been used to withstand and secure the tension (Figure 15-60). The advantage of such cable is its ease in being threaded through bone holes.

The joint capsule, femoral patellar ligaments, and fascial lata are sutured as described with the graft technique. A lateral imbrication is performed as well and a stent is applied over the skin incision (Figure 15-61).

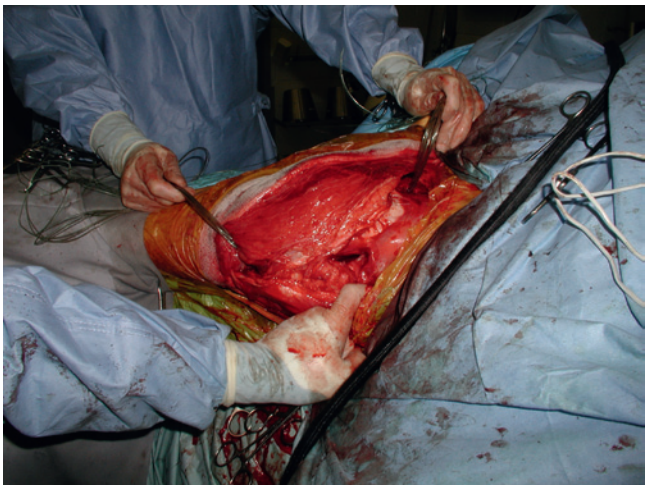


Figure 15-57 Multiple strings of 100-lb fishing line were passed through the bone tunnels.

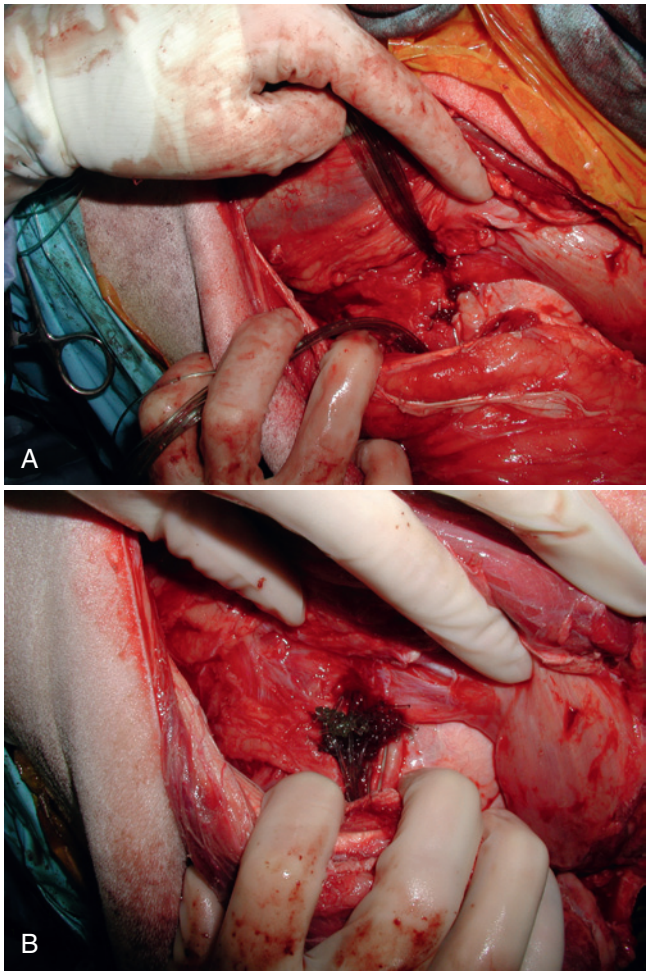


Figure 15-58 *A* and *B*: The strings were tunneled underneath the muscles and are ready to be tightened.

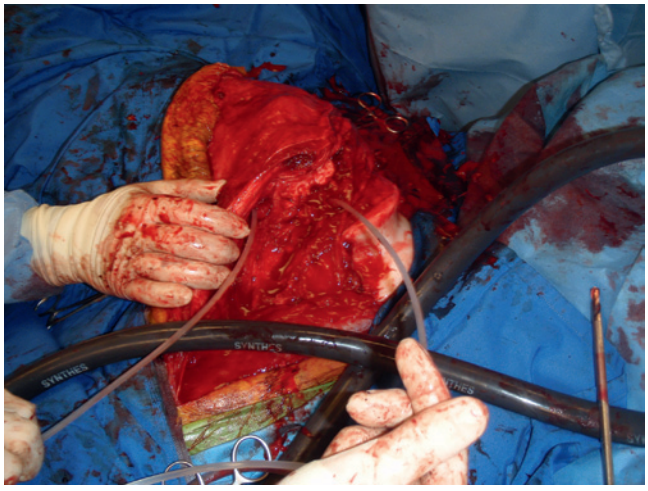


Figure 15-59 One 1000-lb nylon cable was passed through bone tunnels.

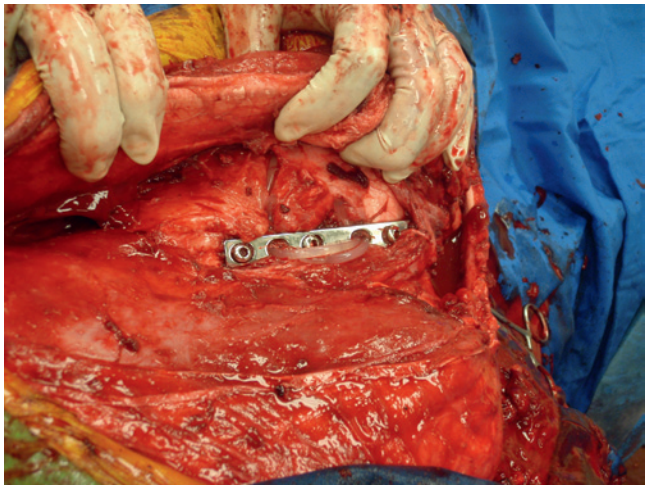


Figure 15-60 Plate fixation of the nylon cable on the femoral epicondyle.

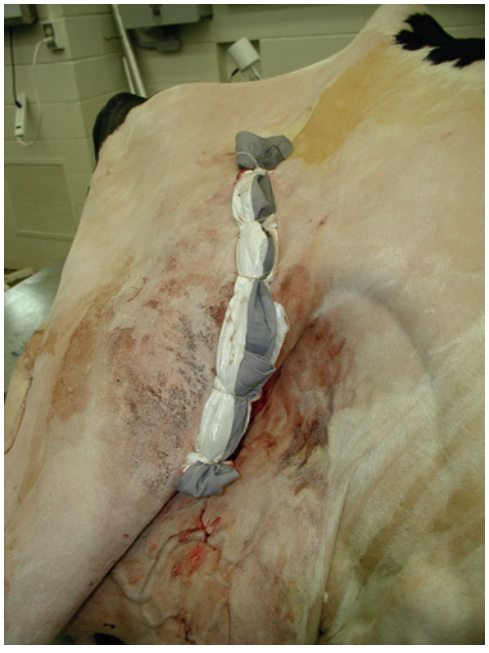


Figure 15-61 A stent bandage is applied after the surgery to decrease the tension and protect the incision.



Figure 15-62 Three weeks postoperatively after skin suture removal. The animal is bearing weight on the affected limb and the swelling is minimal.

Postoperative Care and Prognosis

In both procedures, patients should be kept in a box stall for 6 to 8 months. Skin sutures are removed in 3 weeks because the skin incision is not strong enough to hold in some cattle, given the tension present during joint flexion (Figure 15-62). Postoperatively, successful animals are toe touching for the first few days with gradually increased weight bearing. Marked improvement is seen by 2 months, with further improvement up to 6 months after surgery. Joint distention will be present for many months as well. It should not be a concern if there are no signs of sepsis, and arthrocentesis should be avoided.

Prognosis for return to soundness suitable for breeding function depends on the size of the animal, degree of degenerative joint disease present before joint stabilization, and animal behavior (lying down on a good leg, etc.). We have operated on 27 animals (14 bulls and 13 cows) to date with the graft technique. Out of 14 bulls (≥900 kg), 6 bulls developed incisional failure (with 4 developing fatal septic arthritis) and 2 experienced graft failure, which makes a total success rate of 43%. Of the 13 cows operated on, 11 (85%) were successful, but 2 had residual lameness. Cranial crucial rupture has been observed in the contralateral limb in 2 cows a few months after repair.

Similar results were obtained with prosthetic ligaments. Of the nine cows that underwent this procedure, seven were discharged from the hospital. Two cows developed septic arthritis and were euthanized during hospitalization. One cow was turned loose on pasture, which was against the recommendation, and ruptured her prosthetic ligament. The remaining six cows were kept for at least a year with mild residual lameness.

In conclusion, the CCL replacement procedure gives the best results in regard to stability of lameness and return to normal ambulatory function, but catastrophic failure in especially large patients (>900 kg) is a risk. Stall rest after discharge cannot be overemphasized. Stifle imbrication is most successful in lighter animals (<400 kg) and has less risk of catastrophic failure.

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DAMAGE TO THE COLLATERAL LIGAMENTS OF THE STIFLE

Norm G. Ducharme

Injury to the MCL of the stifle is associated with trauma and may be seen in conjunction with CCL injury. The MCL may be torn or stretched. Injury to the medial meniscus of the medial femorotibial joint may occur as a result of joint instability created by MCL injury. This is because the medial meniscus is attached to the medial collateral ligament. Injury to the lateral collateral femorotibial ligament is rare and more difficult to assess clinically, owing to the greater musculature and collateral support on the lateral side of the stifle.

Clinical signs of collateral ligament injury include lameness referable to the stifle joint, increased synovial effusion, reduced weight bearing, and a shortened cranial phase to the stride seen in cattle with femorotibial collateral ligament injury. Swelling and pain are noted when the site of the MCL is palpated. If the distal limb is passively abducted while palpating the site of the MCL, opening of the medial side of the femorotibial joint can be appreciated if the ligament has ruptured. Craniocaudal radiographs may reveal an avulsion fracture at the origin or insertion of the affected collateral ligament (Figure 15-63). Ultrasound is the key imaging modality used to identify complete or partial tears and characterize the degree of damage to the medial meniscus.

Ruptured collateral ligaments of the stifle may heal within 6 to 8 weeks of box stall confinement if the injury is not associated with CCL rupture or moderate to severe meniscal injury. Alternatively, considerations should be made for surgical stabilization (i.e., meniscopexy).

Surgical Procedure

The animal is positioned in dorsal recumbency with the affected limb placed in a 90° flexion. The extent of the meniscal damage is better confirmed by arthroscopy. This also allows for debridement of meniscal tears. If medial meniscus detachment is present, reattachment to the joint capsule at the level of the collateral ligament (i.e., meniscopexy) has been reported.

A horizontal skin incision centered on the MCL but immediately dorsal and parallel to the medial meniscus is made. The incision is extended through the subcutaneous tissue. Three to four nonabsorbable sutures (size 0 suture material such as nylon or polypropylene) are used to secure the meniscus to the medial joint capsule and collateral ligament. The sutures are placed just proximal to the tibia: starting extraarticularly, entering the joint capsule, proceeding through the wide abaxial edge of the meniscus, and exiting through the joint capsule so the knots can be tied extraarticularly. The procedure's goal is to limit movement of the meniscus.

There are two options for stabilizing the collateral ligament. Option 1: a 5.5-mm cortical screw and appropriate washer are placed at the insertion sites of the collateral ligament on the femur and tibia. Two or three No. 5 polyester sutures are placed in a figure-8 pattern between the two screws. The degree of tension is adjusted to allow a normal flexion range. Option 2: imbrication of the medial periarticular tissues is performed by placing four to six Lembert sutures using No. 5 polyester sutures. A 10-cm skin incision is made at the cranial edge of the collateral ligament and incision extended through the subcutaneous tissue and superficial fascia. See discussion earlier in this chapter on imbrication of femoropatellar joint for details on the imbrication techniques.

No leg support is provided postoperatively, and the animal is confined to a stall for 2 to 3 months. Improvement is observed within 2 to 4 weeks postoperatively.

Prognosis

In the only series of significance, medial collateral injury and meniscal detachment was seen in 34 cattle, the majority under 2 years of age. These were therefore unlikely to be associated with cranial cruciate injury, which is seen in older animals. Following the aforementioned surgical treatment, 20 of 34 (74%) cattle improved after surgery. As expected, the consequence of suboptimal response to treatment includes contralateral limb breakdown with varus deformity.

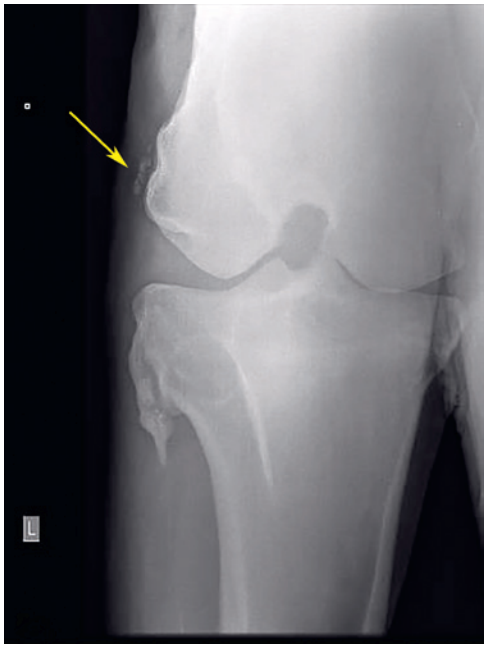


Figure 15-63 A 10-year-old Holstein cow with an injury to the lateral collateral ligament. Note the area of mineralization at the proximal aspect of the lateral collateral ligament (*yellow arrow*; craniocaudal view).

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GASTROCNEMIUS RUPTURE

André Desrochers

Gastrocnemius muscle rupture is a dramatic and often fatal injury in cattle. The gastrocnemius muscle has lateral and medial heads originating from the supracondyloid tuberosities and epicondyles of the distal femur. Its insertion is at the tuber calcaneus. It allows flexion of the stifle and extension of the hock. Although not as developed as in the horse, it is still part of the reciprocal apparatus with the peroneus/fibularis tertius muscle.

The tendinous portion is rarely affected. The rupture occurs at the musculotendinous portion or more proximal. The causes are usually traumatic. Around calving, cows are often weaker, which is associated with calcium, phosphorus, or magnesium imbalances. Having difficulty rising and standing with hyperextension of the stifle while bearing weight might lead to a partial or complete rupture of the gastrocnemius muscle. Postpartum neurogenic muscle weakness can certainly be at the origin of the rupture as well. Heavy muscular calves like Piedmontese and Blue Belgian calves may have spontaneous rupture at a young age. Strenuous exercise in a beef-fattening unit was at the origin of the rupture in a few animals. Necropsy lesions revealed swollen, firm, darkened gastrocnemius muscle with large hematomas. Local necrosis from injection has also been reported as a cause of rupture.

The clinical signs are typical and diagnostic. They will vary depending on the age, severity, and causes of the rupture. A young animal with partial rupture can still stand with a dropped tuber calcaneum (Figure 15-64), whereas a peripartum downer cow will be unable to stand (Figure 15-65). Some adult animals can stand but with a plantigrade



Figure 15-64 Young Holstein Heifer with a partial gastrocnemius rupture at its insertion can still stand with a dropped tuber calcaneum.



Figure 15-65 A downer cow with a complete rupture of the gastrocnemius muscles. The hock is abnormally flexed with the stifle partially extended.



Figure 15-66 A standing adult Holstein cow with a plantigrade stance. She has obvious bilateral gastrocnemius muscle rupture. (Courtesy of Dr. Caroline Lafontaine, Victoriaville, QC, Canada.)



Figure 15-67 *A*, Lateral and, *B*, dorsoplantar radiographs after application of the intramedullary pins. (Courtesy of Dr. Tony Pease, Cornell University.)

stance (Figure 15-66). On a downer cow, the diagnosis is made by manipulating the leg while the animal is in sternal or lateral recumbency with the affected leg uppermost. The hock is flexed and the stifle is partially extended. With an intact reciprocal apparatus, the stifle and hock will either flex or extend synergically. With the gastrocnemius muscle rupture, the hock is easily flexed while the stifle is partially extended (see Figure 15-65). This manipulation is usually painless. Ultrasonography of the affected muscles can be done and will be compatible with severe muscle damage.

Treatment has been attempted successfully only in young cattle able to stand. The affected leg must be immobilized with a full limb Robert Jones bandage with or without splinting (see Figure 15-64) or by transfixation casting (Figures 15-67 and 15-68; also see section on External Fixation). The animal must be confined to a stall by itself for a duration of 2 to 3 months. A retrospective study on seven young beef calves with gastrocnemius muscles rupture reported an immobilization duration of 6 to 8 weeks with an excellent long-term prognosis. Adult cattle standing as a plantigrade



Figure 15-68 A calf with a transfixation cast applied. Acrylic has been applied over the extremity of the transfixation pin. Note normal weight-bearing without assistance to the fixation of the hock.

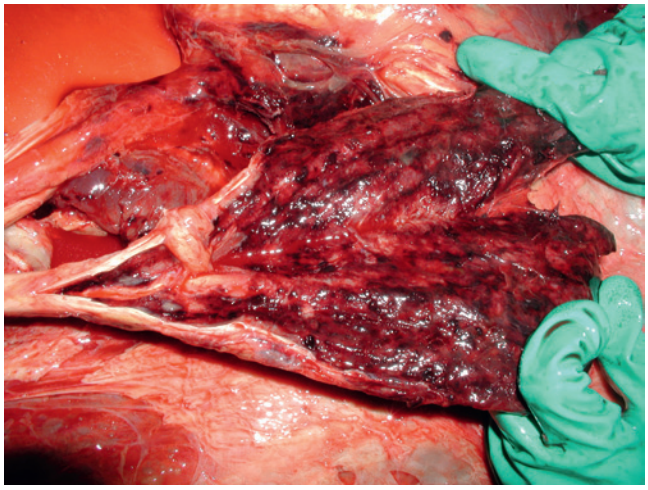


Figure 15-69 Postmortem examination on an adult cow. Note that the ruptured gastrocnemius muscles are swollen, darkened, and hemorrhagic and the tendon is intact.

or unable to rise are euthanized. The necropsy findings are compatible with severe muscular trauma and the tendon itself is intact (Figure 15-69).

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SUSPENSORY LIGAMENT (INTEROSSEUS MUSCLE) INJURY

Karl Nuss

The suspensory ligament is a musculotendinous structure in the metacarpal and metatarsal region that usually receives little attention in cattle. It has a multilayered structure, which is similar in both the front and hind limbs, and its function is complex. In brief, it acts as the suspensory ligament of the fetlock joint stabilizing the sesamoid bones by four separate tendons. The suspensory ligament connects through a strong band that further divides into two broad ligaments (i.e., check ligaments) that join the branches of the superficial digital flexor tendon. At the level of the fetlock joint, additional abaxial and interdigital branches of the suspensory ligament run dorsally and at the proximal interphalangeal joints join the proper extensor tendons at their insertion. These components of the suspensory ligament effectively enclose the distal part of the first phalanx and the proximal interphalangeal joint dorsally and stabilize the fetlock joint angle. When the superficial flexor tendon is injured, the two "check ligaments" to the superficial flexor tendons can still stabilize the fetlock joint to some extent and reduce the dropped fetlock conformation.

Traumatic, open flexor tendon injuries with involvement of the suspensory ligament have been described in cattle. However, young individuals, 8 to 15 months of age, incur closed rupture of the suspensory ligament, which still contains muscle tissue (interosseous) at that age. Closed rupture of the interosseus muscle has been described in an adult bull after a fight with another bull. Rupture is characterized by a varying degree of sinking of the fetlock and dewclaws as well as a pastern joint-fetlock axis with a broken-back appearance (Figure 15-70). There is grade 3 to 5 supporting limb lameness, and affected animals are in pain and prefer to lie down. Rupture of the suspensory ligament can be unilateral or bilateral and can occur in the front or hind limbs. It is thought to occur when young cattle land on the front or hind limbs after jumping from a height, which results in excessive stretching of the suspensory ligament. Sinking of the sesamoid bones can be seen on radiographs (Figure 15-70*B*) and on ultrasonograms in standing cattle. Bony fragmentation caused by repetitive hyperextension of the metacarpophalangeal/metatarsophalangeal joint may be present at the dorsal aspect of the first phalanx. Irregularly thickened or tortuous structures corresponding to the parts of the suspensory ligament that stabilize the sesamoid bones can be seen on ultrasonograms (Figure 15-71). To date, the level of the rupture has not been precisely determined. However, because this type of injury has mainly been seen in young cattle, it is likely that the parts of the suspensory ligament containing muscular components are affected.

Rupture of the suspensory ligament is treated by application of a short fiberglass cast extending proximally to just below the carpus or tarsus. Full limb casts may be indicated in adult cattle. The fetlock and pastern joints should be positioned along the same axis as the metatarsal or metacarpal bone or with the digital joints in a slightly flexed position. This reduces the pull on the sesamoid bones, suspensory ligament, and flexor tendons and allows reorganization of the ruptured musculotendinous tissue. The cast should be well padded to prevent pressure sores. A wooden wedge is placed on the claws and integrated into the cast to facilitate normal footing. Conservative treatment is empirical and entails box stall rest for 6 months. The limb remains in a cast for the first 3 months of this period with cast changes scheduled every 3 to 4 weeks. After approximately 12 weeks, the cast is replaced with a short splint bandage, which remains in

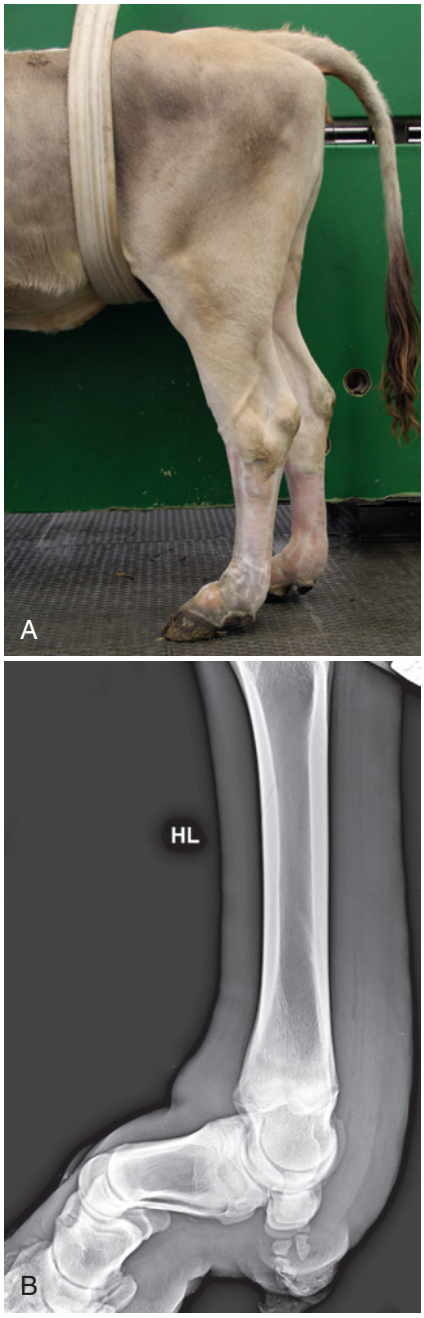


Figure 15-70 An 8.5-month-old heifer with severe signs of rupture of the suspensory ligament in both hind limbs. *A*, The fetlock joints of the hind limbs are sunken and the dew claws nearly touch the ground. The pastern joint-fetlock axis has a broken-back appearance. *B*, Lateromedial radiograph of the left hind limb of this heifer. The sesamoid bones are located directly ventral to the metatarsal condyles. The first phalanx is almost horizontal and appears to be stabilized mainly by pressing against the metatarsal condyles. The pastern joint is hyperflexed. These abnormalities explain the painful nature of this condition.

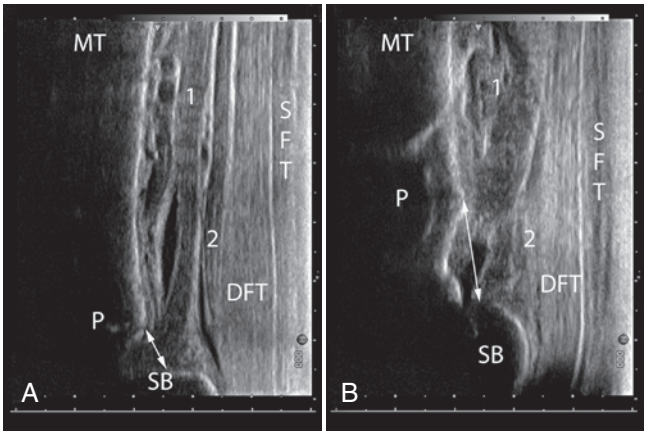


Figure 15-71 Ultrasonograms of a healthy suspensory ligament branch of a 15-month-old Holstein-Friesian heifer (*A*) and rupture of the suspensory ligament branch (*B*) in the 8.5-month-old Brown Swiss heifer shown in Figure 15-70. Both heifers were examined in lateral recumbency with a 7.5-MHz linear transducer. The view is from plantar toward the axial of the two lateral sesamoid bones (SB). MT, metatarsal bone IV; P, physis; DFT, deep flexor tendon; SFT, superficial flexor tendon; 1, branch of the suspensory ligament to the sesamoid bone; 2, connecting branch of the suspensory ligament ("check ligament") to the SFT. In *A*, the suspensory ligament (1) is irregularly thickened and has lost its typical tendinous structure. The sesamoid bone is not positioned normally as the distance from P to SB is increased (*arrows*). In the healthy limb (*A*), the check ligament to the SFT (2) is better delineated. There is subcutaneous edema in the region of the SFT in the diseased limb (*B*).

place for another 4 weeks. The remaining 2 months of box stall rest allow for regeneration and remodeling of the healing tissue. The prognosis is good in cattle with unilateral rupture or mild bilateral rupture, but signs of degenerative joint disease or ankylosis can occur.

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LUXATIONS/SUBLUXATIONS

Norm G. Ducharme (The editors wish to acknowledge and thank prior author Dr. Steven S. Trostle)

SCAPULOHUMERAL JOINT

Scapulohumeral luxations are a rare disease in farm animals, and the authors have only observed this in adult cattle and camelids. They are generally cranial and lateral and can be recognized by a prominent swelling on the cranial aspect of the shoulder (Figure 15-72). A severe lameness but no dropped elbow is seen. During examination, one hand is placed on the point of the elbow and the other hand on the proximal end of the humerus to apply internal and external rotation. A humeral fracture should be suspected with crepitus and a lack of movement of the proximal end of the humerus. However, a scapulohumeral luxation is identified by detecting movement of the humeral head. The diagnosis is confirmed by radiography when available (Figure 15-73*A* and *B*).

Closed reduction is obtained by placing the animal in lateral recumbency under heavy sedation; general anesthesia is preferable. With the affected limb uppermost, traction is applied on the appropriately padded distal limb, with counter-traction applied by placing a rope (with appropriate padding) in the pectoral region away from the scapulohumeral joint. The following two manipulation techniques have been reported: 1) traction can be applied caudally with simultaneous manual pressure on the humeral head in a caudal direction, and 2) alternatively, traction can be applied distally and slightly cranially and then firm pressure is applied caudally during slow release of the traction. Post reduction, the animal should be confined to a stall for 3 months.

We have only done surgical stabilization in a small (i.e., mini) steer and we are unsure if the technique is applicable in heavier animals. Under general anesthesia and with aseptic preparation of the shoulder joint a craniolateral approach is done, with the skin incision starting at the midpoint of the spine of the scapula extending over the major lateral tuberosity of the humerus and then extending along the cranial lateral surface of the humerus to the level of the deltoid tuberosity. The deep brachial fascia is started at the acromion process and extended caudal to the aspect of the deltoid tuberosity. This exposes the lateral aspect of the joint and the tendon of the infraspinatus tendon. The joint capsule is incised and the joint cleaned of debris. A combination of traction and limb abduction and rotation is used to reduce the luxation. The joint capsule is closed routinely. A cortical screw (4.5 or 5.5 mm) is placed in the greater tubercle, and two or three 3.2-mm drill holes are made in the distal aspect of the scapula (Figure 15-74*A*). Reinforcing sutures (Fiberwire No. 5[11]) are placed between the greater tubercle and the cortical screw and washer using a figure-8 pattern to minimize the chance of relaxation (Figure 15-74*B*). The deep branchial fascia and subcutaneous tissue are closed separately with a simple continuous pattern using an absorbable monofilament suture. The skin is closed in a simple interrupted or cruciate pattern and a stent sutured over the incision. Postoperative radiographs confirmed the

[11]Fiberwire No. 5, Arthrex, Bonita Spring, FL, USA.



Figure 15-72 An 11-month-old mixed breed steer with left scapula-humeral cranial luxation viewed dorsally. Note the prominent left shoulder. (Courtesy of Dr. Alan Nixon, Cornell University.)

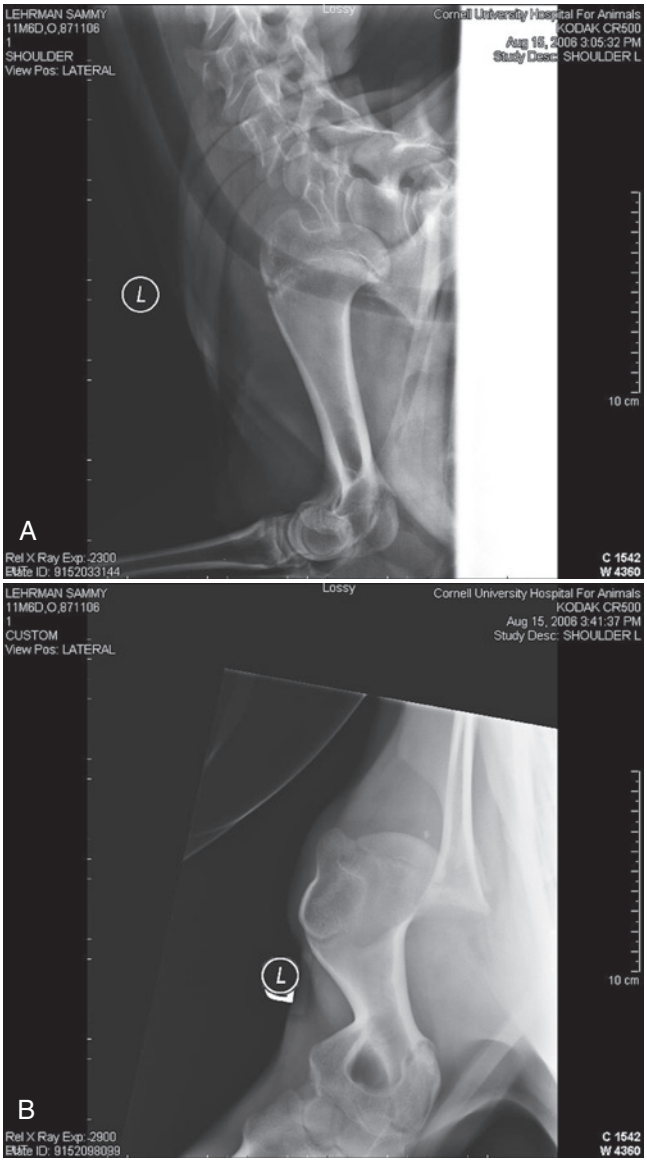


Figure 15-73 Lateral (*A*) and dorsocaudal (*B*) radiographs of the steer in the previous figure showing dorsal scapulohumeral luxation. (Courtesy of Dr. Alan Nixon, Cornell University.)

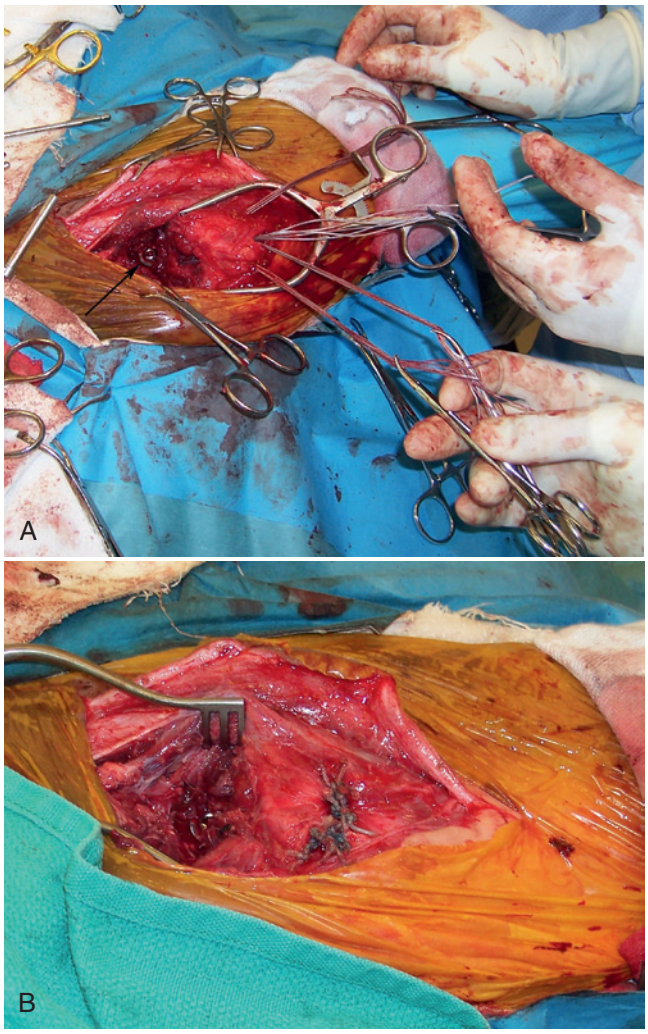


Figure 15-74 *A*, Intraoperative view showing a screw with washer in distal aspect of the scapula (*black arrow*) anchoring multiple threads of nonabsorbable polybend sutures that are passed distally into two 3.2-mm channels made in the caudal part of the lateral tubercle of the humerus. *B*, After knotting of the sutures. (Courtesy of Dr. Alan Nixon, Cornell University).

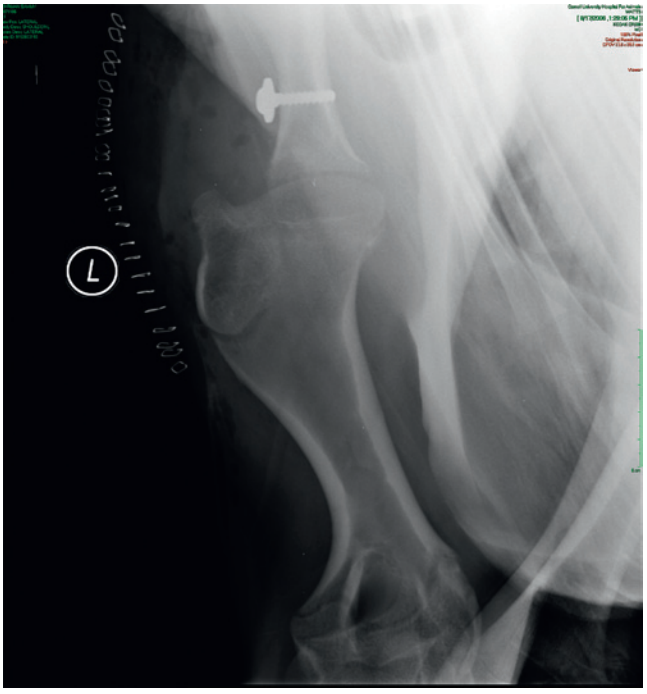


Figure 15-75 Postoperative radiographs showing reduction of the scapulohumeral luxation. (Courtesy of Dr. Alan Nixon, Cornell University.)



Figure 15-76 Modified Velpeau sling placed on a 10-month-old mixed breed steer after surgery for scapulohumeral luxation. (Courtesy of Dr. Alan Nixon, Cornell University.)

reduction (Figure 15-75). If possible, a Velpeau sling is protective of the repair (Figure 15-76).

A guarded prognosis is given although an accurate prognosis is not available because of the paucity of description in the literature and our very limited experience in cattle.

COXOFEMORAL JOINT

The stability of the coxofemoral joint depends on the integrity of the joint capsule, the confluence of the femoral head and acetabulum, and the gluteal muscles. Coxofemoral luxations are commonly associated with a traumatic episodes and dystocia in adult cattle (falls—sometimes during hypocalcemic episodes) or falling in calves. Coxofemoral luxations are generally craniodorsal, but cranioventral luxation (cranial and ventral to the pelvis) or luxation into the adductor foramen is also seen (Tulleners and Nunamaker, 1987). The clinical presentation varies depending on the location of the femoral head (i.e., luxation). Animals with craniodorsal luxation are generally ambulatory with moderate lameness. Part of the lameness component is mechanical in nature because of the associated shortened limb. On physical examination, there is swelling at the level of the greater trochanter associated with a shift in the normal gluteal musculature, and the ipsilateral tuber coxae is more ventral because the pelvis is not supported on the affected side (Figure 15-77). Viewed from the side, the normal ventral position of the greater trochanter in relation to the tuber ischia and tuber coxa (see Figure 3-20) is lost. In addition, the point of the hock on the affected side is displaced dorsally. Animals with a ventral coxofemoral luxation are less able to stand. This is particularly true if the femoral head is in the obturator foramen. The limb is actually longer and held in abduction at a typical, and clearly abnormal, angle (see Figure 3-21*B*). In ventral



Figure 15-77 Caudal view of an adult cow with right craniodorsal coxofemoral luxation. Note the swelling at the level of the greater trochanter (*yellow arrow*) associated with a shift in the normal gluteal musculature and the ipsilateral tuber coxae is more ventral than the contralateral side (*black arrows*).

luxation, the area of the greater trochanter is asymmetric because of the associated displaced musculature. With the animal placed in lateral recumbency, one can abduct the limb at near 90° from the pelvis (see Figure 3-21*A*). Rectal examination can identify the femoral head cranial to the pelvis or in the obturator foramen.

Imaging modalities are useful to get an exact diagnosis and identify associated skeletal damage. Indeed, laterolateral 25-degree oblique radiographs (Figure 15-78*A*) can usually be obtained with the animal standing and are often sufficient to identify the luxation. More recently a laterodorsal-lateroventral left or right 30-degree dorsal-right (or left) ventral radiographic view has been described for standing cattle. A ventrodorsal view under heavy sedation or general anesthesia works best to identify the luxation (Figure 15-78*B* and Figure 15-79) but require more powerful fixed radiography (100 kV and at least 200 mAS). Ultrasound can be a quick method of identifying a dorsal luxation because the femoral head can be seen more superficially (compared with the contralateral side) under the gluteal muscle. This diagnostic modality is much easier in younger and smaller animals.

In preparation for treatment, hypocalcemia should be treated because adductor muscle damage is likely in the recovery period. Treatment options for coxofemoral luxation involve closed and open reduction techniques. In both cases, significant traction is required. Therefore the animal is anesthetized and placed in lateral recumbency with the affected limb uppermost. Traction and countertraction are applied on the distal limb and inguinal area, respectively. Both areas must be appropriately padded. Reduction is obtained by applying traction on the distal limb in the direction opposite to the femoral head. External rotation is useful during the traction for craniodorsal luxation because it rotates the femoral head cranially instead of toward the contralateral side, facilitating lateral passage over the dorsal acetabulum rim. Closed reduction is rarely successful long term in cows affected with craniodorsal luxation because the dorsal joint capsule attachment on the acetabulum has a fibrocartilage rim that becomes trapped between the acetabulum and femoral head during reduction. This leads to a high rate of reluxation because of the combined effect from associated muscular damage and the fibrocartilage rim being trapped in the acetabulum preventing proper seating of the femoral head. Open reduction offers two significant advantages. First, the head of the femur can be seated appropriately in the acetabulum through open reduction because the dorsal joint capsule is prevented from being trapped in—or is removed from—the acetabulum. Second, the dorsal joint capsule can be reinforced (as described later) to minimize the risk of resubluxation.

Preparation for surgery and approach to the coxofemoral joint are described in the Slipped Capital Femoral Physis section. During open reduction of dorsal luxation, traction is applied distally to move the femoral head ventral to the dorsal rim of the acetabulum. At that time, debris from the acetabulum is removed and the surgeon ensures that the dorsal rim of the joint capsule is not within the lumen of the acetabulum. Traction is then released with the limb in slight abduction and with internal rotation until the femoral head is seated comfortably in the acetabulum. Sometimes a shoehorn retractor is used to guide the femoral head into place (this must be done very carefully to avoid damage to the articular cartilage). At this point, the distal limb is manipulated to a full range of flexion and extension and the femoral head should not be reluxated during these manipulations. If it does reluxate, some debris may be trapped in the acetabulum, and this is preventing correct seating of the femoral head. To minimize the likelihood of reluxation, the dorsal acetabular joint capsule is reinforced as follows: two screws (4.5 mm or 5.5 mm) and washers are placed in the craniodorsal rim of the acetabulum and one screw in the greater trochanter. A 3.2-mm (or 4-mm, respectively) bit is used to create a drill hole (size of core diameter of screw) through the mid portion of the rostral aspect of the greater trochanter. Multiple No. 5 nonabsorbable polyester or polyblend sutures are placed between the screws. The limb is placed in mild flexion, internally rotated, and the sutures tied in place (Figure 15-80). These sutures restrict the range the limb can be flexed, so a sufficient degree of flexion (approximately 30 degrees) must be maintained. The various muscle planes are closed by reapposition. Postoperatively, the animal should be stall confined for 3 months.

If performed within 12 hours of injury, the success rate with closed reduction is reported to range within 43% to 74%. Open surgical reduction of coxofemoral luxation is around 75% for calves and 50% for adults. If the animal is down and unable to rise on presentation, a poor prognosis is given and euthanasia is recommended. Complicated coxofemoral luxations associated with fractures are treated by internal fixation with a combination of techniques described earlier (see Figure 15-78*C*) but carry a guarded prognosis.

DORSAL PATELLA LUXATION

Dorsal luxation (or upper fixation) of the patella is a rare anomaly in cattle in North America (perhaps because of predominant dairy breed) yet apparently quite frequent in South America, where a review of 309 cases was described. It has been reported most commonly in beef cattle (Brahma, Angus Simmental, Charbray, Beefmaster, and Chianina), buffalo, and most rarely in Holstein-Friesian dairy cattle. Females near calving are predominantly affected, but the condition is also seen in males although at a much lower frequency. Desmitis of the medial distal patellar ligament associated with work or slippage that results in hyperextension of the limb is believed to be a predisposing factor.



Figure 15-78 Lateral oblique (*A*) and ventrodorsal (*B*) radiographs of a 3-year-old 630-kg adult cow's pelvis, which shows a luxated coxofemoral joint (in the adductor foramen). Note how the acetabulum is free of the femoral head compared with the contralateral side. In addition to the luxation, there is a greater trochanter fracture (*black arrow*) and a slipped capital femoral physeal fracture (*white arrow*). *C*, Postoperative ventrodorsal radiograph after the fractures and luxation are reduced and stabilized with internal fixation.

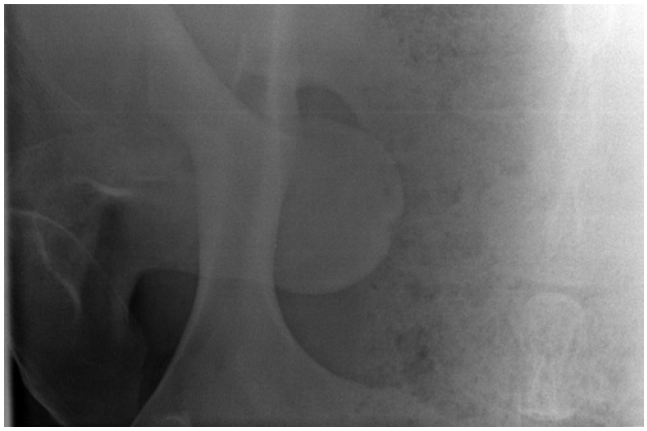


Figure 15-79 Ventrodorsal radiograph of a 3-year-old Holstein cow with caudoventral luxation into the obturator foramen.

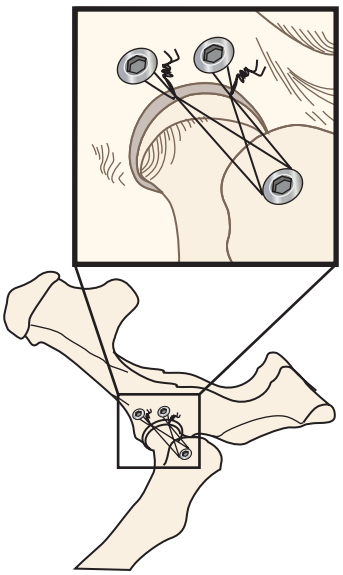


Figure 15-80 Schematic showing placement of sutures and screws to reinforce the dorsal joint capsule and prevent craniodorsal reluxation.

Stretching of the medial distal patellar ligament allows it to catch on the medial trochlea, which it normally would not. The condition is most commonly unilateral. Historically, it is seen in working dairy cattle but rarely in those less than 2 years old.

A complaint of lameness after a long period of rest is reported. Clinical signs include a normal posture at rest with clinical signs, depending on the frequency and permanence of the upward fixation. The limb locks in an extended state, so the animal has to drag the limb (tip of hoof) to move forward. When the patella returns to its normal position, the release from the extension makes the limb jerk forward. If upward fixation is very frequent, the toe becomes worn down. The condition somewhat resembles spastic paresis (see Chapter 18). However, spastic paresis is seen in young animals (<2 years of age) with backward movement of the extended limb, whereas forward movement of the extended limb is associated with upward fixation.

The treatment principle is to transect the medial distal patellar ligament near its attachment on the tibia. Because of safety to the animal and operator, or because the udder interferes with the procedure in dairy cattle, the animal is treated, preferably, in lateral recumbency with casting and sedation. With the affected limb uppermost and the leg tied slightly backward, local anesthetic is applied over the medial patellar ligament attachment on the tibia or the midpoint between the tibial crest and the medial aspect of the femoral condyle. Using a 10 Parker-Kerr blade, a 5-cm incision is made over the cranial aspect of the medial patellar ligament just proximal to the tibial crest. A large curved hemostat is passed axial to the ligament to isolate it, and the ligament is clamped. The ligament is transected proximal and distal to the hemostat with a tenotome and a segment of the ligament is removed. The end of a gloved finger is used to explore the ligament remnant to ensure that no fiber remains. The subcutaneous tissue is closed with a single cruciate suture using an absorbable suture, and the skin is closed with simple interrupted sutures.

The prognosis is very good, with a 99% success rate reported. Complications are related to wound infection or dehiscence. Although the condition is generally unilateral, approximately 4% present for occurrence in the contralateral limb after treatment.

TARSOCRURAL JOINT LUXATION

These luxations are rarely seen in farm animal and are generally associated with periarticular swelling and tarsocrural joint effusion with various severities of lameness. Radiographs and ultrasound are needed to confirm the diagnosis. We have seen tarsocrural luxation associated with medial malleolar fracture (Figure 15-81). Treatment is by immobilization with Robert Jones bandage (with or without splint) or casting for 4 to 8 weeks.

A distinctive luxation is that of the proximal intertarsal joint where the appearance is pathognomonic. It has been reported in young animals (1 year or less) after an acute traumatic episode. Immediately after the traumatic episode, the animal is unable to extend the tarsocrural joint (Figure 15-82). Because of the reciprocal apparatus, the stifle and fetlock are also held in flexion. The animal does not appear to be in pain but is unable to extend the limb.

Physical examination reveals a limb locked in a flexed position. Manually, one cannot extend the limb, and little or no swelling is present to localize the injury site. However, the characteristic appearance of the limb indicates a need to focus on radiographic examination of the hock joint. Radiographically, the luxation involves the proximal intertarsal joint as the calcaneus and centroquartal bone are luxated in a plantar-distal direction (Figure 15-83). Therefore both the calcaneoquartal and proximal intertarsal joints are involved. The distal displacement of the calcaneus into the groove between the two condyles of the talus appears to be the reason for the locking mechanism. During reduction, the calcaneus tip (coracoid process of calcaneus) is unlocked from the condyles, thus allowing extension of the limb.



Figure 15-81 Two-year-old Guernsey cow with acute swelling and lameness of the right hock. Note the medial malleolar fracture (*yellow arrow*) and increased spacing at the lateral aspect of the tarsocrural joint (*white arrow*).



Figure 15-82 A heifer with luxation of the proximal intertarsal joint. The limb is kept in flexion and cannot be manually placed into extension with standard manipulation.

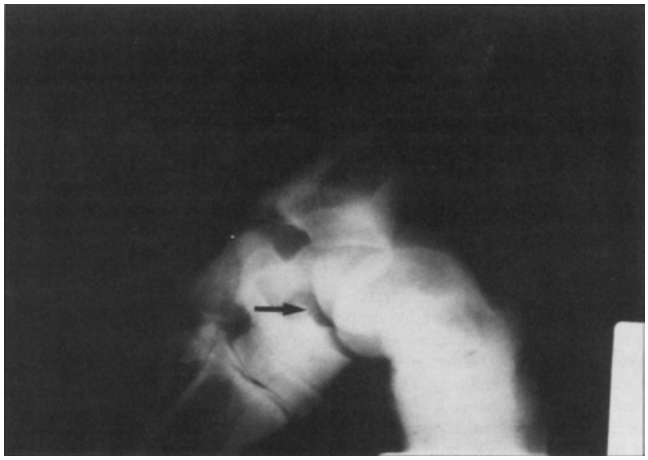


Figure 15-83 Plantarodistal subluxation (*arrow*) of the calcaneus and centroquartal bone in a heifer (flexed lateral view). (From Arighi et al: *Can Vet J* 28:710-712, 1987. This figure was initially published in The Canadian Veterinary Journal and is reprinted here with the kind permission of the Canadian Veterinary Medical Association.)

Under sedation with xylazine hydrochloride or general anesthesia, the animal is placed in lateral recumbency with the affected limb uppermost. Traction is applied distally and slightly caudally, and reduction occurs with little difficulty. A complication of the reduction is a small fracture of the proximal dorsal articular tip of the calcaneus, but this appears to have no significant consequence. Ideally, the fragment could be removed by arthroscopy, but this has not been performed by the author. Because the limb is stable once the luxation is reduced, no bandage or splinting is required. The animal is confined to a box stall for 6 weeks before resuming normal activity.

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INTERNAL FIXATION

Karl Nuss

Long bone fractures are the most dramatic cause of lameness in cattle, and a prompt decision must be made to treat or euthanize the animal. If surgical treatment is chosen, the fracture should be protected and the limb stabilized to ensure safe transport of the patient to a clinic. Fractures that are neglected result in soft tissue damage that severely impedes surgery and healing. In most commercial operations, the cost of surgery exceeds the value of the patient, and thus internal fixation at a referral clinic is usually limited to valuable breeding stock and animals belonging to rescue operations, although cattle kept as pets are also referred occasionally. Some owners choose surgical treatment because they feel responsible for the fracture, for example, when forced extraction of a calf resulted in fracture of a limb. There is an emerging trend among some clients to request treatment for conditions once thought irreparable.

The cost of internal fixation is considerable, and pre-, intra-, and postoperative radiographs, implants, the number of surgeons and anesthetists, anesthetic drugs, surgical time, medical treatment, complications, postsurgical hospitalization, cast changes, and rehabilitation measures all must be taken into account. Internal fixation is usually the treatment of choice for fractures in valuable patients or show cattle because—under ideal circumstances—it provides rigid stabilization of the fracture and allows immediate functional use of the limb postoperatively. Internal fixation may also be the preferred option for fractures that are considered to heal more reliably after surgical treatment (Figure 15-84). Cattle are able to compensate for mild angular deformities that may occur during fracture healing, and therefore this problem is of little consequence provided that productivity is maintained.

SELECTION OF PATIENTS FOR INTERNAL FIXATION

The decision to treat a fracture surgically is first based on the history and the results of a physical examination. Each bovine fracture patient is unique and presents specific challenges that require careful consideration. Cattle generally have a good propensity for callous formation and thus for secondary fracture healing, which makes them candidates for several treatment options, including external fixation using casts and splint-cast combinations. Internal fixation is indicated with marked fragment dislocation and in spiral fractures and long oblique fractures without fragment contact that carry the risk of shifting and subsequent skin penetration. Difficulty in immobilizing a proximal limb fracture is also an indication for internal fixation, and fractures involving a joint usually require internal reconstruction and fixation. Internal fixation of an open fracture is usually limited to Type I fractures of only a few hours' duration, and external fixation may be the better treatment option for an

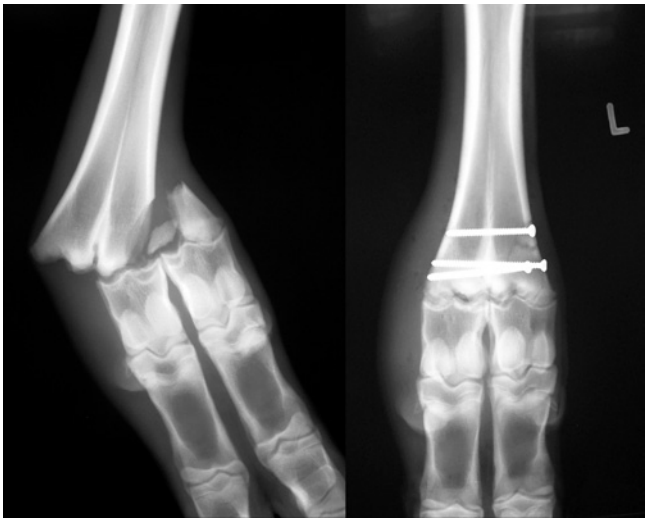


Figure 15-84 Salter-Harris Type II fracture of the left metatarsal bones III and IV in a 2-month-old Holstein-Friesian calf. Closed anatomically correct reduction was not possible because of the small third fragment. Open reduction and apposition of the fragments using 3.5-mm cortical screws inserted in lag fashion was carried out.

open fracture. Treatment of open Type II or Type III fractures is not recommended in cattle.

Fracture stabilization using internal fixation is much more difficult in adult or heavy cattle than in younger or lighter animals. In adult cattle, fractures are often caused by severe trauma, which results in splinter fractures, and surgical approach, repositioning, and wound closure are difficult in these cases. Furthermore, the bone-implant construct must be able to withstand extreme physical forces postsurgically. In severely comminuted humerus or femoral fractures in adult cattle, surgical treatment should be forgone. To minimize the risk of overload and failure of the bone-implant unit, distal limb fractures and most radius and ulnar fractures can be protected with a splint bandage or a cast after internal fixation; however, this adds to the cost of treatment and prolongs the time of postoperative care.

The fracture, possible complications, and prognosis should be assessed and discussed with the owner. Treatment options and prognosis are affected by concurrent injuries or diseases, and the risk-benefit ratio should be examined before a treatment decision is made. Owner expectations, perceived value of the animal, economic constraints, prognosis, and return to productivity are among the factors to be considered. The veterinarian is responsible for ensuring that the owner can make an informed decision by considering the cost of treatment as it relates to the ultimate outcome of the case. During the postoperative period, the owner must be prepared to house the patient alone in a box stall for 3 to 4 months and be willing to provide physiotherapeutic treatment and a rehabilitation program should the need arise.

Special Considerations in Calves

The most common cause of fracture in newborn calves is excessive traction during assisted delivery. It is particularly important to assess the systemic health in these calves. Birth trauma predisposes the calf to weakness and inadequate colostrum intake, which in turn result in compromised immunity and secondary infection. Passive transfer of antibodies should be determined and a plasma transfusion given before surgery if needed. Lower limb fractures caused by calving chains are the most common complication of forced extraction, but rib and vertebral fractures may also occur. An effort should be made to rule out these fractures because they can be difficult to diagnose in newborn calves. Fractures caused by calving chains are often associated with devitalization of the distal aspect of the limb(s).

Newborn calves have not learned to stand and will try to bear weight on the fractured limb rather than protect it. Pneumonia, enteritis, and umbilical infection often develop in the first few days after fracture treatment because of increased recumbency and the stress of anesthesia and surgery. This emphasizes the need for intensive postoperative care that includes assisting the calf with rising, standing, and lying down; turning when lying down; and wound care. It may be necessary to treat omphalitis surgically later on to prevent hematogenous spread of infection resulting in osteomyelitis at the fracture site.

In addition to these general risks, the bone structure in newborn calves poses problems in terms of internal fixation. On the one hand, only the central part of the diaphysis contains cortical bone thick enough to hold screws, and on the other hand the cancellous metaphyseal region is the predilection site for fractures. In newborn calves, 60% of femoral and tibial fractures occurred in the metaphyseal region near the stifle and only 25% in the diaphyseal area. It is often difficult to find sufficient bone for insertion of screws and plates in short metaphyseal-epiphyseal fragments containing a growth plate (Figure 15-85).

An insertion torque greater than 3 Nm is necessary to achieve adequate stability with compression of the plate to the bone and to prevent movement between the components of an osteosynthesis. Because this insertion torque is often not achieved with cortex screws in the bone of a newborn calf, movement of the plate results in loosening of the screws, subperiosteal saucer fractures in the near cortex, and subendosteal saucer fractures in the far cortex.

Locking screw systems are a promising alternative for surgical fracture treatment in young calves. Locking plates were developed for, and have been used successfully in, soft osteoporotic bone and are therefore likely to improve the success rate of plate osteosynthesis in calves. However, locked plate constructs are very rigid and may cut into soft bone when undergoing excessive cyclic loading. Another important aspect of plate osteosynthesis in calves is the availability of sufficient soft tissue to cover the implant. Affected bone is susceptible to infection unless the plate is covered by several tissue layers, or at least by fascia, subcutis, and skin. The metacarpal/metatarsal bones and the medial aspect of the tibia are areas where this problem may arise. When internal fixation is indispensable in the cannon bones, minimal osteosynthesis using screws accompanied by a fiberglass or transfixation cast rather than plate osteosynthesis may be chosen (Figure 15-86).

Many fractures that occur in calves and heifers involve the growth plate, especially in animals 6 months to 2 years of age, when growth rate is most rapid. One particular part of the growth plate constitutes a place of least resistance. The first three layers of the physeal cartilage (resting, differentiation, and proliferation zones) and the fifth layer (zone of provisional calcification) are relatively strong and resistant to shear forces, but the fourth layer (zone of hypertrophy) is a zone of relative weakness and susceptible to fracture. The Salter-Harris classification (Figure 15-87) is typically used to describe fractures that involve the physis and adjacent metaphysis. This classification has traditionally been used to estimate prognosis and risk of growth arrest with an increasingly poor prognosis from Types I to V, although a correlation between type and prognosis has not been confirmed in farm animals. In clinical practice, Salter-Harris Type I and

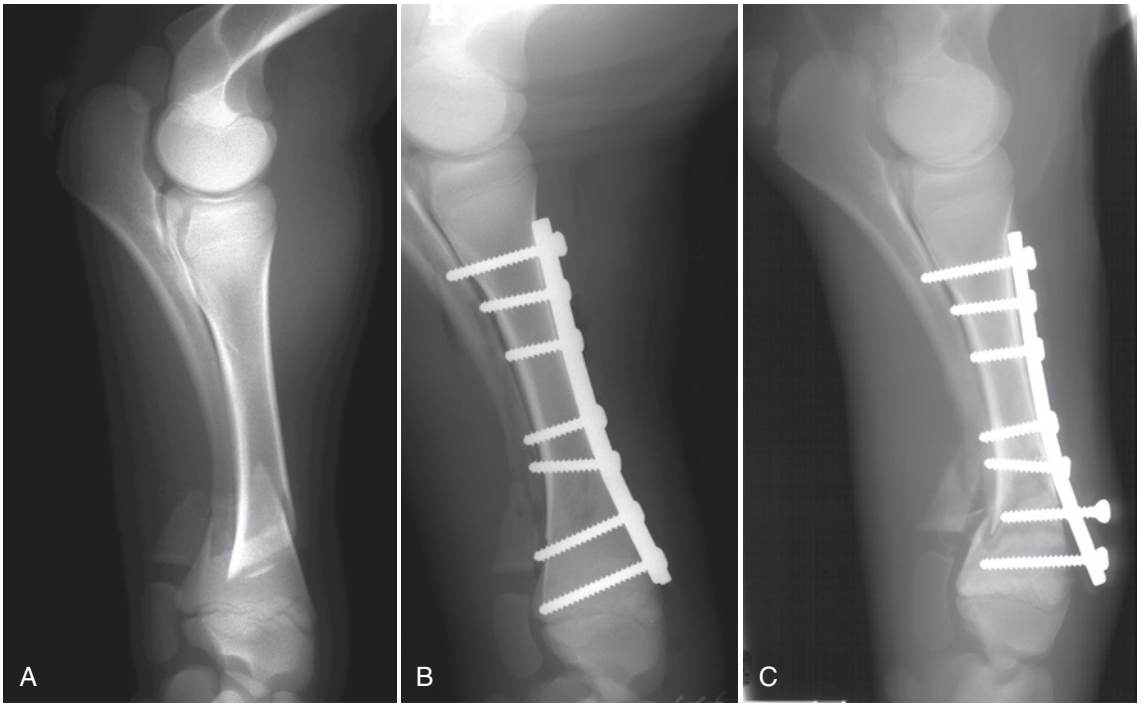


Figure 15-85 *A*, Lateral radiograph of a 3-day-old calf with distal metaphyseal fractures of radius and ulna. *B*, Lateral radiograph of the same fractures treated with a bone plate and screws placed dorsally on the radius. *C*, Lateral radiograph of previously described repair 14 days postoperatively. The distal screws are backing out and there is loss of contact between the distal radial fragment and the bone plate.

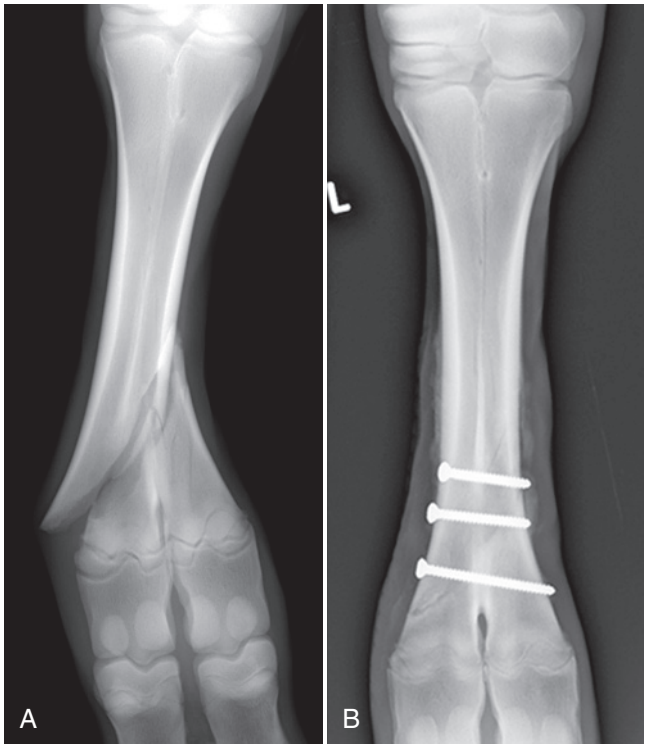


Figure 15-86 *A*, Dorsoplantar radiographic views of a distal metaphyseal fracture of the left third and fourth metatarsal bones in a 2-day-old calf. The fragments were adapted with 3.5-mm lag screws, and a full-limb fiberglass cast was applied. *B*, Good axial alignment, bone remodeling, and periosteal bone formation are apparent 3 weeks postoperatively.

II fractures make up a large majority of physeal fractures in farm animals. Type I fractures involve complete separation of the epiphysis from the metaphysis through the growth plate. A typical Type I physeal fracture is slipped capital femoral physis, which occurs through the proximal femoral growth plate (Figure 15-88).

Other common Salter-Harris Type I fractures occur in the metacarpal/metatarsal bones and less frequently in the calcanean or olecranon tuberosity. The latter two fractures occur through traction growth plates (apophyses), where tendons insert or originate. The most common physeal fracture in farm animals is the Salter-Harris Type II fracture, in which the epiphysis separates from the metaphysis together with a small corner of the metaphysis. These fractures are common in the distal growth plates of the metacarpal/metatarsal (see Figure 15-84) bones and less common in the distal growth plate of the femur and in the proximal growth plate of the tibia.

Salter-Harris Type I and II fractures generally have a favorable prognosis in farm animals, but the long-term results can be disappointing because of limb deformity. Salter-Harris Type III (Figure 15-89) and IV are very rare. They involve the joint surface and have a less favorable prognosis because arthrosis and angular limb deformities are likely complications.

A Salter-Harris Type V fracture is a crush injury to the physis. On radiographs, this injury appears similar to a nondisplaced Type I injury, but the fracture is the result of a high-energy impact, typically related to excessive axial stress on the bone. The germinal cells are injured by the crush, and growth arrest is common. An additional Salter-Harris Type VI (or Rang VI) fracture is not truly a physeal fracture but an injury to the perichondral ring and typically results in asymmetric growth arrest.

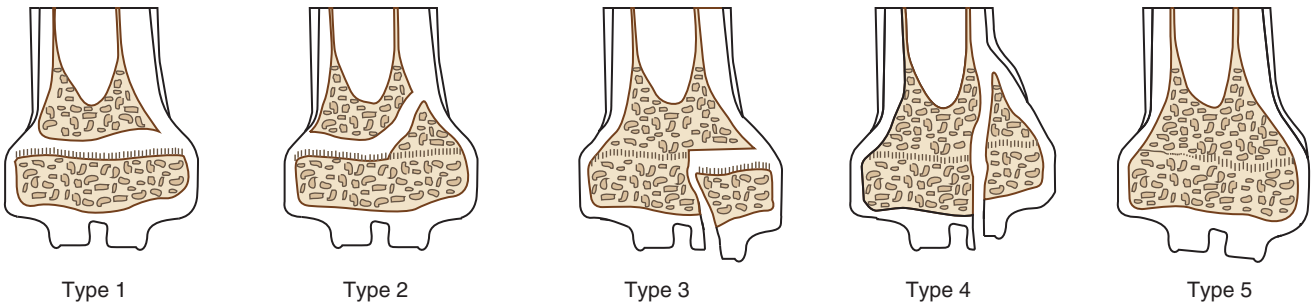


Figure 15-87 Schematic of the Salter-Harris physeal fracture classification system.

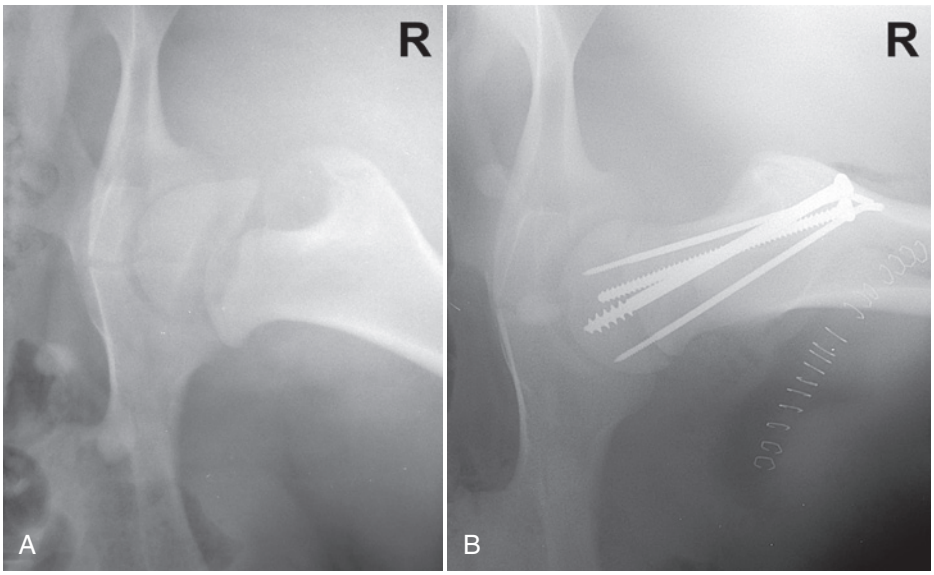


Figure 15-88 *A*, Ventrodorsal radiograph of a slipped capital femoral physeal fracture in a 5-month-old calf. *B*, Previously described fracture repaired with two threaded Kirschner wires, a 6.5-mm cancellous screw, and a 4.5-mm cortex screw inserted in lag fashion.

Special Considerations in Adult Cattle

Older cattle often have a guarded to poor prognosis because implants designed for large bones in heavy animals are simply not available. Fractures in mature cattle are usually the result of massive trauma and therefore are often severely comminuted. For successful large-animal fracture repair, there must be adequate contact between the ends of the bone fragments because plates and screws alone do not provide enough strength, even when two strong plates are used.

Adult cattle, like calves, are expected to be able to rise, lie down, stand, and walk on three legs when the fourth limb is compromised. Additional injuries need to be ruled out when adult cattle are unable to rise, and the prognosis adjusted accordingly. Implants must be strong enough to sustain the weight of adult cattle during rising and lying down, which is often a problem with fractures of the tibia, humerus, or femur. Therefore fractures of long bones proximal to the carpus or tarsus in heavy cattle are difficult to repair with internal fixation alone. Surgical treatment may be combined with external fixators, transfixation pin casts, or Thomas splints. Likewise, for radius-ulna repair, a full-limb cast that includes the olecranon tuberosity may be applied during the critical period of fracture healing. Double plating is recommended for most long-bone fractures in mature cattle; one plate is placed on the tension side of the bone, and a second plate is positioned in a plane that is 90 degrees to the first plate.

Fracture healing and convalescence take longer in adult than in young cattle. Weight loss and decreased production in dairy animals are common after fracture fixation, and the owner must be willing to accept a guarded prognosis and a considerable amount of nursing care for the animal. During convalescence, cattle should be housed in a well-bedded box stall with good footing.

EVALUATION OF A FRACTURE FOR INTERNAL FIXATION REPAIR

Diagnostic Imaging

Radiographs are usually sufficient to make a diagnosis of a fracture in farm animals, although multiple radiographic views may be necessary to define the fracture configuration in some cases. In fractures involving a joint or the carpal or tarsal bones, other imaging modalities including CT or magnetic resonance imaging (MRI) increase the diagnostic accuracy. Ultrasonography aids in the detection of fissures or fissure fractures (Figure 15-90) and can also be used to assess fracture healing and to document the development of vascularization at the fracture site. Radiographs should be of high

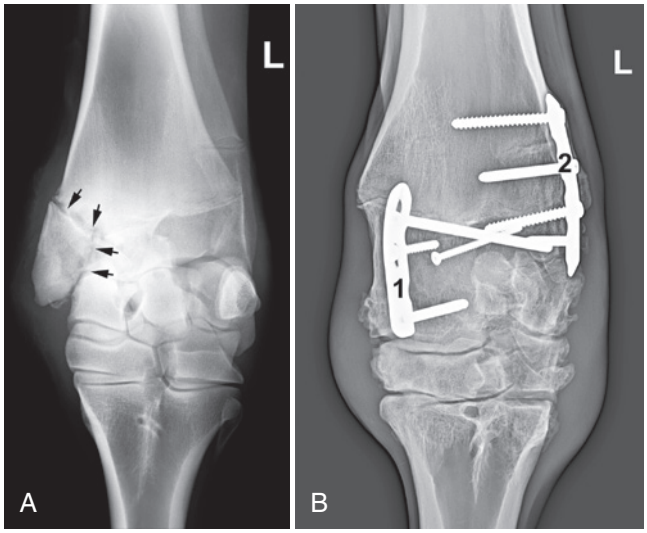


Figure 15-89 Salter-Harris Type III fracture of the medial epiphysis (*arrows*) of the left distal radius in a 34-month-old heifer. *A*, The fracture was several days old and comminuted at the time of surgery. Arthrodesis of the antebrachiocarpal joint was carried out using a locking compression plate (LCP, 1) placed dorsomedially over radius and radial carpal bone. Reduction was protected with a transfixation pin cast. Ankylosis was achieved but was accompanied by varus deformity. *B*, The deformity was addressed 6 months later by applying a second LCP (2) laterally. This heifer became a productive dairy cow but was still lame and had angular limb deformity 2 years later.

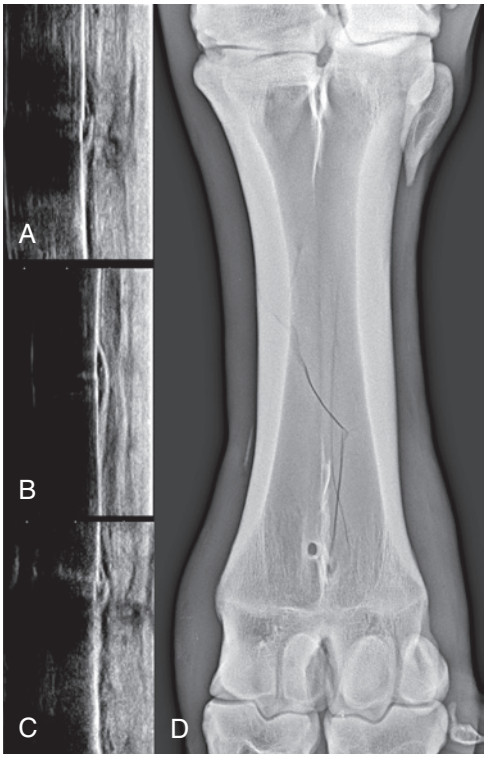


Figure 15-90 Ultrasonographic (*A-C*) and radiographic assessment of the left metacarpal bones in a 31-month-old breeding bull with 3/5 degree supporting limb lameness. Ultrasonographic examination of the metacarpal bones was carried out because of painful soft tissue swelling in the area and revealed elevated periosteum in several areas over the bone surface (*A-C*). Radiography (*D*) confirmed a nondisplaced fissure fracture of the third and fourth metacarpal bones, whereas ultrasonography indicated minimal displacement of the cortices. Healing was uneventful with conservative treatment (full-limb casts).

quality and show the entire bone(s) in two standard planes to ensure that all fragments are clearly visible and fissures or multiple fractures are not missed. Because of the large size of the radius and ulna, tibia, and femur, multiple radiographic views may be required in large cattle for complete evaluation of fractures of these bones.

Intraoperative radiography or fluoroscopy is mandatory when using any type of internal fixation. Intraoperative radiography aids in the assessment of the correct length of plates and screws, the correct positioning of plates, screws, or pins relative to joints or growth plates, the reduction of the fracture, and the final conformation of the bone-implant construct. It helps to avoid errors and allows the surgeon to make corrections before wound closure. Intraoperative radiographs should be taken in more than one view if possible to ensure that the repair is appropriate.

General Presurgical Considerations

The type of surgical treatment chosen in bovine fracture patients depends on many factors. The fracture must be assessed in terms of the bone affected, feasibility of fracture reduction, and achievement of adequate implant purchase in the major fracture segments to form a stable bone-implant unit. The success of fracture repair depends on the size, weight, age, and temperament of the patient. Calves older than 3 weeks and weighing about 80 to 250 kg generally have the best prognosis for fracture healing after internal fixation because they are immunocompetent, they have sufficient bone quality, and their weight is not likely to interfere with the strength of the implants. In these animals, stabilization is often achieved with one plate, but two plates should be used in heavier animals in an effort to obtain adequate stabilization of the fracture. The degree of soft tissue damage, especially when the function of vascular and nervous tissue is compromised and skin integrity impaired, must be considered for the prognosis. Sepsis, nerve damage, and vascular trauma adversely affect the prognosis and significantly increase the cost of treatment. Closed fractures can be expected to heal without bacterial infection, whereas open fractures are more likely to be associated with complications such as bone sequestration, delayed union, nonunion, and osteomyelitis.

Instruments and implants are expensive, and most clinics do not have all types of instruments at their disposal, which limits the number of feasible repair methods. One problem with the multitude of different available surgical techniques is that the number of cases is often relatively small in retrospective studies, which renders critical evaluation of the techniques difficult. Internal fixation is time consuming, and complications associated with ruminal distention during anesthesia should be minimized. In all adult ruminants, feed should be withheld for 24 to 36 hours and water for 6 hours, preoperatively, to minimize regurgitation and ruminal distention during anesthesia. However, preoperative fasting often is not possible—for instance, with fractures that require immediate surgery to prevent further soft tissue damage and fracture fragmentation or in cases with open fractures. A few hours of fasting are sufficient in unweaned calves. If there is no time for preoperative fasting, an oral or nasal stomach tube is passed into the rumen to prevent ruminal distention. In certain cases, ruminal distention can be relieved at the normal trocar site using a large-bore hypodermic needle.

Several hours should be planned for internal fixation of long-bone fractures. With clamp rod internal fixators, the mean surgical time has been reported to be 3.4 hours ± 33.2 minutes for metacarpal/metatarsal bone fractures and 4 hours ± 53.5 minutes for fractures proximal to the carpus/tarsus. Duration of open reduction and intramedullary pinning of femoral fractures in calves ranged from 50 minutes to 3.8 hours. Bellon and Mulon (2011) required 1 hour 15 minutes to 2 hours 30 minutes for insertion of intramedullary interlocking nails into the femur of calves. Recently developed cortical screws and locking screws are self-threading, which reduces the intraoperative time considerably. However, locking screws are very expensive and therefore not commonly used in commercial cattle. Preoperative planning must ensure that the appropriate implants are ready and that the surgery team has been properly trained to minimize the time required for surgery. All equipment and supplies potentially needed for the surgery should be laid out and readily available at the start of the operation.

Anesthesia

See Chapter 5 for in-depth discussion of anesthesia.

GENERAL PRINCIPLES OF INTERNAL FIXATION IN CATTLE

Positioning

Long surgical times increase the risk of pressure-related tissue injury and infection. Careful positioning of cattle on the operating table is critical for prevention of nerve and muscle damage. Adult cattle are prone to radial nerve paralysis and torn adductor musculotendinous structures. The lowermost forelimb should always be well padded and extended forward. The hind limbs should be supported and padded to avoid myopathy, which predisposes the animal to slipping and tearing of the adductor muscles. Positioning of heavy cattle on the operating table should be assisted by a ceiling-mounted crane and manual pull on the legs; pulling on the tail must be done carefully to avoid sacral fractures and dislocation of caudal vertebrae.

Optimal access to the fracture for the entire surgical team determines the positioning of the affected limb. Traction is routinely applied to the limb to reduce fractures of the metacarpal/metatarsal bones and radius/ulna once the patient has reached a sufficient plane of anesthesia. Considerable tension is required to reduce long-bone fractures, and therefore the animal should be securely fixed to the operating table without compromising respiration during anesthesia. The limb is fixed in a horizontal position with the help of a pulley or hoist, which allows optimal traction and surgical preparation of the suspended limb. The area of the limb where the rope is attached, usually the pastern, must be well padded, and a loop of a rope is placed around the padded area and the end attached to a pulley, which is fixed to a wall or a post. The direction of traction can be changed by changing the position of the loop at the pastern (dorsal, lateral, or palmar/plantar), thus facilitating reduction of the fracture. A traction device with a controlled-release mechanism is helpful for reduction in axially loaded bones. Overriding of the fracture fragments can result when traction is applied to a limb with a humerus, femoral, or tibial fracture. Other measures to aid in fracture reduction are the use of local anesthesia under certain circumstances, a deeper plane of anesthesia, and less frequently muscle relaxants and fragment distractors. Tenting of the fragments should be done cautiously because it can exacerbate fissure fractures or cause chip fractures. The traction is released as soon as repositioning has been achieved to allow relaxation of tendons, muscles, nerves, and blood vessels.

Surgical Approach and Fracture Reduction

The goal of internal fracture repair is to produce anatomically correct and stable fixation that allows rapid painless use of the limb. The implementation of this target starts with the surgical approach. The approach chosen is based on optimal access to the fracture and best possible placement of the implants with minimal soft tissue trauma. Internal fixation in small animals and humans now focuses on the biological rather than the mechanical aspects of bone healing. Relative stability and secondary bone healing via callus formation can be achieved using locked plates, which are preferred over precise anatomic reconstruction and compression plate osteosynthesis. However, in heavy cattle scheduled for plate osteosynthesis, optimal stability achieved through correct anatomic reconstruction is still indispensable because of high loading forces after surgery, and fixation still depends on friction obtained by pressure at the plate-bone interface. Repositioning of fragments must be done in an anatomically correct fashion to facilitate fit of the plate, which together with the bone provides the majority of support. Precise repositioning usually requires sufficient exposure of the fragments and adjacent bone as well as incision of the periosteum. Depending on the nature of the injury, the periosteum is frequently detached from the bone at the fracture site. Once the fracture has been exposed, clotted blood and devitalized tissue are removed before reduction is attempted. By freeing the periosteum before the fragments are repositioned, blood vessels and nerves can be protected by keeping them out of the surgical field. On the other hand, even surgical techniques deemed minimally invasive for plate application can lead to nerve and blood vessel damage. A bacteriologic culture of material taken from the deep surrounding soft tissue is recommended in open fractures to identify potential pathogens and select appropriate antimicrobials. During the surgical procedure, the fracture site should be repeatedly rinsed with a solution containing an antibiotic to reduce contamination and bacterial growth.

In fractures with two fragments, the fragments are repositioned and held in place with large pointed reduction forceps. Extra-large bone forceps may be needed for large cattle. Reduction can be maintained by placing lag screws across the fracture gap or by using cerclage wires. Several 3.5-mm or 4.5-mm cortical screws are placed, usually in lag screw fashion, to maintain the position of the fragments. The reduction forceps are removed so that they do not interfere with plate application. If the 3.5-mm positioning screws are not removed, the screw heads must be recessed into the cortex so the plate can be applied over them. Otherwise, the positioning screws are replaced by lag screws, which are placed in the plate. Multiple fragments are repositioned and held in place with lag screws to create two main fragments, which are then adapted as described previously.

The fracture configuration, possible approach(es), and presumed tension side of the bone(s) are considered before application of the plate(s) to the bone surface (Figure 15-91). The plates are usually not removed after fracture healing in cattle, but it must be remembered that they may become incorporated into the bone, forming a weak point, which may result in refracture years after fixation. Torn or incised periosteum rarely can be resutured over the fragments and even less so over the plate(s). The fasciae, muscles, subcutis, and skin are sutured to provide a soft tissue cover over the fracture site and implant.

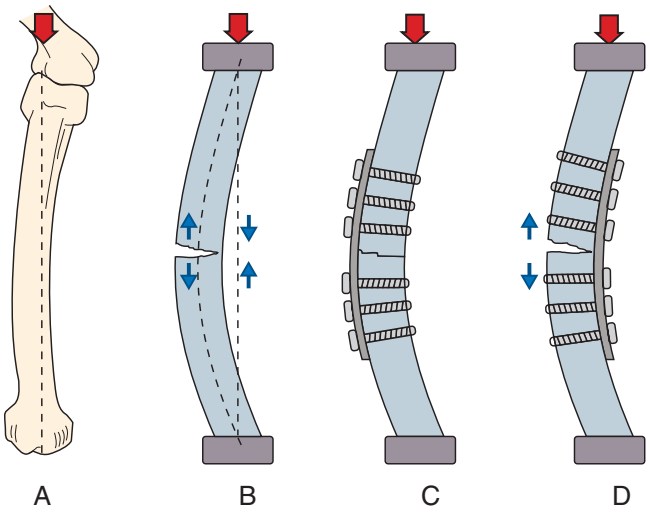


Figure 15-91 Illustration of the principle of placing a bone plate on the tension surface of a bone, so the bone receives compressive forces. For example, the long bone (*A*) can be compared to a bent column (*B*). A plate applied to the convex or tension side of the bone (C) when it is loaded counteracts the tension forces and provides rigid internal fixation in the bending closed position. If the plate is applied on the concave surface (*D*), it does not give as rigid fixation, and the plate is subjected to excessive bending forces that predispose it to failure. (Modified with permission from DeCamp CE, Johnston SA, Dejardin LM, Schaefer SL, editors: *Brinker, Piermattei, and Flo's Handbook of small animal orthopedics and fracture repair*, ed 5, St. Louis, 2016, Elsevier.)

Implants and Techniques

The materials used for fracture reduction and internal fixation in cattle include Kirschner wires, Rush pins, intramedullary Steinmann nails, intramedullary interlocking nails, and plates of various shapes and sizes. The surgeon must be familiar with the various implant systems and their unique qualities, applications, and limitations. There are few implants designed specifically for cattle and few studies on implants used specifically in cattle. Cerclage or hemicerclage wires are used for adaption of fragments, often combined with intramedullary fixation or Kirschner wires.

Plates and screws have been modified considerably over the years (Tables 15-3, 15-4, and 15-5) and there has been a trend to create special plates for specific parts of certain bones. Such plates have also proven advantageous in cattle. New implants such as the locking compression plates (LCP) and region-specific locking implant systems have become the new standard, which has necessitated the purchase of new and expensive instrument sets in many referral specialty clinics.

Bone Plates

Plating provides the most rigid form of internal fixation in ruminant orthopedics. Dynamic compression plates (DCP, LC-DCP) are currently being replaced with locking compression plates (LCP). These new locking systems use plates with combination holes that accept conventional screws as well as locking head screws. LCP are therefore versatile. Recently the dynamic hip screw system and the dynamic condylar screw system (Figure 15-92), which were occasionally used for osteosynthesis in cattle in the past, were upgraded and equipped with combi holes to allow insertion of locking screws. The Equine 5.5 broad LCP (Headquarters Synthes, Inc., West Chester, PA, USA) is a particularly strong plate for fracture fixation in adult horses and cattle. It has a rounded end, which allows for more coverage of the length of bone and facilitates placement near joints.

Locking plates were originally designed to act as rigid internal fixators. The locking screw heads are threaded and can be locked in the plate. An angle-stable construct is formed between bone, screw, and plate (Figure 15-93). Locking plate constructs prevent primary as well as secondary loss of reduction. Primary dislocation of fragments is not possible because the thread in the screw head is inserted in the thread of the plate, and therefore the bone is not pulled toward the plate. A strong unit is created after insertion of the screw head in the locking plate, which accounts for the lack of movement between the plate and screws even under load. Locked plates are more resistant than compression plates because they convert shear stress to compressive stress at the screw-bone interface. However, locked plates cannot be used as buttress plates because cyclic compressive loading with a fracture gap leads to plate fatigue and breakage. Similar to limited-contact dynamic compression plates (LC-DCP), locking plates have a low-contact surface that serves to protect blood vessels and can be applied in a minimally invasive fashion because of their pointed ends. It is preferable to apply the LC-DCP and LCP over the periosteum. LCPs are particularly suited for osteopenic or osteoporotic bone and should also provide better stability in long bones of newborn calves. Locked plating provides superior fixation in anatomic regions that prove difficult for conventional plating, such as articular and comminuted metaphyseal fractures.

In vitro studies have shown that the stability of the LCP corresponds to that of the DCP only when its distance from the bone is less than 2 mm. The principles of conventional dynamic compression plating with minimal motion between the plate and bone must therefore also be observed when the LCP is used in large animals. The plates must be molded precisely and attached firmly to the surface of the bone for optimum friction. The combi holes in the LCP allow the plate to be compressed to the bone using cortex screws and then secured with locking screws (hybrid use of screws). Cortical screws must be placed before the locking screws to prevent fragment malalignment, stress to the cortex, or pullout of the cortical threads. The strategic placement of cortex and locking screws can improve the function of the osteosynthesis; placement of cortical screws at the plate ends provides the desired reduction in stiffness of locked plating constructs though retaining construct strength.

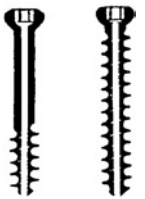
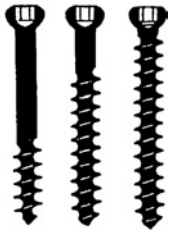
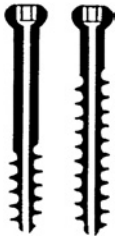
Double plating improves the torsional and bending strengths of the bone-implant unit considerably. To avoid stress concentration in the diaphysis, where secondary fracture is most likely, the plates should begin and end in the metaphysis and be staggered in their relative proximal and distal orientation. Staggering prevents stress concentration at the plate ends and facilitates screw placement. Screw placement is more difficult with LCP double plating. The locking head screws must be inserted orthogonally to the long side of the plate. It is easy for the screws of the two plates to interfere with each other if only locking screws are used. In general, screws should be placed in all plate holes because an empty screw hole represents a place of relative weakness that could break under load.

Screws

Because of their large core diameter (4.3 mm), the 5.0-mm locking-head screws are the strongest screws available for large-animal fracture treatment. Locking screws are self-tapping and therefore reduce application time. Self-drilling and self-tapping screws are expensive and can only be used in unicortical fashion because they cause soft tissue damage to the transcortical aspect of the bone. These screws are

Table • **15-3**

Veterinary Large-Animal Screw, Drill Bits, and Tap Chart

SCREW NAME	3.5-MM CORTEX	4.5-MM CORETX	4.5-MM SHAFT	4.5-MM CANNULATED	3.5-MM LOCKING	4.0-MM LOCKING	5.0-MM LOCKING	5.5-MM CORTEX	6.5-MM CANCELLOUS	7.3-MM CANNULATED
Screw Ø	3.5	4.5	4.5	4.5	3.5	4	5	5.5	6.5	7.3
Glide hole Ø	3.5	4.5	4.5	4.5	None	None	None	5.5	4.5	7.3
Thread hole Ø	2.5	3.2	3.2	3.2	2.8	3.2	4.3	4	3.2	5
Tap Ø	3.5	4.5	4.5	4.5	None	None	None	5.5	6.5	7.3 Optional
Screw shape										
Cannulation guide pin	–	–	–	150-mm long/1.6-mm Ø	–	–	–	–	–	300-mm long/2.8-mm Ø
Type thread	Cortical	Cortical	Cortical	Cancellous	Cortical narrow	Cortical narrow	Cortical narrow	Cortical	Cancellous	Cancellous
Pitch	1.25	1.75	1.75	1.75	0.8	1	1	2	2.75	2.75
Screw head diameter	6	8	8	6.5	5	6.6	6.6	8	8	8.2
Special head design	–	–	–	–	Conical threaded	Conical threaded	Conical threaded	–	–	–
Thread length	Fully threaded	Fully threaded	Variable	1/3 of length/ fully threaded	Fully threaded	Fully threaded	Fully threaded	Fully threaded	16 mm/32 mm/ Fully threaded	16 mm/32 mm/ Fully threaded
Shaft diameter	–	–	4.5	3.1	–	–	–	–	4.5	4.8
Core diameter	2.4	3.0	3.0	2.7	2.9	3.4	4.4	3.8	3.0	4.5
Self-tapping	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes
Self-drilling	No	No	No	Yes	Available (Europe only)	Available (Europe only)	Available (Europe only)	No	No	Yes
Drive	Small (2.5-mm) hex	Large (3.5-mm) hex	Large (3.5-mm) hex	Large (3.5-mm hex)	T15 stardrive	T25 stardrive	T25 stardrive	Large (3.5-mm) hex	Large (3.5-mm) hex	Large (4.0-mm) hex

From Auer JA: Principles of fracture treatment, In Auer JA, Stick JA, editors: *Equine surgery*, ed 4, St. Louis, Elsevier-Saunders, 2012, pp 1047–1081.

Table • **15-4**

Standard and Special Plates Used in Large Animals

NAME	LC-DCP 3.5	LC-DCP 3.5 BROAD	LC-DCP 4.5	LC-DCP 4.5 BROAD	DCP 3.5 BROAD (NOTES 1,2)	DCP 4.5 BROAD	DCS PLATE	DHS PLATE	LCP 3.5	LCP 3.5 BROAD (NOTE 4)	LCP 4.5 NARROW	LCP 4.5 BROAD	EQUINE LCP 5.5 BROAD	ONE-THIRD TUBULAR PLATE
Plate type	Standard	Standard	Standard	Standard	Special (note 3)	Special (note 3)	Special (note 3)	Special (note 3)	Standard (note 3)	Standard	Special (note 3)	Special (note 3)	Special	Special
Plate cross section														
Width (mm)	11	13.5	13.5	17.5	12	16	16	19	11	13.5	13.5	17.5	17.5	9
Thickness (mm)	3.3	4.2	4.2	5.2	3.6	4.8	5.4	5.8	3.4	4.2	4.2	5.2	6	1
Length (mm)	28 (2 holes) to 288 (22 holes)	94 (7 holes to 289 (22 holes)	34 (2 holes) to 394 (22 holes)	106 (6 holes) to 394 (22 holes)	86 (7 holes) to 266 (22 holes)	103 (6 holes) to 359 (22 holes)	114 (6 holes) to 370 (22 holes)	See Table 15-5	27 (2 holes) to 287 (22 holes)	94 (7 holes) to 289 (22 holes)	66 (3 holes) to 287 (16 holes) (note 5)	116 (6 holes) to 440 (24 holes)	188 (10 holes) to 440 9 (24 holes)	28 (2 holes) to 148 (12 holes)
Plate angle	Straight	Straight	Straight	Straight	Straight	Straight	95°	(130° also) 135° (140°, 145°, 150°)	Straight	Straight	Straight	Straight	Straight	
Angled portion	–	–	–	–	–	–	Barrel 25 mm long	Barrel 25 and 38 mm long	–	–	–	–	–	–
Screw size (mm)	3.5, 4.0	3.5, 4.0	4.5, 5.5, (6.5)	4.5, 5.5, (6.5)	3.5, 4.0	4.5, 5.5, (6.5)	4.5, 5.5, 6.5	4.5, 5.5, 6.5	3.5, 4.0, 3.5 LS	3.5, 4.0, 3.5 LS	4.5, 5.5, (6.5) 5.0 LS	4.5, 5.5, (6.5) 4.0/5.0 LS	4.5, 5.5, (6.5) 4.0/5.0 LS	3.5, 3.5, LS
Hole arrangement	Straight	Staggered	Straight	Staggered	Straight	Staggered	Staggered	Staggered	Straight	Straight	Straight	Staggered	Staggered	Straight
Hole spacing	13	13	18	18	12	16	16	16	13	13	18	18	18	12
Hole design	DCU	DCU	DCU	DCU	DCP	DCP	2 round, rest DCP	DCP	Combi-hole	Combi-hole	Combi-hole	Combi-hole	Combi-hole	Oval, round w/ collar
Place midsection	No	No	No	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Hole spacing in plate midsection	–	–	–	–	16	25	–	–	LO-LO 9 DCU-DCU 15	LO-LO 9 DCU-DCU 15	LO-LO 13 DCU-DCU 20	LO-LO 13 DCU-DCU 20	LO-LO 13 DCU-DCU 20	16

From Auer JA: Principles of fracture treatment, In Auer JA, Stick JA, editors: *Equine surgery*, ed 4, St. Louis, Elsevier-Saunders, 2012, pp 1047–1081.
DCP, dynamic compression plate; DCS, dynamic condylar screw; DCU, dynamic compression unit; DHS, dynamic hip screw; LC-DCP, limited-contact dynamic compression plate; LCP, locking compression plate; LO, locking.



Figure 15-92 *A*, Lateral and, *B*, craniocaudal radiographs of an adult bull weighing 900 kg with a comminuted distal radius fracture. *C*, Lateral and, *D*, craniocaudal radiographs of the previous fracture repaired with a dynamic condylar screw and plate system. (Courtesy of Dr. Ryland B. Edwards III, University of Wisconsin.)

Table • **15-5**

Dynamic Hip Screw Plate Lengths

BARREL LENGTH	BARREL ANGLE	PLATE LENGTH
38-mm barrel	130°	46 (2 hole) to 238 (14 hole)
	135°	46 (2 hole) to 333 (20 hole)
	140°	46 (2 hole) to 270 (16 hole)
	145°	46 (2 hole) to 270 (16 hole)
	150°	46 (2 hole) to 333 (20 hole)
25-mm barrel	130°	46 (2 hole) to 110 (6 hole)
	135°	46 (2 hole) to 110 (6 hole)
	140°	46 (2 hole) to 110 (6 hole)
	145°	46 (2 hole) to 110 (6 hole)
	150°	46 (2 hole) to 110 (6 hole)

From Auer JA: Principles of fracture treatment, In Auer JA, Stick JA, editors: *Equine surgery*, ed 4, St. Louis, Elsevier-Saunders, 2012, pp 1047-1081.

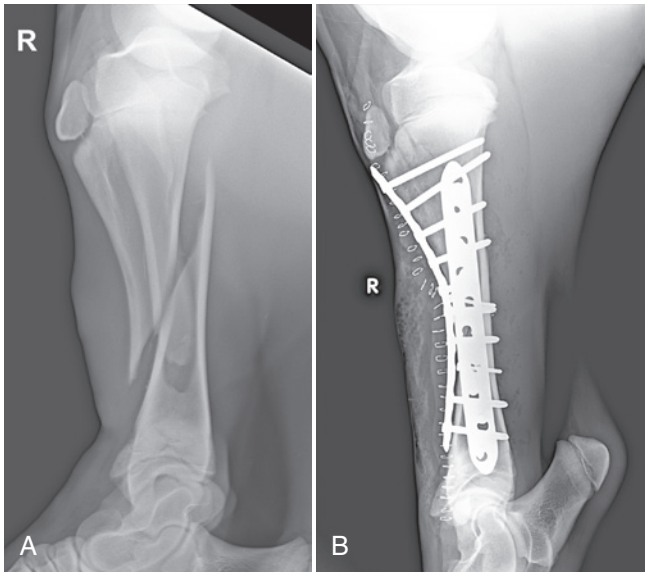


Figure 15-93 Radiographs of a tibia fracture in a 3.5-month-old Brown Swiss calf. *A*, Preoperative mediolateral view shows a long oblique tibia fracture with a large fragment that was situated medially. *B*, Radiographic view taken immediately postoperatively shows fixation performed in a stepwise fashion using 3.5-mm lag screws, a standard LCP placed cranially, and a broad LCP placed medially. The patient was completely healthy according to the owner 1 year after surgery.

rarely used in large-animal orthopedic surgery. In addition to the 5.0-mm locking head screws, the 4.5- and 5.5-mm cortex screws are the standard screws for fracture fixation in cattle. The size of the screw is determined by the outside diameter of the threads. The 5.5-mm screw has greater holding power and tensile strength than the 4.5-mm screw in horses. In cattle heavier than 200 kg, 5.5-mm cortical screws should be used. A stripped 5.5-mm hole can still be engaged by a 6.5-mm cancellous screw. The 6.5-mm cancellous screw is available in three configurations: a 16-mm thread length, a 32-mm thread length, and fully threaded. In vitro studies of bones of young calves have shown that 6.5-mm cancellous screws have greater holding power in the metaphysis than 4.5-mm and 5.5-mm cortical screws. Therefore 6.5-mm cancellous screws should be preferred for use in the metaphysis of young calves. Cannulated screws with a 7.0-mm diameter have been used in bovine capital femoral physeal fractures. Furthermore, cannulated screws can be used in a stripped 6.5-mm cancellous screw hole. Insertion of cannulated screws uses the same technique as the insertion of cortex screws; however, all instruments are cannulated to accept a guide wire for determination of the length of the screws to be inserted. The 7.3-mm cannulated screw has a self-drilling and self-tapping tip, and therefore a screw of predetermined length can be inserted without drilling a thread hole.

A disadvantage of locked screws is that they cannot be inserted at an angle, for example, across a fracture line or to avoid a joint or the screws of another plate in double-plating techniques. A slight off-axis deviation was shown to significantly lower load-to-failure force. Unicortical locking screws, or cortex screws or plates with polyaxial threads, can be used to solve this problem. A torque-limiting attachment is used on the screwdriver for locking screws to ensure that the appropriate amount of torque (4.0 Nm) is applied. However, hand tightening of locking screws is recommended in large animals to ensure that the head thread is tightened sufficiently.

Intramedullary Pins and Interlocking Nails

Kirschner pins, Rush pins, Steinmann nails, and intramedullary interlocking nails are relatively inexpensive for use in fracture fixation in cattle. Kirschner pins have been used to adapt and fix fragments associated with epiphyseal or growth plate fractures in calves and heifers. Kirschner wires combined with cerclage wires are used to treat apophyseal fractures, for example, of the calcaneus, but additional external stabilization is usually required.

Intramedullary pins are indicated for the treatment of diaphyseal fractures of relatively straight bones. They are not indicated for the repair of long oblique, spiral, or comminuted fractures without the use of other devices (cerclage wires, screws, external skeletal fixators) that prevent overriding or rotation of the fracture fragments. Intramedullary rods act as internal splints in fracture stabilization by aligning the bony columns and providing resistance to bending forces. The disadvantages of intramedullary pins are poor torsional stability and lack of resistance to collapse in oblique and comminuted fractures. Steinmann pins have been used most commonly in cattle, particularly in calves, for humerus and femoral fractures. The pins have a diameter of up to 6.35 mm and are available with or without a threaded end. The use of these pins is associated with considerable callus formation, suggesting instability and most likely pain, at least until stability has been achieved. The use of multiple pins (stack pinning) in the medullary cavity (Figure 15-94) increases the contact area between the implants and cortex and improves resistance to torsion and bending. Threaded Steinmann pins that can be anchored in the subchondral bone are used for fixation of fractures in newborn calves. In some cases, screws and cerclage wire are used for additional support (Figure 15-95). Migration of pins may occur in association with damage to the intramedullary cavity and the physeal cartilage.

The interlocking nail (Figure 15-96) represents an improvement over the Steinmann pin because it decreases torsional instability and can prevent collapse of comminuted fractures caused by weight bearing and migration of the pin. An open surgical technique is recommended with interlocking nails because of their large diameters. A 6.35-mm-diameter intramedullary pin placed in normograde fashion from the proximal location into the medullary cavity and seated distally in the subchondral bone of the distal epiphysis

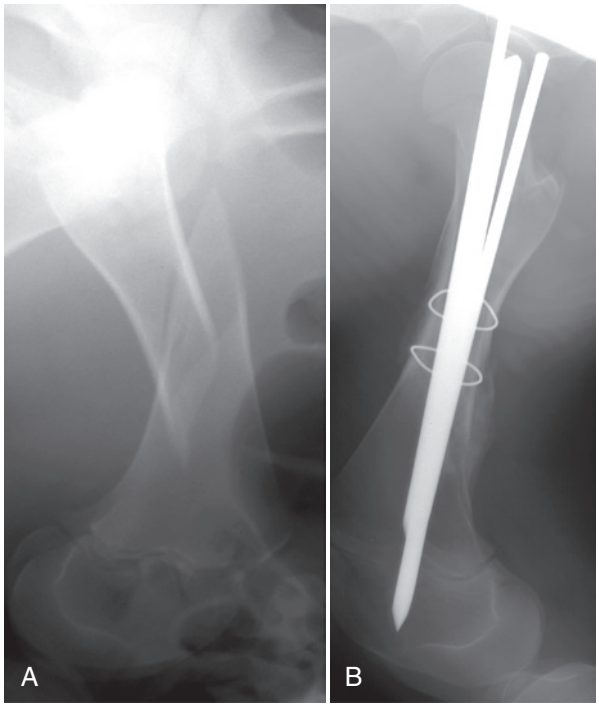


Figure 15-94 *A*, Lateral radiograph of a 2-day-old calf with a middiaphyseal femoral fracture. *B*, Previously described fracture repaired by using intramedullary pins (stack pinning) and cerclage wire. (Courtesy of Dr. Ryland B. Edwards III, University of Wisconsin.)

creates a pathway for interlocking nail insertion. A reaming device with a slightly smaller diameter than the interlocking nail can also be used for this purpose. The intramedullary pin is removed and the interlocking nail driven into the space created by the pin; this minimizes the likelihood of bone fracture during interlocking nail placement. The interlocking nail is inserted with a large hand chuck. The aiming device is then attached to the proximally exposed portion of the interlocking nail; this device ensures that the holes in the nail are correctly located, the drill is correctly centered, and the drill bit meets the screw holes of the interlocking nail. Two screws each are usually placed in the distal and proximal primary fracture fragments. The quality of the surrounding bone in neonates determines the strength of a repair when an interlocking nail is used. Correct distal placement of the intramedullary rod in the femur should be checked by intraoperative radiography or stifle arthrotomy. Intramedullary pins should be cut proximally at the level of the skin to allow for pin removal and prevent impingement of the sciatic nerve in femoral fractures. Intramedullary pin removal can be difficult in rapidly growing animals that have achieved clinical union, but the pin poses no problem to the animal if it remains in situ. Removal should be considered if the pin has migrated or is associated with infection. The interlocking nail should be as long as possible although still allowing soft tissue and skin coverage of the proximal end.

Solid interlocking nails have been shown to be much more resistant than tubular interlocking nails. However, the compressive stiffness of an interlocking nail-bone construct with an experimental 1-cm gap was reported to be only 15% of intact bone. This is important when interlocking nails are considered in unsupported fractures such as those that commonly occur in the femur. Interlocking nails have a diameter

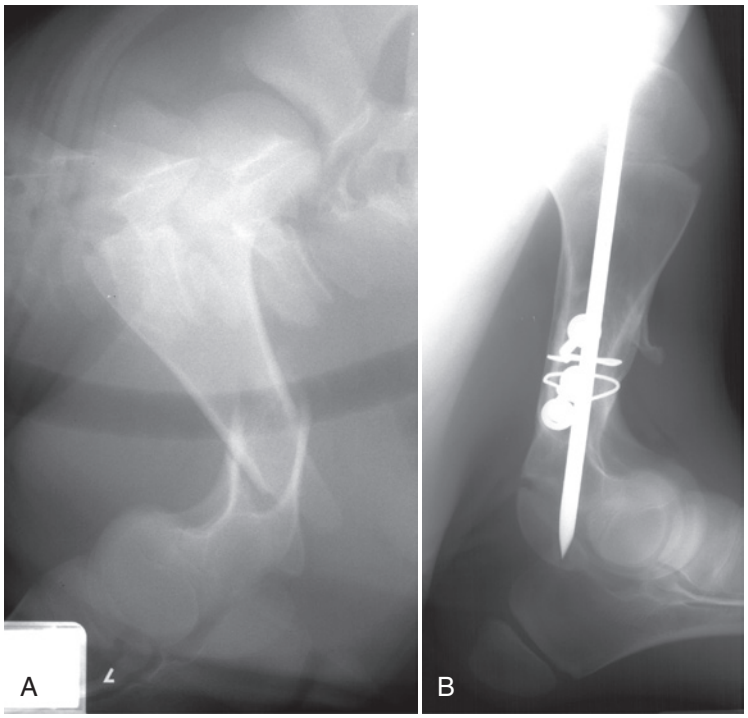


Figure 15-95 *A*, Lateral radiograph demonstrating a middiaphyseal fracture of the humerus in a 2-day-old calf. *B*, Previously described fracture 30 days after being repaired with a single intramedullary pin, lag screws, and cerclage wire.

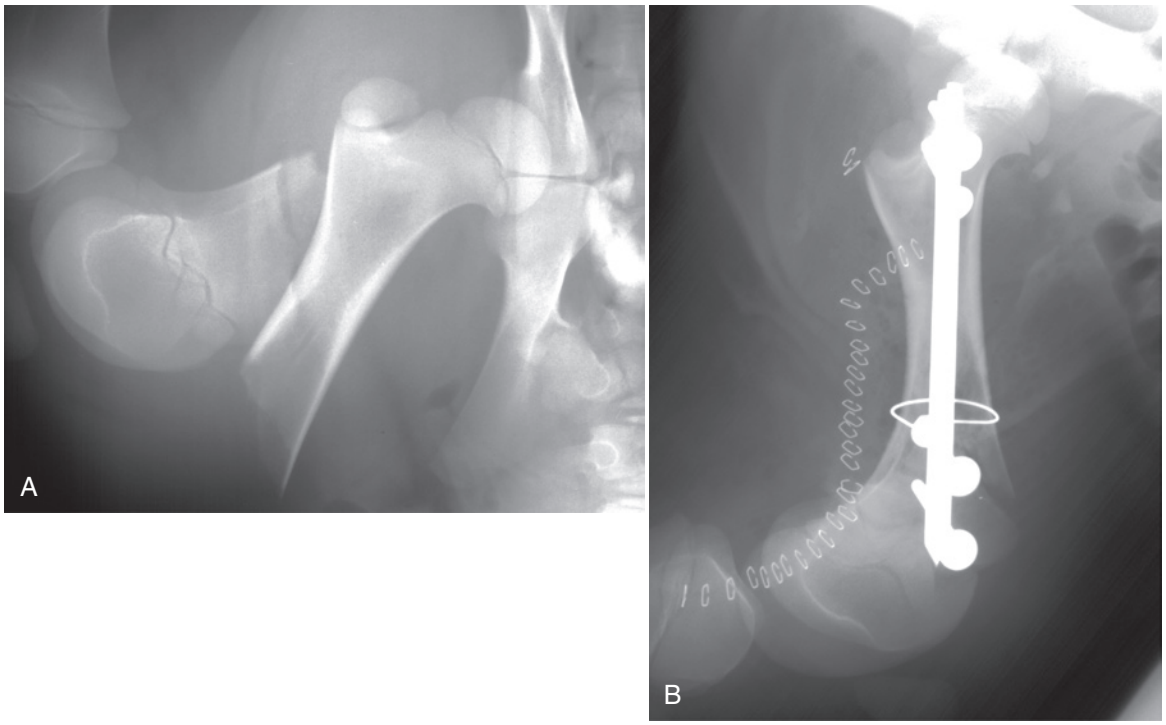


Figure 15-96 *A*, Lateral radiograph of a 1-day-old calf with a diaphyseal femoral fracture. *B*, Previously described fracture repaired using an interlocking nail. (Courtesy of Dr. Ryland B. Edwards III, University of Wisconsin.)

of up to 13 mm, which is adequate for the femoral medullary cavity in calves, and screw holes placed 16.5 mm apart along the entire length of the nail, or they have only two screw holes on either side of the fracture. The screws are inserted using an aiming device secured to the proximal end of the pin that ensures accurate drilling and placement of the screws. Empty screw holes should be avoided because they represent points of weakness and are the first parts of the pin to fail under load. An in vitro biomechanical comparison of an interlocking nail (6 hole, 13-mm diameter, 230-mm length) and double plate fixation (two 4.5-mm broad DCPs) of ostectomized equine cannon bones revealed the same biomechanical values for bending but inferior values for torsion for the bone-interlocking nail composite. However, placement of the nail involved opening of the carpometacarpal joint and partial carpal joint arthrodesis.

Bellon and Mulon (2011) developed a special intramedullary nail for repair of femoral fractures in 25 Charolais calves. The custom-made stainless steel interlocking nail was 190 mm long and 10 mm in diameter and had four divergent 4-mm pins at the distal end. After insertion of the pin, the 4-mm pins became seated in the distal fracture fragment, two pins in the trochlea and two in the femoral condyle. This prevented rotation of the pin, which in most cases was locked only in the proximal fracture fragment with two cortical screws.

An in vitro study of femoral bones of young horses found that stabilization with two DCPs provided significantly greater structural and gap stiffness than intramedullary interlocking-nail constructs under bending and torsion. However, because there was no significant difference in structural stiffness, tested in compression, and yield and failure loads between intramedullary interlocking nail fixation and intact bone, intramedullary interlocking nail fixation should be considered for the repair of diaphyseal femoral fractures in calves.

Various polymers have been tested experimentally for use as interlocking intramedullary nails for the repair of humerus and femoral fractures in calves and in a computer model. Polymers are lightweight, inexpensive, and purported to be biocompatible. They also resulted in less stress protection, and an aiming device was not needed for insertion of the interlocking screws. The results of humerus fracture fixations in calves had been encouraging, but when used in the femur intramedullary interlocking nails made of polyacetal or polyamid 6 provided insufficient stability and resulted in refracture.

COMPLICATIONS OF INTERNAL FIXATION

Cattle with severe injuries may have to be operated quickly without the benefit of a fasting period. This can cause complications during anesthesia, including respiratory and circulatory depression caused by ruminal tympany. Some fractures turn out to be worse intraoperatively than originally thought, and repositioning and stable internal fixation cannot be achieved. This scenario and the possibility of euthanasia on the operating table should be discussed with the owner beforehand.

The complication rate can be minimized by planning the procedure properly and by using correct techniques and the proper implants. When plating the tibia or radius of a calf, the plate should be placed in a location that allows sufficient soft tissue coverage of the implant. The use of cancellous bone grafts can be beneficial in selected cases. During surgery and before closure, the wound is rinsed repeatedly with a solution containing an antibiotic. The wound should be closed in several layers so that the implant is covered by at least two tissue layers in addition to the skin. Broad-spectrum antibiotics should be administered in the perioperative

period. The length of postoperative antibiotic treatment depends on whether the fracture was open or closed, the degree of surrounding soft tissue trauma before and during surgery, surgical time, soft tissue coverage of the implant, and response to initial antibiotic treatment. Cattle should be hobbled when they are brought back to the recovery stall to prevent splaying of the hind limbs and injury to the adductor muscles. Postoperative nerve damage that becomes evident in the contralateral limb is treated, for example, with splint bandages and supportive medications.

Postoperative swelling of the wound area because of clotted blood, seroma formation, and edema cannot be avoided after open fracture reduction and internal fixation but can be reduced by applying a stent bandage over the incision or a regular bandage to the limb. Persistence of the swelling for more than 7 to 10 days combined with discoloration of the skin, wound dehiscence, and wound secretion indicate instability of the fixation and wound infection.

The postoperative care of ruminants after internal fixation of a fracture includes stall confinement until clinical union is achieved. Cattle are generally less prone to implant failure and refracture during recovery from anesthesia than horses, but the risk for this is considerable for internal fixation of humeral, femoral, and tibial fractures. Cattle must periodically rise, stand, and lie down; to achieve this, they can be supported by slings and belts but cannot remain suspended in a sling because of pressure sores. Difficulty rising and pressure sores are signs of possible fracture instability and pain.

Newborn calves require regular assistance with rising and lying down, and the bedding should be changed frequently to make sure that the wound and the umbilicus remain dry. Extended periods of recumbency increase the risk of wound infection and pressure sores. A temporary splint or fiberglass cast can be beneficial for protection of the fracture, but full-limb casts on the hind limbs increase the risk of muscle rupture, primarily the peroneus/fibularis tertius muscle/tendon, during attempts to rise. This can adversely affect fracture healing and result in permanent malpositioning of the leg.

Current methods available for evaluating fracture healing, other than clinical assessment, are radiography, ultrasonography, CT, and MRI. While CT and MRI are not commonly used in cattle, ultrasonographic techniques are useful for the diagnosis of refracture, implant loosening, local abscesses, and sequestration. They also allow the assessment of vascularity in the fracture region and can document the process of bone formation.

The time required for fracture healing and weight bearing may be as short as 30 days in immature animals treated conservatively. However, the period of immobilization should be extended after internal fixation because healing that allows unrestricted weight bearing may be delayed due to soft tissue trauma and periosteal detachment in the fracture region. Furthermore, vascularization of the bone may be compromised by compression caused by the plates. The intramedullary blood supply is impaired as a result of reaming of the medullary cavity or insertion of intramedullary nails. Therefore calves may require 60 to 90 days and adult cattle up to 6 to 9 months to reach fracture stability sufficient for weight bearing, particularly if bone remodeling and modeling are delayed.

Owners of dairy cows scheduled for orthopedic surgery must be willing to accept a substantial decrease in production as a result of the procedure. Pain associated with the fracture, surgery, and possible follow-up operations adversely affect the appetite and, combined with feed changes because of hospitalization, may result in metabolic disturbances, weight loss, and decreased production.

Cattle usually adapt well to mild angular limb deformities that may occur during fracture healing. Contralateral-limb laminitis is rare because cattle lie down more often than horses. However, with inadequate fixation or with complications during fracture healing, considerable valgus or varus deformity of the contralateral joints may occur. In addition, laxity of the fetlock occurs in the contralateral limb. Decubitus ulcers are seen in cattle of all age groups and are controlled by good husbandry, bandages, and nursing care. Physiotherapeutic measures can also have a positive effect on healing and nerve regeneration.

Infection

Osteomyelitis and septic arthritis are serious and potentially devastating complications of internal fixation. Infection can result from a number of factors, including severity of soft tissue damage before and during surgery, prolonged surgery time, and instability of the fixation. The clinical signs of postoperative complications include exacerbation of lameness, localized pain and soft tissue swelling, exudate from the incision, or a tract in the granulation tissue. Septic arthritis occurs mainly in immunocompromised animals when the joint had to be opened for fracture repair or when the joint was involved in the fracture. Septic arthritis or osteomyelitis can develop from joint injuries caused by screws or intramedullary pins. Pin migration through the skin predisposes the fixation to osteomyelitis because the pin tract serves as a direct communication between the environment and the medullary cavity. Infection is to be expected after the fixation of an open fracture but is rare after closed fractures as long as correct procedures are followed and guidelines for antisepsis strictly adhered to. Exceptions are surgeries of long duration, fractures in young calves accompanied by systemic disease, and fracture fixation that lacks sufficient soft tissue coverage. Radiography aids in the assessment of implant migration and infection. Obvious implant migration is readily detected on follow-up radiographs, but comparison with the initial postoperative radiographs may be needed to detect subtle changes. Osteolytic changes of the bone near the fracture margins or near the implants are indicative of osteomyelitis.

Management of osteomyelitis is particularly frustrating and often unrewarding. Most cases involve a profound long-term financial and time commitment from the owner and veterinarian. The three goals in the treatment of osteomyelitis are 1) establishment of drainage through debridement of the infected bone and tissue; 2) culture and selection of appropriate (and in compliance with local governmental regulations except perhaps in rescue centers) antimicrobial agent(s); and 3) removal of the implant after union has occurred. Despite valiant efforts, the prognosis for successful treatment and resolution of osteomyelitis is poor.

Implant Failure or Migration

There are numerous reasons for failure of a bone-implant construct. Implants undergo patterns of failure similar to that of bones; the cause can be a single catastrophic event or failure can result from cyclic fatigue (Figure 15-97). Catastrophic failure usually occurs in the immediate recovery period when the bone-implant construct is exposed to forces that exceed its strength. This event is initiated at the weakest point of fixation or at a point of stress concentration. Cyclic fatigue usually leads to screw loosening or failure from shear forces at the screw-plate interface and may eventually involve the entire length of the repair. Failure from cyclic fatigue is a typical occurrence of cortex screws inserted into soft bone of calves (see Figure 15-85). On the other hand, implant failure can also occur with locking constructs and involve the bone adjacent to the

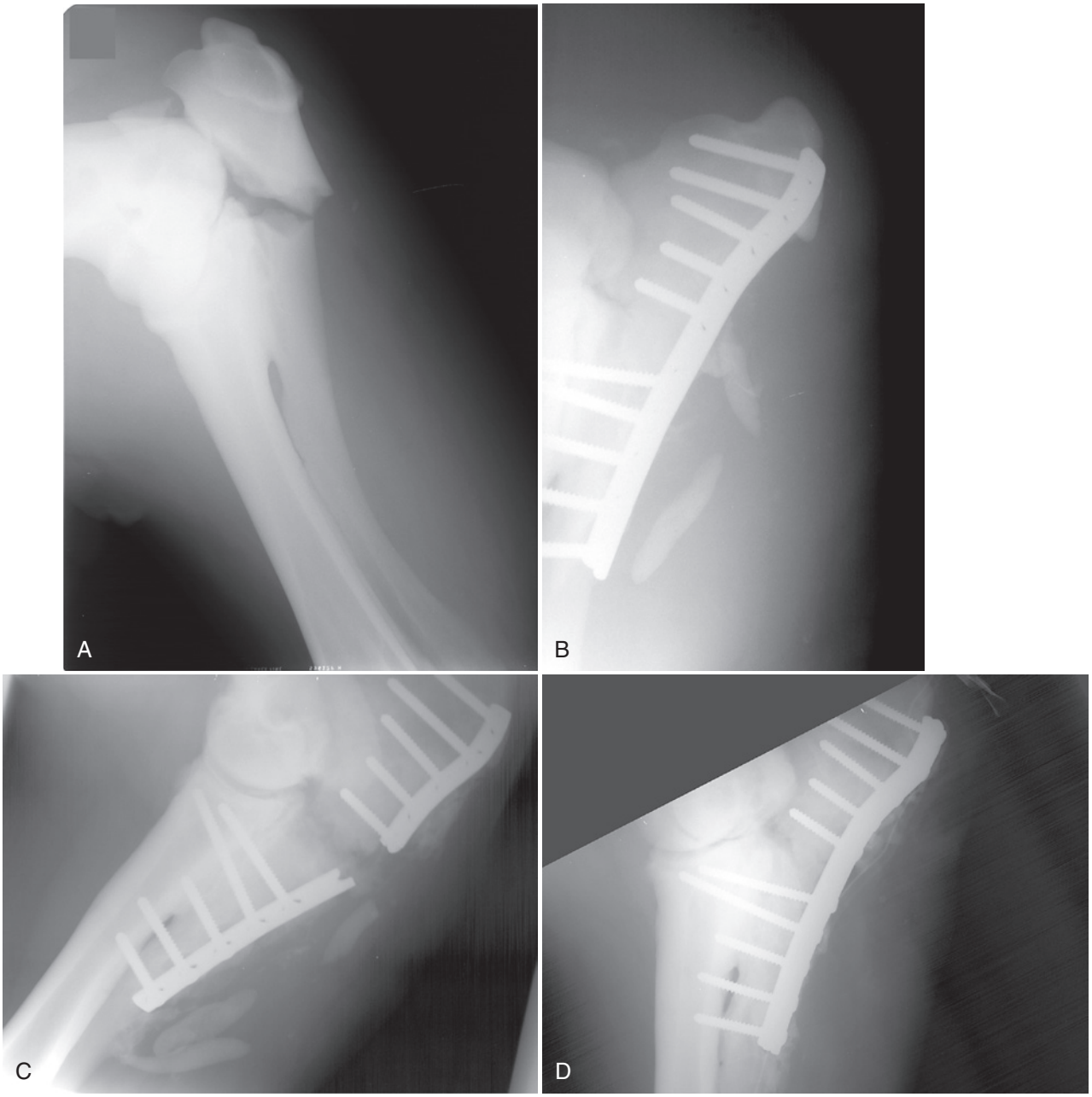


Figure 15-97 *A*, Lateral radiograph of the olecranon of a 3-year-old 500-kg Hereford cow with an acute olecranon fracture. *B*, After repair with a narrow dynamic compression plate (DCP). *C*, The implant failed and (*D*) was repaired by removing the broken plate and replacing it with 2 DCPs using the same screw holes. In addition, bone grafting was performed. (Courtesy of Dr. Ned Dykes, Cornell University.)

construct because the screws that are locked with the plate at a fixed angle cut into, and thus weaken, the bone during cyclic stress. Locking screws are less likely to loosen in areas with insufficient bone-implant contact when the fixation composite undergoes excessive axial loading, and screw breakage usually occurs at the neck of the screw just below the plate.

Delayed union or nonunion is associated with inadequate fracture reduction, inadequate immobilization, soft tissue disruption, disruption of the blood supply to the bone because of periosteal detachment and compression plating, and infection. The most common form of implant migration in femur fracture repair occurs in neonatal calves and is associated with pins used for intramedullary repair or external skeletal fixation. Because of the relative softness of the bone, intramedullary pins can migrate proximally or distally within the intramedullary cavity and the epiphyseal bone.

PROGNOSIS

The reported success rates for internal fracture repair in cattle vary widely. Several factors must be considered when estimating the prognosis for the restoration of a functional, pain-free limb including the type of bone fractured, the

region of bone fractured (diaphyseal, physeal, epiphyseal), the type of fracture, the severity of trauma, the integrity of the vasculature, whether the fracture is open or closed, the age and weight of the patient, the duration of the fracture, and the temperament of the patient. Because of the multitude of factors, it is difficult to determine the influence of a single factor on fracture outcome. In addition, it is difficult to compare results among studies because the end point of success or satisfaction is not clearly defined.

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EXTERNAL FIXATION

Pierre-Yves Mulon
(The author and editors acknowledge the contribution of prior authors Drs. Guy St. Jean and David E. Anderson)

GENERAL PRINCIPLES

Temporary stabilization of limb fractures may be performed before moving the animal or attempting to get the animal to stand. As a general rule, fractures below the level of the midradius or midtibia may be temporarily stabilized with a splint or casts. In our experience, field stabilization of fractures proximal to this level should not be attempted. These efforts often result in the creation of a fulcrum effect at the fracture site and result in increased soft tissue trauma, damage to neurovascular structures, or compounding of the fracture. Cattle with these fractures should be carefully loaded into the trailer and allowed time to lie down before being transported. For these proximal injuries, cattle will usually protect the limb adequately for transport and any additional trauma that occurs is less severe than that which may occur as a result of the fulcrum effect.

External coaptation for temporary stabilization may be done by using splints or a cast. Two boards or a large polyvinyl chloride pipe cut in half, placed 90 degrees to each other (e.g., caudal and lateral aspect of the limb), create a stable external coaptation. A padded bandage is placed on

the limb, the splints positioned, and elastic tape applied firmly. Circular clamps (e.g., hose clamps) may be used to achieve firm placement of the splints on the limb. All external coaptation devices should extend to the ground. For injuries distal to the carpus or hock, the splints should be placed to the level of the proximal radius or tibia, respectively. For injuries proximal to the carpus or hock and distal to the midradius or midtibia, the lateral splint should extend to the level of the proximal scapula or pelvis, respectively.

The location of the fracture, the presence of soft tissue and neurovascular trauma, a closed or open fracture environment, the behavioral nature of the animal, and the experience of the veterinarian are important factors for considering the type of treatment to choose. For fractures that involve the appendicular skeleton, the following questions must be answered:

1. Is treatment required?
2. Can the fracture be acceptably reduced or closed, or is internal reduction required?
3. Can the fracture be adequately immobilized by using external coaptation alone, or is internal fixation—with or without external coaptation—required?
4. What is the cost-benefit analysis?

In farm animals, external coaptation as a practical, relatively easy approach should be considered as an option for many fractures (except humeral and femoral fractures). Casts and splints—separately or in combination—have been used successfully in all types and sizes of ruminants. Closed treatment is the preferred method for many types of fractures in commercial operations. The more distal the injury, the more external fixation becomes the optimal method for success. The materials for fabricating casts and splints are readily available, and ruminants usually become accustomed to fixation within a few days, so reasonable locomotion is possible.

Transfixation pinning with some type of external fixation has been used successfully in ruminants. The technique involves limited surgical invasiveness with reduced cost, improved stability over external coaptation alone, and prospects for early ambulation and preserving joint mobility. It is simple and useful, even in field situations. Over the years, external fixators have improved and all manner of external supports have been used successfully, including cast material, metal rods, steel plates, and acrylics. Either external coaptation alone or combined with transfixation pins provides the veterinarian techniques to manage virtually all fractures distal to the elbow and stifle in most ruminant patients.

Casting

Ideally, the cast should be extended at least a joint above and a joint below the fracture site to reduce distracting forces. This ideal aside, some relatively stable physeal and distal metaphyseal fractures of the metacarpus and metatarsus can be immobilized with a short limb cast that incorporates the digit and extends to just below the carpus. Unstable physeal, distal metaphyseal, and all diaphyseal and proximal metaphyseal fractures require the use of a full-limb cast extending to the proximal radius or tibia.

Placement of the cast is facilitated by use of rope restraint. Sedation or general anesthesia is used as needed. An assistant should help maintain alignment of the limb during application and check the position of the limb in craniocaudal and lateromedial planes. Tension on the limb during casting may be achieved by placing wires through holes drilled in the hoof wall and applying traction. The holes should be placed such that the hoof is positioned in a normal to slightly flexed position while applying traction and the cast.

The thick skin and heavy hair coat of ruminants help prevent serious cast sores. The hair is brushed clean of any debris or dirt. The dewclaws and top of the cast are padded with a wide strip of orthopedic felt, but only stockinette or foam resin padding is placed on the remainder of the limb. Thick padding, placed along the entire limb, will quickly become compressed, thus leaving room for the limb to move within the cast so displacement of the fracture occurs. Full-limb casts are used for fractures that occur at or proximal to the midmetacarpus or metatarsus but distal to the midradius or midtibia. Full limb casts are placed similarly to half limb casts, but the bony prominences of the accessory carpal bone and the styloid processes of the ulna, calcaneus, and medial and lateral malleolus of the tibia must be padded appropriately.

Fresh 3-, 4-, or 6-inch quick-setting polyurethane resin–impregnated knitted fiberglass fabric cast material is extremely strong and easy to apply. It is lightweight, porous, waterproof, and quick setting on warm water. Gloves must be worn to protect the operator's hands. The cast material is completely immersed in very warm water for approximately 20 seconds, and excess water is allowed to drip off. The casting tape is applied in even, overlapping spirals, including the foot; however, one must be certain to avoid creases, binding, or finger impressions, particularly in the first layers. Additional rolls are added in an even manner as needed to increase cast thickness and—consequently—strength.

The thickness of the cast is usually based on clinical judgment. Casts 4 to 6 layers thick may be adequate for ruminants less than 150 kg body weight, but adults may require casts 8 to 12 layers thick. Casts used on the hind limbs must be made thicker because of stress concentration by the angulation of the hock. Incorporation of metal rods within the cast (two rods placed 90 degrees to each other) can increase the strength of the cast but is only needed in the largest of patients. The distal aspect of the cast (weight-bearing surface) should be protected from excessive wear and moisture with a layer of acrylic. Elastic bandage tape is placed circumferentially around the top of the cast and applied to the limb to prevent dirt, straw, and debris from getting between the cast and the limb. The animal should be restricted to a box stall or pen with good footing, preferably a dirt floor. The animal's general well-being and appetite should be evaluated daily. Ideally, the animal should ambulate comfortably at a walk, and the cast should be checked daily to be certain no heat, excessive looseness, exudate, or cast fractures are present. Any significant changes in the animal's level of comfort with the affected limb may be grounds for cast removal and reevaluation.

Ruminants younger than 1 month old should have a cast change and reevaluation every 3 weeks because of their growth. Uncomplicated healing usually occurs in 3 to 6 weeks. Ruminants 1 to 6 months of age should be reevaluated at approximately 4-week intervals. Uncomplicated fracture healing in animals 6 to 12 months old usually occurs in approximately 6 weeks with one cast needed. Yearlings and adults usually can tolerate a properly fitting cast between 6 and 8 weeks with radiographic evidence of fracture healing after 12 to 16 weeks (one cast change). Fracture healing after casting is usually characterized radiographically by extensive circumferential periosteal new bone growth.

After cast removal, flexor tendon laxity must be expected. Usually during this transition time the limb is supported with a short-limb bandage constructed of several pounds of rolled cotton, 6-inch-wide rolled gauze, and elastic adhesive bandage material. The bandage usually can be removed after 2 weeks. Confinement should be continued for 4 to 8 weeks after cast removal, depending on the animal's comfort, palpable limb stability, and radiographic evidence of fracture healing.

Metacarpal and metatarsal fractures are among the most common fractures in ruminants. Fortunately, extensive orthopedic experience and great skill are not necessary in dealing with these fractures. They are amenable to external coaptations using a fiberglass cast. The prognosis for long-term, pain-free survival is excellent for closed fractures and fair for open fractures managed in this manner. Surviving animals generally are not lame, do not have significant limb deformity or shortening, and generally become productive. Even considering the narrow profit margin involved in treating cattle with serious injuries, this method of fracture management usually is economically profitable.

Open fractures can sometime be resolved with casting, but the prognosis for a successful outcome diminishes substantially compared with a closed fracture, and the expense of fracture management is significantly higher. Owners must be strongly advised of the difficulties and expense of treating open fractures.

For the treatment of an open fracture with casting, the hair adjacent to the wound should be clipped and the affected area prepared for sterile surgery. All devitalized tissue must be excised sharply, and when necessary the bone is exposed and curetted. The wound can be lavaged by using several liters of balanced polyionic solution. Internal fixation may or may not be used (see Internal Fixation). The wound is then (partially) closed (if internal fixation was used) or wrapped with a sterile gauze bandage and the cast applied. Broad-spectrum antimicrobial therapy should be instituted before surgery and continued for at least 10 to 14 days. Adjustments in antimicrobial therapy can be made based on results of culture sensitivity of fluid and tissue obtained at surgery.

Thomas Splint and Cast Combination

Tibial fractures account for approximately 12% and radial fractures account for approximately 7% of long bone fractures diagnosed in ruminants. These fractures may result in significant economic loss to an individual producer if inadequate fixation methods are employed that result in failure of bony union or creation of an open fracture.

The Thomas splint (Figure 15-98) and cast combination is an economical method for obtaining fracture stability that does not require specialized equipment. Construction of a Thomas splint can be challenging at the time an animal is presented with a fracture. We prefer to have multiple sizes of Thomas splints premade with adjustable sidebar length. These are not perfectly fitted to the individual animal but are adequate for fracture stability and are time efficient. To custom make a Thomas splint, one must measure the circumference of the groin or axillary region with an orogastric (or equine nasogastric) tube. The medial ring should be firmly positioned against the groin or axilla. The lateral and dorsal ring should extend dorsal to the greater trochanter of the femur or the greater tubercle of the humerus and spine of the scapula.

The ring should not impinge on the tuber coxae or tuber ischii. White tape can be used to conform the ring and mark where the cranial and caudal bars of the splint will exit the ring. The ring is removed from the animal. Construction of the splint is started with a 12-foot length of tubular steel. The size of tubular steel is correlated with the size of the animal. For ruminants less than 140 kg, we recommend ¼-inch (6.35 mm) outer diameter steel. For animals between 140 kg and 500 kg, use ½-inch outer diameter steel, and for ruminants above 500 kg use 1-inch steel (2.5 cm).

A vise or round surface is used to bend the steel rod (larger rods may be heated to facilitate bending). The rod must be bent, starting in the center of the rod, 540 to 630 degrees to complete the ring and project the sidebars distally along the limb. Forelimb splints have straight sidebars. For hind-limb splints, the caudal bar is bent to accommodate the hock. The distal aspect of the splint may be completed by bending the bars beneath the digits and overlapping them in a U configuration.



Figure 15-98 Thomas splint.

If the splint is too long, the animal will have difficulty ambulating, and this may lead to angular deformities in the contralateral limb. The bars are then welded together for stability. Alternately, a solid foot-plate may be constructed from tubular steel of a small enough diameter to telescope inside the major sidebars. Holes may be drilled through the two bars at 2.5-cm intervals to make an adjustable splint. The ring of the splint is padded with roll cotton and tape. If the padding is too thick, however, the splint may become loose with time.

Xylazine hydrochloride (0.05 mg/kg IV) is administered, and the animal is positioned in lateral recumbency with casting ropes. For tibial fractures, the limb is cast from the distal metatarsus to the proximal tibia. The cast material should be carefully applied as far proximally on the tibia as possible. Then the splint is placed on the limb; one must be sure to apply the splint fully into the axilla or groin. Holes are drilled into the hoof walls, and bailing wires are used to attach the digits to the base of the splint. Two to three wires per digit should be placed to prevent loosening caused by wire breakage. The wires on the base are encased in methylmethacrylate to protect them. Then the cast is placed into the splint to maximize stability and prevent proximal and distal motion within the splint.

After application of the Thomas splint and cast combination, the animal should be confined to a small pen for 6 to 10 weeks before removal (Figures 15-99 and 15-100). The animal must be examined by the owner several times each day during the first 2 to 3 days. The splinted limb must remain uppermost when the animal is lying down. Otherwise, the animal could become cast with the limb trapped beneath it and bloat. The animals usually learn to manage the splint well by day 2 or 3. The cast should be examined frequently for the first week. If the cast becomes loose after



Figure 15-99 Application of the Thomas splint and cast combination for a fracture of the tibia in a bull.



Figure 15-100 Application of the Thomas splint and cast combination for a fracture of the radius in a calf.

swelling associated with the fracture trauma is reduced, it should be replaced. A loose cast may allow enough motion to create an open fracture or delayed union.

Tibial and radial fractures in animals under 1 year of age or less than 500 kg can be given a good prognosis with the Thomas splint and cast combination. The owner should be prepared for up to 8 weeks of confinement for affected animals with the splint applied and an additional 2 weeks of confinement during the accommodation period after the splint has been removed. Short- and long-term complications have been reported with the use of the Thomas splint and cast combination. These include prolonged recumbency, tympany of the rumen, skin abrasions, pressure sores, osteoporosis, muscular atrophy, joint stiffness, and delayed union of the fracture.

External Skeletal Fixation

External skeletal fixation (ESF) refers to the stabilization of a debilitating musculoskeletal injury (typically fractures but also joint luxation or tendon rupture) by using transfixation pins (or transcortical pins) and any external frame connecting the pins and spanning the region of instability.

Fracture stability therefore is obtained by transferring the biomechanical forces endured by the bone around the fracture environment and through the external device.

The goal of the ESF is to provide a sustainable, comfortable means to return the patient to weight bearing (or function) as soon as possible after surgery, to maintain normal joint mobility, if possible, and to provide an optimal environment for osteosynthesis and wound healing.

Cast immobilization of fractures in ruminants is chosen, whenever appropriate, because of economic considerations. However, when cast immobilization is not appropriate or does not provide optimal management of fractures, other modalities must be considered. Soft tissue injuries and open fractures may not be managed optimally by use of casts or splint-cast combinations. ESF may be chosen based on fracture configuration, soft tissue injuries, or open fractures. Usually, ESF is used in purebred animals, show animals, or other ruminants of perceived high economic value. ESF is being increasingly used in cattle, sheep, and goats.

Biomechanics of ESF

External fixator design is the most important factor that affects fracture stability. External skeletal fixator stability is increased by increasing the number of pins placed in each fracture fragment, angling the pins in each fragment, increasing the size of the pins used, increasing the number of connecting bars, increasing the size of the connecting bars used, using bilateral or multiplanar fixator designs instead of unilateral designs, and minimizing the distance between the connecting bar and the bone.

Diverging pins increase the torsional stability of the fixator compared with parallel pins. Pin diameter must be carefully chosen not to exceed a safe pinhole size in relation to the diameter of the affected bone. In most cases, the authors used ¼-inch (6.35-mm) pins in ruminants. Positive profile threaded pins have superior axial extraction forces compared with smooth pins.

Regardless of the frame configuration, the distance between the connecting bars and the bone should be minimized. Doubling the distance from the bone to the connecting bar reduces the resistance to compressive loads of approximately 25%. The pin clamp of the external fixator is a potential weak link in the fixator if improperly applied and may result in pin-bone junction motion, pin loosening, and loss of fracture stability. Concerns over potential clamp failure, owner monitoring of fixator clamps, clamp fatigue with repeated use, and economic constraints in veterinary surgery have prompted the use of acrylic polymers and casting to replace the sidebar-clamp assembly.

Transfixation pinning and casting (TPC) has been used for many years in veterinary surgery, particularly in cattle. The advantages of TPC include minimal distance from bone to external frame, pin placement restricted only by fracture configuration and anatomic considerations (not by the design of the fixator), biomechanical forces shared with the cast, and application to patients (age, weight, height) not limited by availability of standard equipment. Also, fiberglass casts are not as brittle as acrylic polymers and therefore may be less likely to suffer catastrophic failure. Disadvantages of TPC include poor access to soft wounds, greater difficulty in removal, potential for cast-induced soft tissue injuries, and cost proportional to the amount of cast material needed (no reusable parts).

Clinical Application of an External Skeletal Fixator

ESF has many advantages for the treatment of fractures. ESF provides early return to function of the affected limb, management of soft tissue wounds on the limb, preservation of local blood flow to the fracture site, preservation of bone-stimulatory proteins that exude into the fracture site at the time of initial injury, diversity in design for comminuted fractures, ease of implant removal after clinical union of the fracture, and relatively few complications resulting from the implants. ESF has been applied to most of the long bones of the domestic species. Transarticular application of external fixators has been used in the presence of severe soft tissue trauma or severe comminution of the proximal or distal ends of the affected bone and for arthrodesis of joints. Transarticular use of external fixators must be done with consideration for the potential of inducing damage to the involved joint because of immobilization.

Disadvantages of ESF are suboptimal fracture reduction and poor anatomic alignment, absence of interfragmentary compression, less rigid stabilization of the affected bone compared with bone plates, increased postoperative management compared with bone plates or casting, pain associated with micromotion at the pin-bone interface, and potential failure of the implants before clinical union of the fracture.

We routinely use antibiotics for 7 days after surgery during application of an external fixator for a closed fracture. Antibiotic selection for use in cattle must be made with consideration for extralabel use and potential antibiotic residues (in compliance with regional regulatory compliance). The authors usually repair fractures of the metacarpus/metatarsus, radius, ulna, and tibia with the patient in dorsal recumbency and the limb suspended from an overhead frame. Fractures of the humerus and femur are approached with the animal in lateral recumbency. Excessive soft tissue swelling and inflammation are typical of fractures in large animals. After the animal is clipped and aseptically prepared for surgery, the authors place marker needles (18 gauge, 3.8 cm for most fractures; 18 gauge, 8.9 cm for the tibia in adults) at the sites proposed for placement of the transcortical pins. Radiograph images are obtained and the pin sites are chosen based on the relationship of the marker needles with the fracture, fissure lines, adjacent joints, and intact cortical bone.

A 1-cm incision is made through the skin at the chosen pin site. A hole is then drilled through the bone, and another incision is made for the exit site of the pin (for bilateral transcortical pins). We use a pneumatic orthopedic drill with variable speeds up to 700 rpm. Pins are implanted with the drill at low speed. However, standard electric or battery-powered drills may be used after appropriate sterilization. During drilling, the drill bit should be continuously flushed with a sterile isotonic solution to help decrease thermal injury to the bone. Finally, the pin is implanted (Figures 15-101 and 15-102). A tissue protector, or pin guide, is beneficial to prevent excessive soft tissue trauma during drilling and implantation.

ESF was designed so transfixation pins, sidebars, and clamps could be used to stabilize fractures unsuited for external coaptation alone or for internal fixation. The main limitation of sidebars and clamps is the ability of the assembly to resist failure during loading. We have used commercially available fixator frames in animals that weigh less than 150 kg. We do not recommend the use of traditional sidebar-clamp assemblies for cattle weighing more than 150 kg because of the higher risk that the pin-clamp sidebar unit will fail.

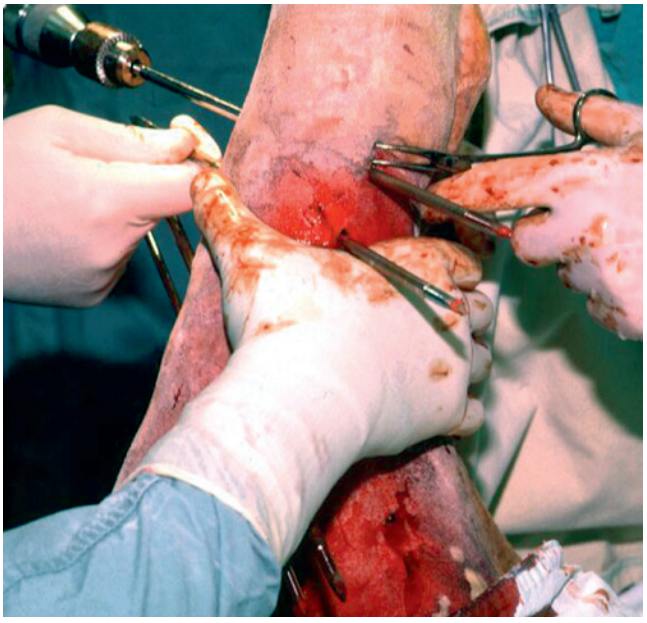


Figure 15-101 Two transcortical pins have been implanted in a calf with a tibial fracture. The patient is in dorsal recumbency with the limb suspended.

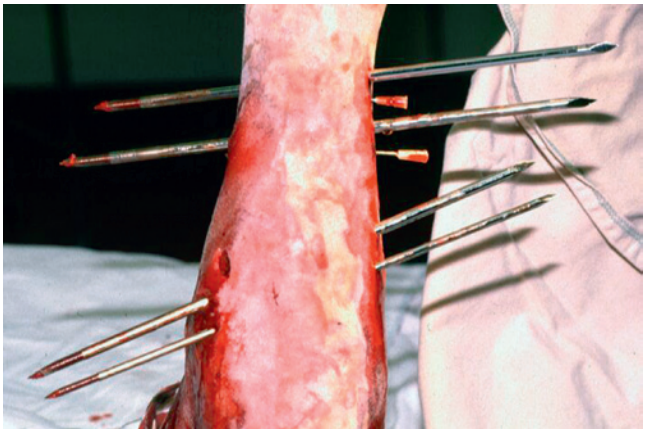


Figure 15-102 Four transcortical pins have been implanted in a calf with a tibial fracture.

Welding the transfixation pins to the sidebar has been proposed as a means to decrease postoperative management and strengthen the attachment of the pin to the sidebar for use in cattle. Welding may result in thermal injury to the bone because of heat conduction in the transfixation pins and may also result in electric shock to the patient. Also, the sidebars are not reusable, and poorly applied welds may break, thus leading to failure of the assembly.

The use of methylmethacrylate as an inexpensive, conformable sidebar has biomechanical advantages compared with the standard steel sidebars and clamps (Figure 15-103). Use of acrylic sidebars has advantages similar to those of traditional ESF. However, acrylic sidebars cannot be adjusted after the resin has hardened and must be replaced if an error in configuration of the frame occurs. Acrylics harden with



Figure 15-103 Methylmethacrylate sidebar used in a Type II external fixator in a cow with an open radial fracture. The patient is in dorsal recumbency.



Figure 15-104 Transfixation pinning and casting used for immobilization of a tibial fracture in a calf.

an exothermic reaction. Therefore potential thermal injury to the skin and bone must be considered. Transfixation pins should be rinsed with fluids during the exothermic period to help dissipate heat. An adequate supply of acrylic should be readily available at the time of surgery, and the acrylic must be poured into the tubing mold while it is relatively liquid. Pouring the acrylic in multiple layers or while it is firming up causes air pockets or cracks in the sidebar and may result in catastrophic failure. Though acrylics have good biomechanical stiffness, they are brittle. Therefore acrylic sidebars must be inspected daily to ensure that failure of the fixator does not occur. The acrylic sidebars may be removed in sections by using obstetric wire to cut the acrylic surrounding the pins.

TPC

In TPC, the cast replaces the external fixator (Figure 15-104) and allows minimal postoperative case management with a high degree of success. This advantage is particularly suited to food animals. We exclusively use fiberglass casting tape for TPC. Pin position and fixator configuration cannot be adjusted after the cast has been applied when using TPC. Also, open wounds or open fractures are difficult to manage with TPC. Complications during TPC, such as creation of an open fracture or development of cast sores, are difficult to assess, and some delay may result before these problems are addressed. We recommend using resin-impregnated foam[12] on the limb before casting. This foam padding conforms to the limb and provides excellent protection, and its porous structure allows the limb to remain dry under the cast. We have observed a decrease in the severity of pin-tract complications when foam padding was used.

[12]3M Custom Support Foam, 3M Animal Care Products, St. Paul, MN, USA.

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SPECIFIC FRACTURES SITES

FRACTURE OF THE SCAPULA

Norm G. Ducharme

Fractures of the scapula are apparently extremely rare in cattle and are generally associated with major trauma such as vehicular collisions. Clinical signs include localized swelling and pain over the shoulder area, and this varies by the location of the fracture. On physical examination one can palpate the spine of the scapula for specific signs of swelling or pain. Ultrasound is one of the best imaging modalities for detecting incongruence and fracture. Fractures of the scapular neck and glenoid are typically associated with a readily appreciable lameness because of the articular component of the scapula-humeral joint.

Conservative management often successfully treats fractures of the body of the scapula because of surrounding muscles that stabilize the scapula. Internal reduction and fixation with plates on either side of the spine of the scapula can be used. Because of the relatively thin cortical bone in the scapula, the holding power is low. To alleviate this problem, the author has placed the plates on the junction of the spine and the scapula. This directs the screws at 30 degrees toward the base of the spine where the bone stock is thicker.

Fractures that involve the scapular neck or glenoid require that injuries to the subscapular nerve also be considered. Treatment of these fractures is difficult and may involve internal fixation methods that reconstruct the scapulohumeral joint. The location makes these fractures' prognosis poor. Fractures of the superglenoid tuberosity have not been reported in cattle or seen by the author.

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FRACTURES OF THE HUMERUS

Karl Nuss

Clinical Presentation

Fractures of the humerus are relatively common, and most are secondary to trauma. Cattle with fractures of the humerus typically have a dropped-elbow appearance and drag the affected limb in the flexed position. The differential diagnosis for cattle with a dropped elbow includes olecranon fracture, triceps myopathy, and radial nerve paralysis. Palpation of the limb reveals extensive soft tissue swelling around the fracture site. The distance from the shoulder to the elbow joint is usually shortened compared with the sound limb. Crepitation is not a consistent feature because the fragment ends overlap without contact and are partially covered with muscle and/or blood clots. Abnormal abduction of the limb distal to the fracture is possible. These clinical signs generally provide strong support for the diagnosis of humerus fracture. The diagnosis is confirmed by radiography of the humerus in standing or recumbent cattle (Figure 15-105*A* and *B*). Radiograph quality is often less than optimal in standing animals, particularly in adult cattle, or when there is extensive soft tissue swelling and pain. Short-acting anesthesia may be required to obtain good-quality images.

Concurrent damage to the radial nerve is often present because the nerve runs along the musculospiral groove of the humerus. Maintaining radial nerve integrity is critical for a

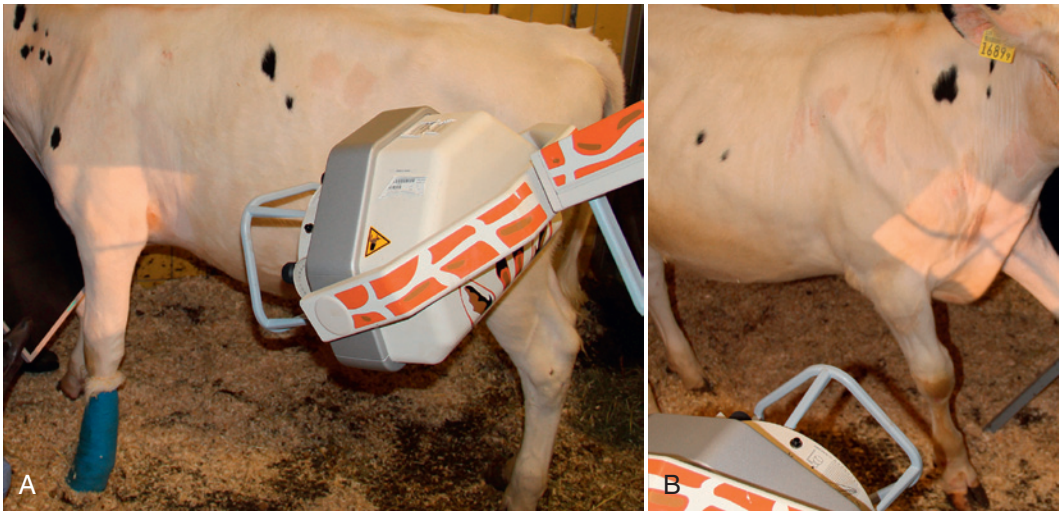


Figure 15-105 Technique for obtaining caudocranial (*A*) and mediolateral (*B*) radiographic views of a humerus fracture in a young heifer.

good prognosis. It is difficult to clinically assess the function of the radial nerve with sensitivity tests or electrodiagnostics such as electromyography and nerve-conduction velocity. Transient interruption of nerve function (neuropraxia) is common because of surrounding inflammation.

The most common types of fractures of the humerus include diaphyseal fractures that typically have a spiral to long-oblique configuration (Figure 15-106*A* and *B*). Most fractures are located in the middle or distal third of the humerus. In cows and steers, humerus fractures are often comminuted because the trauma causing the fracture is considerable. In calves and young heifers, concomitant fissures are common because of the relative softness of the bone structure. Fractures of the humerus are seldom open because of the extensive soft tissue surrounding the bone. Fractures can also occur through the distal physis and usually are Salter-Harris Type II. Fractures of the deltoid tuberosity and greater tubercle can occur but are extremely rare in ruminants.

Surgical Approaches

Surgical approaches to the humerus include lateral, cranial, and combined approaches (Figure 15-107). The radial nerve is the most important vital structure that requires identification and preservation regardless of the surgical approach used. The lateral approach provides exposure to the lateral surface of the humerus, which is smooth in calves and heifers younger than 1 year and therefore suitable for plate fixation. In adult cattle, the lateral surface is irregular because of the development of the deltoid tuberosity, which makes it a less desirable surface for plate application compared with the cranial approach. The lateral approach facilitates placement of intramedullary pins or interlocking nails.

In all approaches, the animal is positioned in lateral recumbency with the affected leg uppermost (Figure 15-107*A*) and extended using a hoist. For the lateral approach, the skin and subcutaneous tissues are incised from the greater tubercle to the lateral epicondyle of the humerus. The incision is cranial to the cranial border of the triceps brachii muscle. To gain access to the proximal aspect of the humerus, a plane of dissection is created under the caudal border of the brachiocephalic muscle. The underlying deltoid muscle is elevated from the deltoid tuberosity. The brachiocephalic muscle is reflected cranially to reveal the cranial border of the brachialis muscle.

The cranial border of the brachialis muscle is retracted caudally and the brachiocephalicus muscle cranially to expose the proximal half of the humerus. In addition, the brachial fascia is further incised caudally to reveal the border between the brachialis and the extensor carpi radialis muscles. To expose the distal half of the lateral aspect of the humerus, the brachialis muscle must be separated from the extensor carpi radialis muscle and retracted cranially, and the triceps brachii muscle must be retracted dorsally and the extensor carpi radialis muscle caudoventrally. The radial nerve runs in close approximation to the musculospiral groove of the humerus and deep to the triceps brachii and extensor carpi radialis muscles. The position of the brachialis muscle in the musculospiral groove of the humerus makes exposure of the middle third of the humerus difficult. To gain further access to the distal and lateral part of the humerus, a portion of the origin of the extensor carpi radialis muscle is elevated from its attachment to the lateral humeral condyle.

The cranial approach provides access to the straighter and more regular surface of the humerus (Figure 15-107*B* and *C*). Incision of the skin and subcutaneous tissues starts at the cranial aspect of the head of the humerus and runs distally over the cranial aspect of the extensor carpi radialis muscle. The plane of dissection is established by separating the brachiocephalic muscle from the omotransversarius muscle proximally and then separating the brachiocephalic muscle from its attachment to the brachial fascia (Figure 15-107*B*). The cephalic vein is identified, double-ligated, and transected. The insertions of the brachiocephalic muscle on the crest of the humerus distal to the deltoid tuberosity are

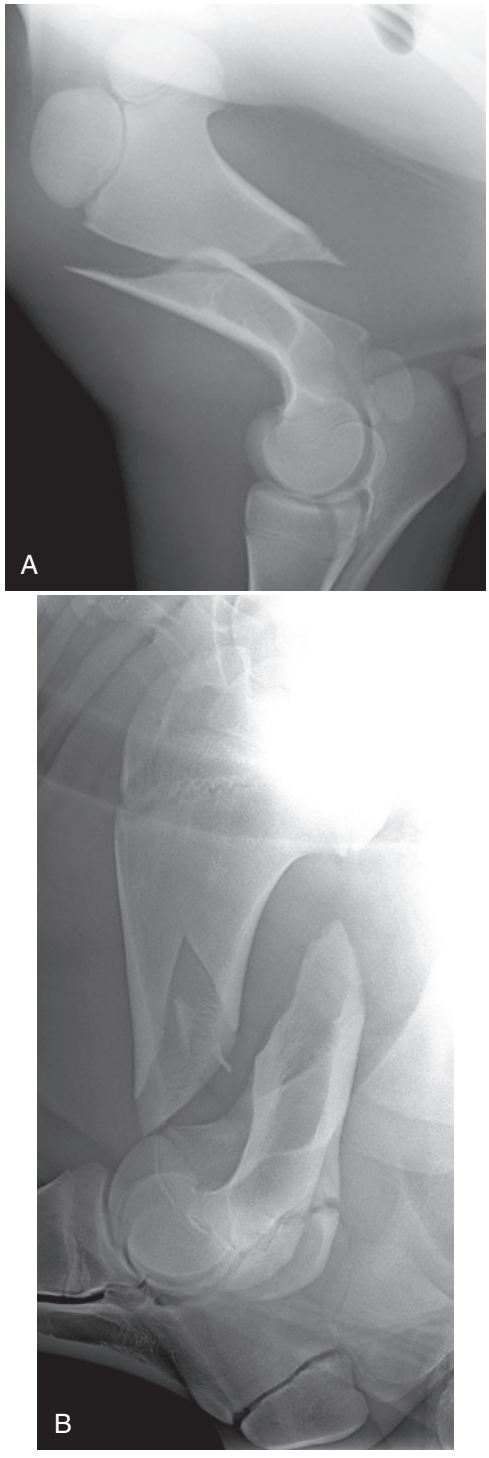


Figure 15-106 Mediolateral radiographic view of a spiral diaphyseal fracture of the humerus in a newborn calf (*A*) and in a 6-month-old calf (*B*) with an estimated body weight of 250 kg. (*A*, Courtesy Dr. Melanie Feist, Clinic for Ruminants, University of Munich, with permission.)

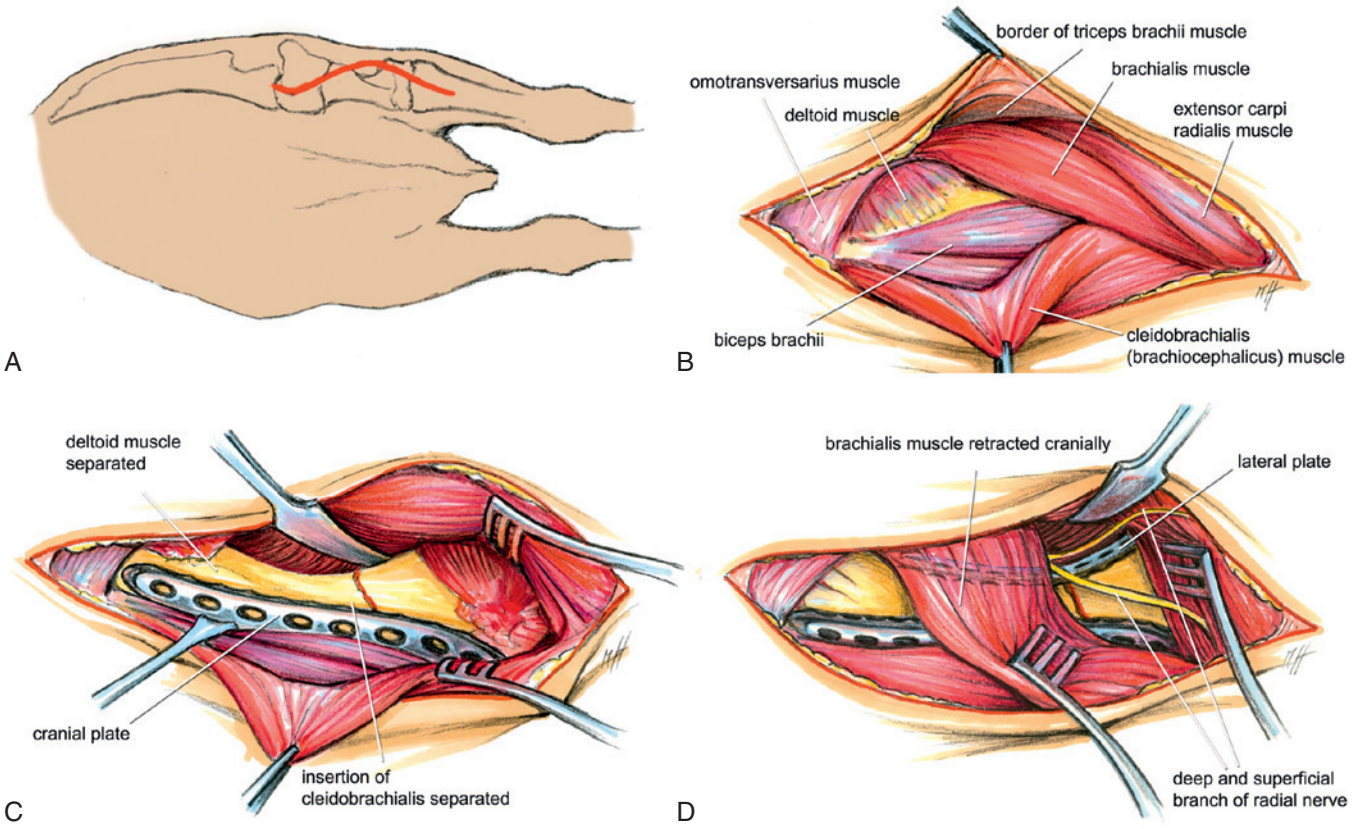


Figure 15-107 Combined approach to the cranial and lateral aspects of the left humerus in a heifer that has been positioned in right-lateral recumbency. *A*, The skin incision curves from cranial to lateral and back to cranial. *B*, Overview of the muscles in this region. Fasciae have been incised to allow differentiation of the muscles and to manipulate the brachialis and extensor carpi radialis muscles separately. C, The deltoid muscle is separated from the deltoid tuberosity and the cleidobrachialis muscle is completely separated from its insertion on the humeral crest. The brachialis and extensor carpi radialis muscles are reflected caudally and the cleidobrachialis muscle cranially to allow application of the cranial plate. *D*, The brachialis muscle is separated from the extensor carpi radialis muscle and reflected cranially. The branches of the radial nerve must be isolated and especially protected during placement of the plate on the lateral aspect of the humerus.

transected, thus exposing the brachialis muscle along the lateral aspect of the humerus in the musculospiral groove. Retraction of the brachialis muscle caudally and the biceps brachii muscle medially provides sufficient exposure for application of a plate to the cranial cortex of the humerus down to the medial condyle (Figure 15-107*C*).

For the combined approach (see Figure 15-107*A* to *D*), the skin and subcutaneous tissues are incised in a curvilinear fashion. The incision starts at the cranial aspect of the head of the humerus distally, curves laterally to the area of the musculospiral groove, and ends over the cranial aspect of the extensor carpi radialis muscle. Both the lateral and cranial aspects of the bone are exposed as described for the lateral and cranial approaches.

Methods of Internal Fixation

Intramedullary pins or interlocking nails may be used to treat diaphyseal fractures of the humerus. Maintaining normal axial alignment of the bone and contraction of surrounding muscles exerts a certain degree of compression on the bone fragments. This together with the ability of cattle to produce good callus aids in healing. Mild displacement of the nail can be tolerated provided that bone alignment is maintained. Intramedullary pins can be placed in normograde fashion, starting proximally from the greater tubercle and passing distally to the medial humeral condyle. Care should be taken to avoid driving pins into the olecranon fossa of the humerus. A single intramedullary pin or multiple stack pins can be used to increase rotational stability and decrease the likelihood of longitudinal collapse of the fragments. Cerclage wire or interfragmentary compression with lag screws is also commonly applied when using intramedullary pins (Figure 15-108*A* and *B*). Interlocking nails can also be used to repair diaphyseal and distal fractures of the humerus. Insertion of interlocking nails and placement landmarks are similar to those of intramedullary pins.

Fractures of the humerus can be treated with internal plate fixation and screws. In calves up to 200 kg, application of a single plate to the lateral or cranial aspect of the humerus can provide enough support for healing (Figure 15-109*A*). Reduction of the fracture is achieved using traction and reduction forceps, and the fragments are secured with 3.5-mm or 4.5-mm lag screws. The cranial plate should be contoured from the cranial side of the humerus proximally to the craniomedial side (Figure 15-109*B*). The distal screws should be placed in the direction of the medial condyle to avoid the condylar fossa and the anconeal process of the ulna.

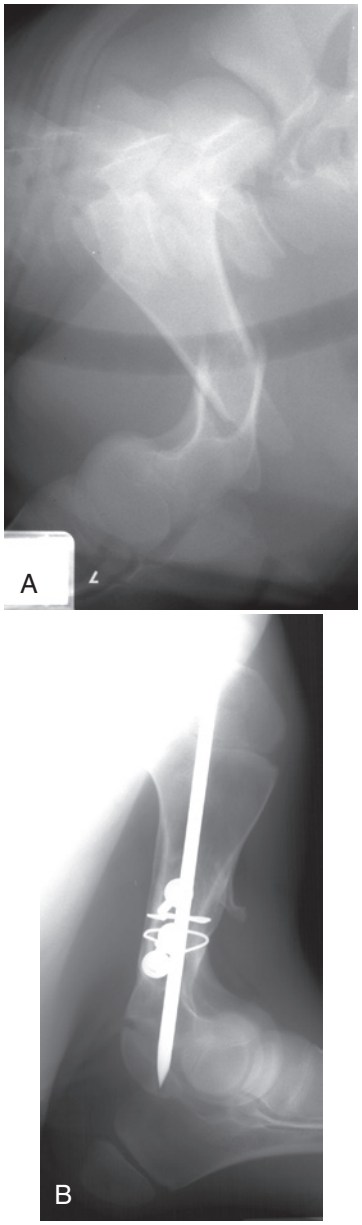


Figure 15-108 *A*, Lateral radiographs demonstrating a mid-diaphyseal fracture of the humerus in a 2-day-old calf. *B*, Previously described fracture 30 days after being repaired with a single intramedullary pin, lag screw, and cerclage wire.

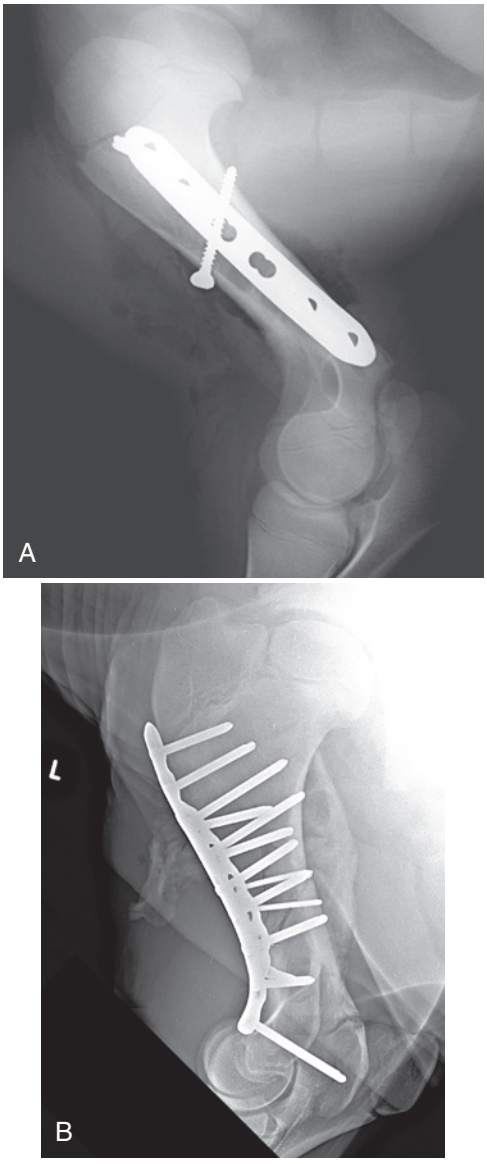


Figure 15-109 Mediolateral radiographic views of locking compression plate (LCP) fixation of humerus fractures 1 day and 14 days postoperatively in the calves shown in Figure 15-106. *A*, In the newborn calf, a 3.5-mm lag screw and a 6-hole standard 4.5-mm LCP were applied via a lateral approach. Long-term healing without complications was achieved. *B*, In the 6-month-old calf, double plating with two standard 4.5 LCPs was used via a cranial approach. The distal screws of the lateral plate were inserted over stab incisions. The calf developed signs of radial nerve paresis postoperatively but could use the limb normally with a short splint bandage. The calf improved with physiotherapy and controlled exercise and was clinically sound 4 months postoperatively. (*A*, Courtesy of Dr. Melanie Feist, Clinic for Ruminants, University of Munich, with permission.)

In animals heavier than 200 kg, double-plating techniques that use both the cranial and lateral surfaces should be attempted (Figure 15-109*B*). Whenever possible, regular and broad LCP plates and 5.0-mm locking screws should be used because of their strength and ease of application. During application of the lateral plate and the distal screws, it is critical to protect the radial nerve and to avoid the olecranon fossa. Even with the cranial approach, the distal aspect of the humerus remains poorly accessible for inspection and manipulation (see Figure 15-107). Particularly in adult cattle and those with multiple or comminuted fractures, fracture reduction is often difficult because of muscle tension and multiple bone fragments. The cranial plate must be bent considerably to adapt to the radial fossa. It is important to avoid the radial nerve during manipulation, reduction, plate application, and suturing. Separated muscle insertions and fascia cannot be completely readapted with sutures, which reduces stability and creates dead space. The large body weight of adult cattle and the weak bone structure of young animals predispose to implant failure after plate osteosynthesis of humerus fractures. The use of locking compression plates may improve the success rate in calves (see Figure 15-109). Radial nerve compromise occurs more commonly

during dual plate application than with IM pinning, interlocking nail fixation, or lag screw placement because more extensive dissection is required and the nerve is manipulated to a greater extent.

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FRACTURES OF THE RADIUS/ULNA

Sylvain Nichols and André Desrochers

Clinical Presentation

Fractures of the radius are more frequent in neonatal calves. They occur during forced fetal extraction or after a direct trauma caused by the dam. They tend to involve the diaphysis and have a transverse configuration. Lack of tissue coverage on the medial aspect makes them susceptible to become open especially if the fracture is oblique in configuration. Most of the time, but not always, the ulna will be fractured (Figure 15-110*A*). In older cattle, fractures of the radius are uncommon. When they occur, they are usually highly comminuted (Figure 15-111). They happen following a direct hit to the radius when the limb is loaded.

Fracture of the radius causes non-weight-bearing lameness, soft tissue swelling, and abnormal deviation of the leg above the carpus (valgus). The diagnosis is confirmed with orthogonal radiographs of the antebrachium.

Fracture configuration and age of the animals will dictate the appropriate immobilization technique. Internal fixation



Figure 15-111 A lateromedial radiographic view of a spiral diaphyseal fracture in a 3-year-old Holstein bull.

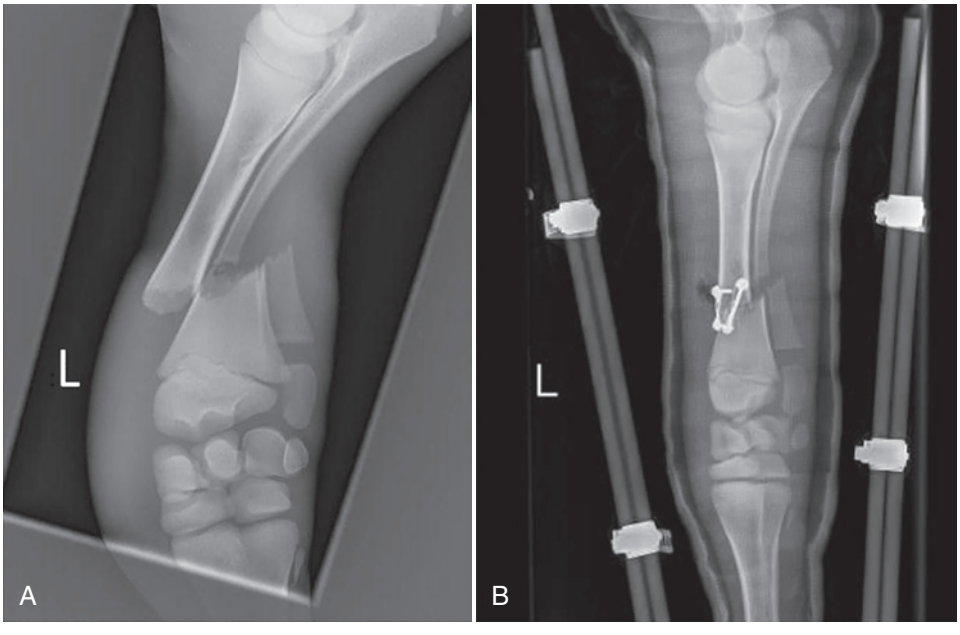


Figure 15-110 *A*, A lateromedial radiographic view of a closed radius and ulna fracture in a newborn Holstein calf. The alignment of the fragments could not be kept with external coaptation. *B*, A 3.5-mm cortical screw placed in lag fashion and three other 3.5-mm cortical screws were combined with two figure-8 wires to maintain the fragments' alignment. A full-limb cast and a Thomas splint were added to increase stability.

only cannot be used in young calves (<6 months) because of their thin cortices. Therefore in young calves, radial fractures are treated by a combination of external coaptation and internal fixation. Respecting casting principles, the joints adjacent to the fracture must be immobilized. It is rather difficult to do in mature cattle. However, in neonates the elbow can easily be included in a full limb cast, increasing the stability of the repair. Keeping that in mind, a distal physeal fracture can be successfully immobilized with a full limb cast including the elbow in neonates. Ideally, the full limb cast is combined with a Thomas splint. For the same fracture configuration in mature cattle, a Thomas splint will be essential to increase fracture stability.

Keeping the fragments aligned is challenging with only external coaptation. To improve alignment and speed up healing, internal reduction and fixation, combined with external coaptation, can be used judiciously. Alignment of the fragments is maintained with screws placed in lag fashion or with cerclage wires. In older calves, a cranial plate (tension side of the bone) can be used. In heavier cattle (more than 200 kg), double plating is certainly safer with a cranial and a medial or lateral plate. It is important to remember that a full limb cast should not be placed when the fracture is repaired with bone plates. Immobilizing the limb shifts the tension side of the bone from cranial to caudal, placing the implants at risk of breaking prematurely.

Surgical Approach to the Radius

The surgical approach to the radius will vary depending on the surgery to be performed. In general, the radius is approached with a lateral curvilinear incision (Figure 15-112). The animal is placed in lateral recumbency with the affected leg uppermost. The leg is prepared for surgery from midmetacarpus to the shoulder joint. The incision of the skin and subcutaneous tissues starts at the lateral epicondyle of the humerus. It curves cranially before coming back laterally at the distal lateral tuberosity of the radius. The flap of skin is retracted laterally, giving access to the cranial and lateral aspect of the radius. A plane of dissection is created between the common digital extensor and the extensor carpi radialis. Proximally, the radial nerve is identified, gently manipulated, and protected.

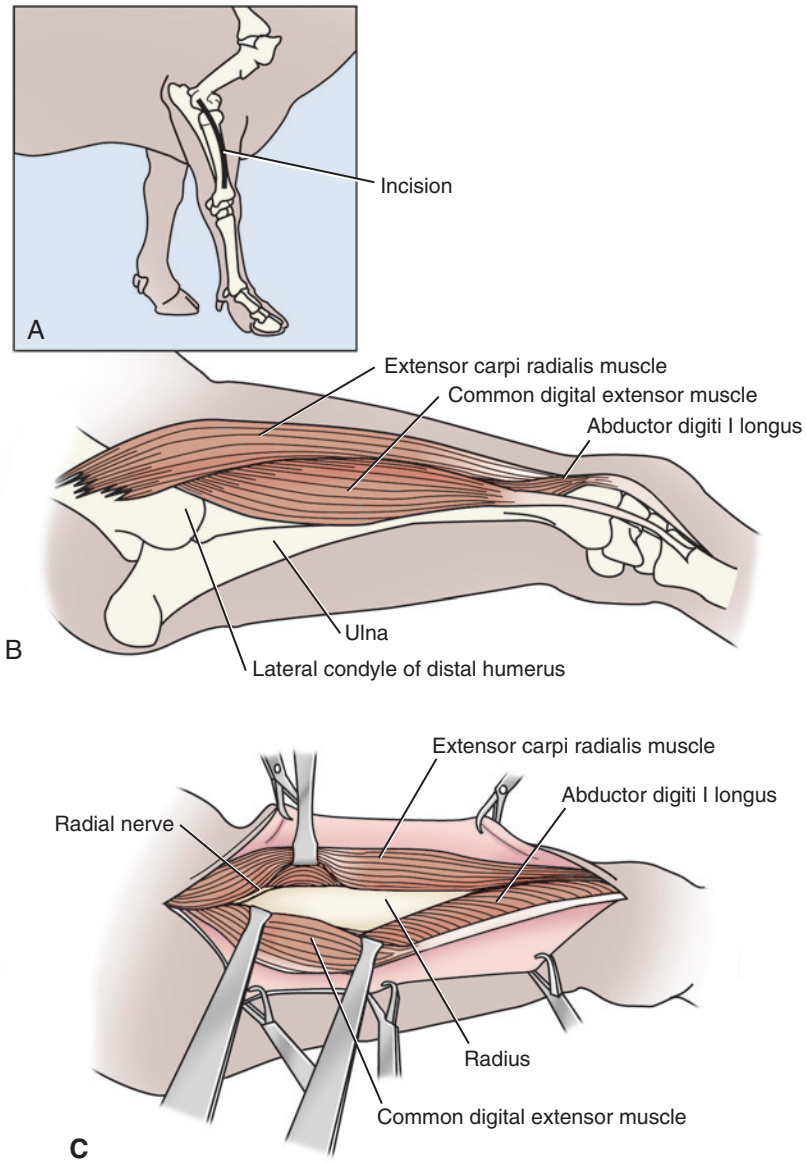


Figure 15-112 Schematic of the lateral approach to the radius.

Methods of Internal Repair

The fracture is reduced by continuous traction of the lower limb. Combining gas inhalation anesthesia to a plexus brachial block is useful to relax the contracted muscles. In older calves or in heavier cattle plate fixation should be considered (Figure 15-113*A* and *B*). If available, LCPs should be used in heavy animals. The fracture configuration will dictate the location of the plates (cranial, lateral, or medial). Because of the shape of the bone (bowed in a craniocaudal direction), it can be difficult to place a true lateral and medial plate. Therefore the plates are frequently placed craniolateral or craniomedial. However, the radius is certainly one of the easier bones to plate in a large animal.

In neonates, the goal of internal fixation is solely to keep the fragments aligned during immobilization with external coaptation. A smaller incision just above the fracture site is sufficient. A combination of lag screws and cerclage wires is used to keep the fragments in place (see Figure 15-110*B*). A full limb cast, combined or not with a Thomas splint, is then applied. External fixator with lateral bars can also be applied if the fracture is open, allowing direct access for further wound management. A pin cast is an interesting alternative when alignment is crucial and the fracture is close. Depending on the fracture configuration, two transcortical pins are inserted proximal, and additional pins are placed distal to the fracture line. To increase stability the proximal transcortical pins should be placed with a 30-degree diverging angle in the dorsocaudal plane, staying parallel to the long axis of the fracture (same for distal pins). Pin loosening will occur rapidly in neonates, preventing their placement for more than 3 weeks. By then the fracture should be solid, with a significant callus, and a cast with or without a Thomas splint should stabilize the fracture sufficiently for healing.

Surgical Site Closure

The common digital extensor and the extensor carpi radialis are reapposed with a simple continuous pattern using polydioxanone. Walking sutures or a subcutaneous layer is done to secure the skin flap. The skin is closed with an interrupted pattern. A compression bandage is applied on the antebrachium.

Postoperative Treatments and Complications

Antibiotics are given for the first 5 days postoperatively. NSAIDs are given as needed. The incision is monitored daily and kept under a bandage for the first 5 days postoperatively. The sutures are removed 14 days after surgery. The animal is kept in a box stall, by itself, for the first 8 weeks postoperatively. Exercise is then allowed by letting the animal have access to a small nonslippery paddock for another 8 weeks.

Early postoperative complications, after bone plating, are pulling (neonate) and/or fracture (heavier animal) of the implants. Surgical wound infection leading to osteomyelitis can be diagnosed in the early postoperative period. Persistent swelling and lameness should warrant investigation of the fracture site to evaluate a possible infection.

Long-term complications include nonunion or malunion (usually from infection), deformed fractured limb and breakdown, or varus deformity of the contralateral limb. All complications may lead to persistent lameness.

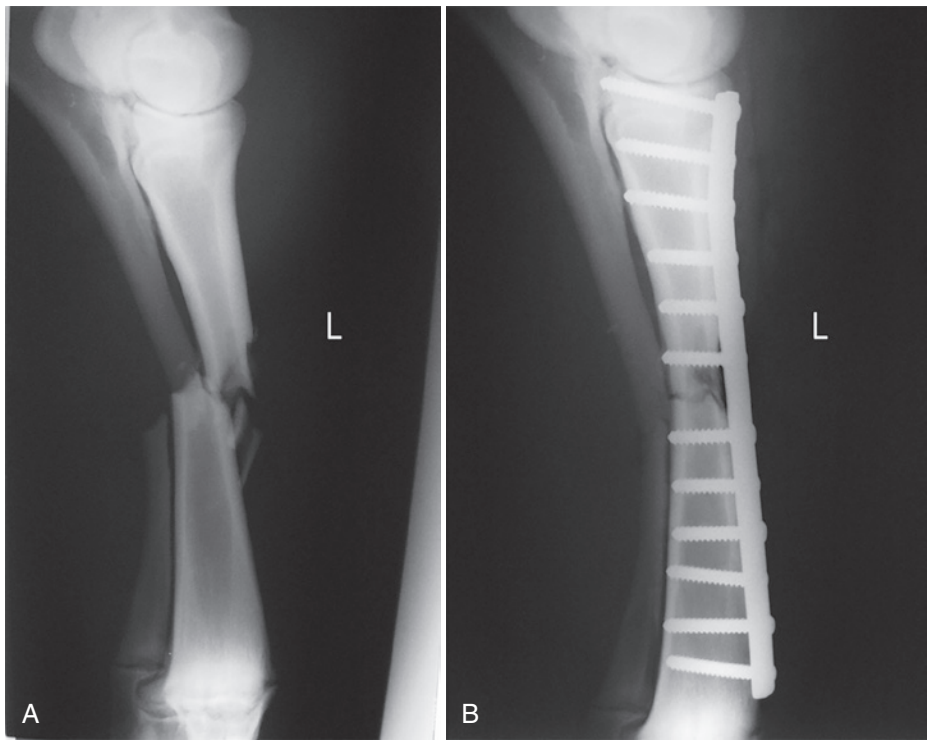


Figure 15-113 *A*, A lateromedial radiographic view of a closed transverse radius and ulna fracture in a 4-month-old Holstein calf. *B*, The fracture was fixed with a cranial 4.5-mm broad DCP and 4.5-mm cortical screws. (Courtesy of Dr. André Desrochers, Université de Montréal.)

FRACTURE OF THE ULNA

Clinical Presentation

The ulna is complete in cattle. Proximally, it articulates with the humerus within the elbow joint. Distally, it articulates with the ulnar carpal bone within the radiocarpal joint. Fracture of the ulna without fracture of the radius is uncommon. When it occurs, it usually involves the olecranon. The clinical signs will be similar to a humeral fracture or a radial paralysis: dropped elbow with a flexed carpus (Figure 15-114). Diagnosis is obtained radiographically. The nomenclature used in equines can be used to describe the fracture configuration in cattle. Internal reduction and fixation are ideal. However, a nondisplaced fracture can be treated conservatively by using a cast or a caudal splint.

Surgical Approach to the Ulna

The animal is positioned in lateral recumbency with the affected leg uppermost. The limb is shaved from the shoulder joint to the proximal metacarpus and prepared aseptically for surgery. The skin incision starts 5 cm above the proximal aspect of the olecranon just caudal to the humerus. It rapidly bifurcates toward the caudal aspect of the olecranon. The incision is extended on the caudal midline toward the distal aspect of the ulna. A plane of dissection is created between the flexor carpi ulnaris and the ulnaris lateralis. The attachment of the triceps tendon on the olecranon is partially dissected to allow placement of the implant.

Methods of Internal Repair

Olecranon fractures are repaired based on tension-band principles. The triceps, pulling on the olecranon, creates a perfect tension surface on the caudal aspect of the ulna. To create the tension band, a plate or an intramedullary pin and wires can be used. Because of the thin cortex on the ulna, the intramedullary pins should be entered carefully to avoid splitting the bone. This technique is not suitable for larger cattle.

Ideally, an LCP (larger cattle) or an LC-DCP should be used. To speed up the surgery, it is recommended to appropriately plan the length of the plate to be used, the location, and the length of the screws to be used. To obtain a flat surface to receive the plate, the caudal aspect of the ulna must be chiseled carefully. To increase the strength of the construct, the distal screws should engage the caudal cortex of the radius. Putting 2 plates above each other (Figure 15-115) or using plate luting (with DCP plates) has been tried in heavier cattle to increase the strength of the construct.



Figure 15-114 Photograph of a 2-year-old Holstein heifer with a left thoracic limb olecranum fracture. The typical drop elbow and flexed carpus are present in this picture.

Surgical Site Closure and Postoperative Care

The implants are covered by suturing the flexor carpi ulnaris and the ulnaris lateralis together. A subcutaneous and a skin layer closure is then performed. Depending on the fracture configuration and the strength of the fixation, a modified Robert John bandage combined with a caudal polyvinyl chloride splint can be used for the first month postoperatively. The splint/bandage have to be changed weekly to evaluate the surgery site and to avoid creation of pressure sores. Antibiotics and NSAIDs are given according to the comfort level of the animal and inflammation at the surgery site. In general, antibiotics are given for at least 5 days postoperatively.

CARPAL AND TARSAL FRACTURES

Karl Nuss

Fractures of the bones forming the carpal and tarsal joints are rare. Non-weight-bearing lameness, joint effusion, and instability are indicative of intraarticular fractures. Ultrasonographic examination can be helpful to determine the origin of the joint effusion. To salvage an animal, the feasibility of external forms of fixation should be considered if reduction and maintenance of limb axis are possible. Chip and avulsion fractures of the smaller carpal or tarsal bones can be repaired with lag screws, similar to methods used in horses. Arthrodesis and additional fixation with a transfixation pin cast should be considered for fractures and luxations of the small joints (Figure 15-116*A* and *B*). Degenerative joint disease is likely to develop postoperatively.

Sudden, nonreducible hock flexion is a clinical sign highly suggestive of intraarticular tarsal fracture (Figure 15-117*A*) or luxation (see Figure 15-82) and is confirmed radiographically (Figures 15-117*B* and 15-83). If the goal is to keep the animal for production, anatomic reconstruction with bone screws for internal fixation of the bone(s) that comprise the joint surface(s) provides the best chance for a positive outcome. Fractures of the talus are difficult to treat, because the bone has an important function in weight bearing and the approaches to the tarsocrural joint are limited due to its complexity. Most of the talus surface is covered by cartilage and has contact to other bone surfaces, which makes reconstruction and stabile fixation of this bone demanding. When surgical repair is indicated, CT (Figure 15-117C) is helpful to determine the fracture configuration, feasibility of repair, and optimal surgical approach.

Fractures of the calcaneus have been successfully treated with steel plates, a lag screw, or figure-8 wires secured with Kirschner pins. Bilateral physeal fractures of the calcaneus have a poor prognosis.

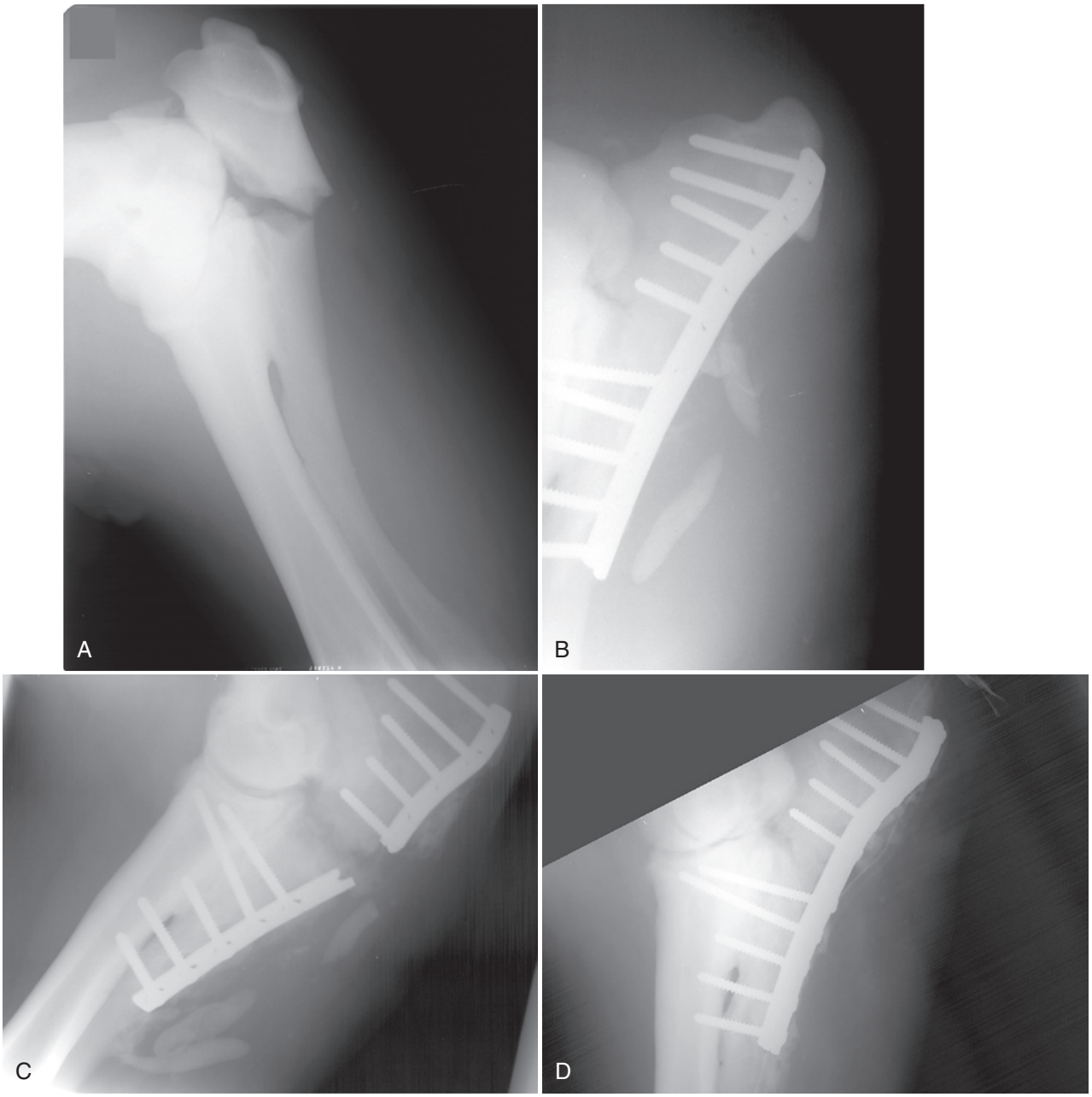


Figure 15-115 *A*, Lateral radiograph of the olecranon of a 3-year-old 500-kg Hereford cow with an acute olecranon fracture. *B*, After repair with a narrow dynamic compression plate (DCP). *C*, Implant failed and, D, was repaired by removing the broken plate and replacing it with two overlapping DCPs using the same screw holes. In addition, bone grafting was performed. (Courtesy of Dr. Norm G. Ducharme, Cornell University.)

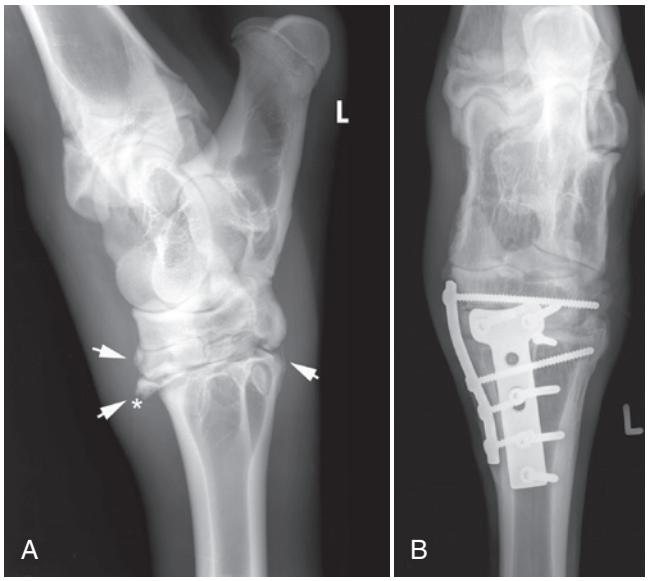


Figure 15-116 Radiographs of a 12-month-old Brown Swiss heifer with sudden lameness in the left hind limb. On radiographs, subluxation of the metatarsal bones (MT) and several small fragments including the small second and third tarsal bones (*arrows*) are evident (*A*). A 3.5-mm cortical screw was used to hold a larger dorsal fragment (*asterisk*), and arthrodesis was carried out with a T plate and a standard DCP. To protect the fixation and to prevent weight bearing, a transfixation pin cast was applied. *B*, Three months after surgery, there were signs of ankylosis and degenerative joint disease. Clinically, the hock was straighter than normal and the heifer had grade 1/5 lameness.

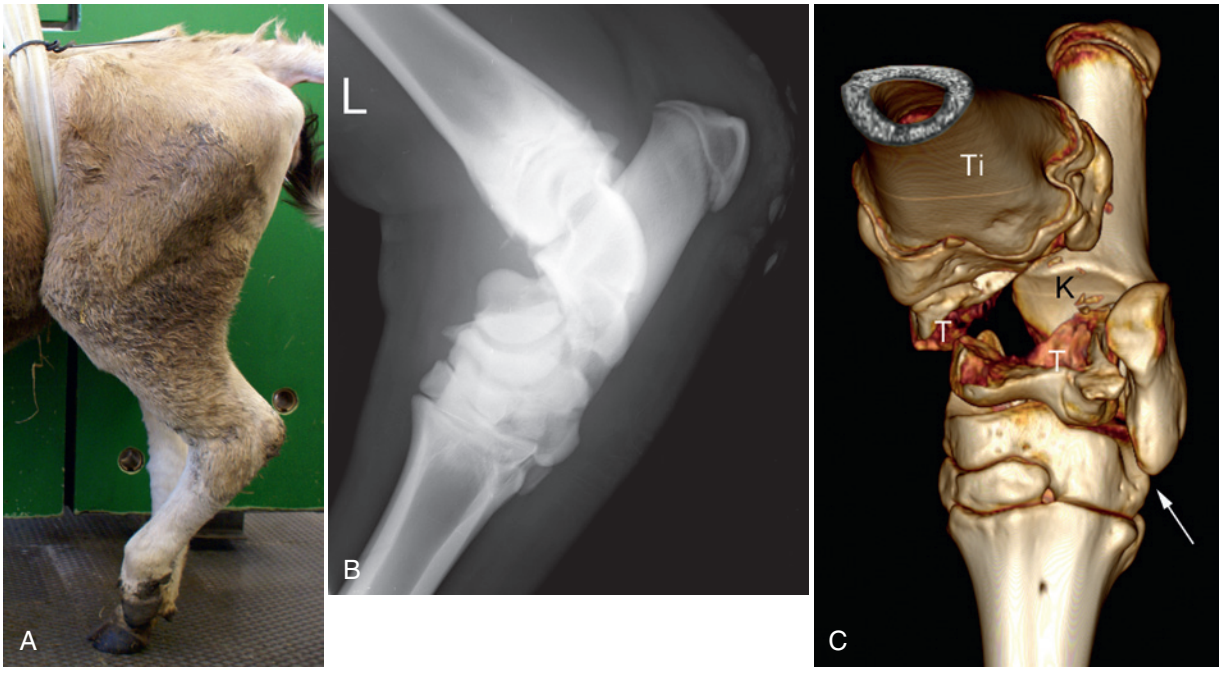


Figure 15-117 A 17-month-old Brown Swiss heifer that incurred an injury on pasture 4 days before referral. *A*, Left hind limb held in constant flexion. *B*, Lateromedial radiographic view showing a fracture of the talus with deviation of the proximal fragment and the tibia. C, Computed tomographic three-dimensional reconstruction of the tarsus clearly shows the oblique fracture of the talus with luxation of the talocalcaneal joint (Ti, tibia; K, calcaneus; T, parts of the talus). In addition, subluxation of the calcaneus (*arrow*) is evident. The heifer was euthanized without treatment.

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FRACTURES OF THE METATARSAL/METACARPAL

Pierre-Yves Mulon

Fractures of metacarpal/metatarsal III/IV are among the most common fractures in cattle. The bones are covered by tendons, ligaments, and the skin, offering a limited protection to trauma whether they are self-inflicted or consequences of an external action (herdmate or calving chain).

Calving chain fractures of metacarpal/metatarsal III/IV represent a separate entity of those fractures. Most of them occur at the metaphysis and are of short oblique configuration. A close examination of any wound should be performed. Those fracture are generally well treated by external coalition with a full limb cast changed every 3 weeks with either a full or half-limb cast depending on the stability of the fracture. Alteration of the blood supply distally to the chain location is impossible to predict without CT angiography; therefore the owner should be warned that, although rare, skin sloughing or complete necrosis of the distal aspect of the limb may happen at the time of the first cast removal.

The most common fracture of the metacarpal/metatarsal III/IV in juvenile animals is the epiphyseal fracture Type II according to the Salter-Harris classification. Those fractures are commonly closed and best treated with closed reduction under heavy sedation or short-term total IV anesthesia and external coadaptation. The fracture usually stays very stable after the reduction due to the serration of the growth plate. Those fractures can be managed by a full or short limb cast depending on the weight of the animal. Internal fixation can be added to the management of those fractures through the metaphyseal component of the Salter-Harris fracture (see Figures 15-84 and 15-86). For young animals with a rapid growth rate, the cast should be changed after 3 to 4 weeks.

Only short horizontal diaphyseal and proximal metaphyseal fractures are treated by a full leg cast without transfixing pins. Long and short oblique diaphyseal fractures are at great risk of becoming open fractures due to the overriding of the fragments immediately after weight bearing by the animal if a simple external coaptation is used. In addition to oblique fracture, highly comminuted fractures are best treated by a TPC method. Fractures resulting from a high-energy trauma for which comminution and soft tissue damage are very important should also be treated using a TPC method. Position of the pins depends of the integrity and length of the proximal metacarpal/metatarsal III/IV bone fragment; otherwise pins should be positioned in the radius/tibia (see TPC in the External Fixation section). In adult animals, the cast should are changed after 6 weeks. If comminution is minimal, internal fixation is used (Figure 15-118).

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PELVIC FRACTURES

Karl Nuss

Fractures of the pelvis generally occur in heifers and adult cows and most commonly involve the wing of the ileum and the acetabular region and less commonly the body of the ileum and parts of the ischium. Fractures of the wing of the ileum occur in mature cows and are sometimes called *knock down hip*. Dairy cows in confined housing sustain these fractures from being ridden by other cows or from striking immovable objects. When viewed from behind, cows with pelvic fractures have asymmetry of the tuber coxae (Figure 15-119). On palpation, the fractured tuber coxae is displaced ventrally. Depending on the location of the fracture, the gluteal, abdominal, and lumbar muscles near the fracture site can be affected, causing impairment of gait or lameness. The abdominal wall may also be affected because parts of the internal and external oblique abdominal muscles originate from the wing of the ileum. Palpation of the region where the fragments are located elicits pain and reveals signs of edema and hematoma. Conservative treatment consisting of stall rest for approximately 60 days is indicated when a small part of the ileal wing is fractured. However, the sharp end of the remaining ileal wing or column fragment can penetrate the skin, causing infection, even in fractures that were closed initially. Immediate diagnostic and possibly therapeutic measures should therefore be instituted to prevent the development of phlegmon, purulent infection, and osteomyelitis, which tend to gravitate ventrally. Radiographs are indicated to determine the extent of skeletal involvement, and ultrasonography is useful for outlining the extent of soft tissue involvement or inflammation. Surgical debridement is feasible in cattle in which a sequestrum has developed, but general anesthesia is usually required. In cases with diffuse soft tissue infection and osteomyelitis, treatment may be elected in valuable animals, but the prognosis is grave to poor.

Fractures of the pubis and ischium occur as a result of trauma—for instance, when an animal falls on pasture or indoors on hard flooring or when it is hit by a moving vehicle (Figure 15-120). The degree of lameness is variable and ranges from 2 to 3/5 with ischial fractures without acetabular involvement to 5/5, or recumbency, in animals with acetabular fractures and central luxation of the femoral head toward the pelvic cavity. A tentative diagnosis can be made based on the results of a clinical examination that includes transrectal palpation. Pelvic ultrasonography is also a useful diagnostic procedure (Figure 15-121) because pelvic fractures often have little dislocation and small hematomas. The diagnosis can be confirmed radiographically in the standing patients. In young cattle and dairy cows, radiographs are usually diagnostic provided that the equipment is powerful

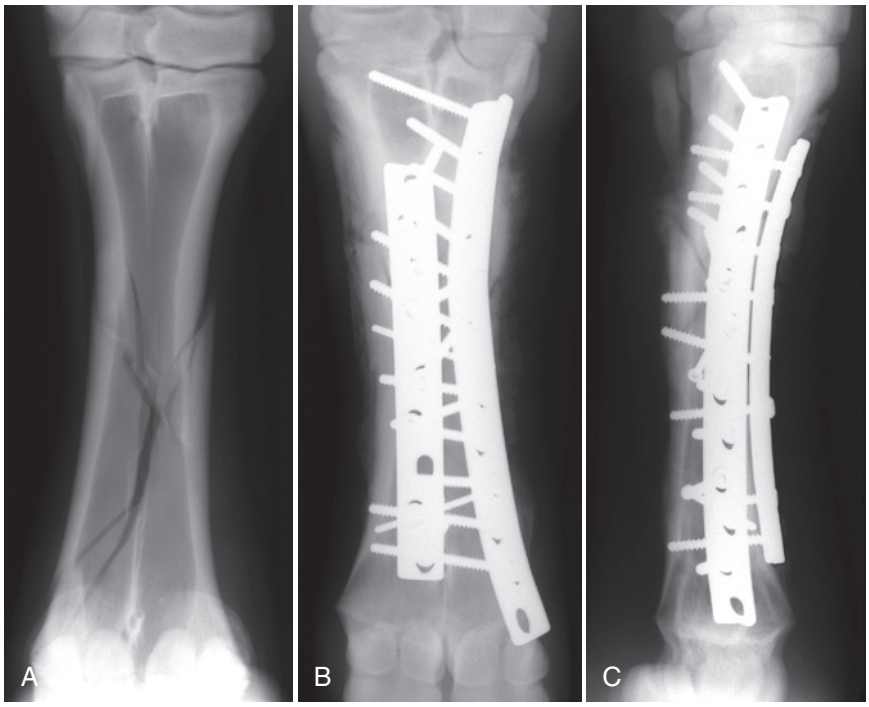


Figure 15-118 *A*, Dorsoplantar radiograph of a 500-kg bull with a comminuted metatarsal fracture. Previously described fracture repaired by using dorsally (*B*) and laterally placed bone plates and screws (*C*). Note that the distal screw hole of the lateral plate is overlying the physis and is left open because inserting a screw could lead to permanent physeal damage and subsequent growth deformation. (Courtesy of Ryland B. Edwards III, University of Wisconsin.)



Figure 15-119 Caudal view of a cow with a right fracture of the ileal wing (tuber coxae).

enough (Figure 15-122), but in large cows and bulls, body size and heavy muscling are limiting factors and make diagnosis more difficult. Because not all parts of the pelvis can be visualized on radiographs of standing animals and pelvic fractures are often multiple, additional views may have to be taken in the recumbent animal.

Surgical treatment of pelvic fracture has not been described in cattle. The musculature makes surgical access difficult, and fixation would have to withstand considerable physical load; the chance of success (Figure 15-123) is

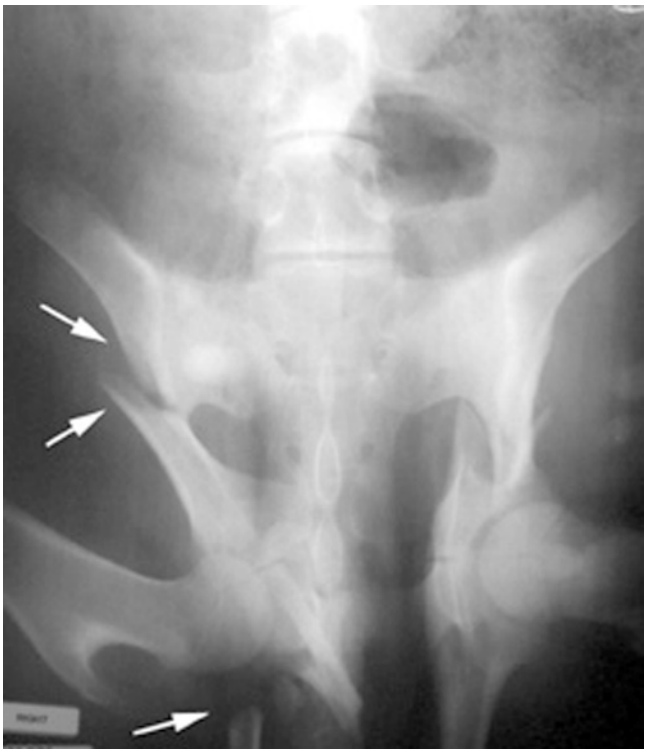


Figure 15-120 Ventrodorsal radiograph of the pelvis of a 7-month-old heifer hit by a car. There are ilial and ischial body fractures (*arrows*).

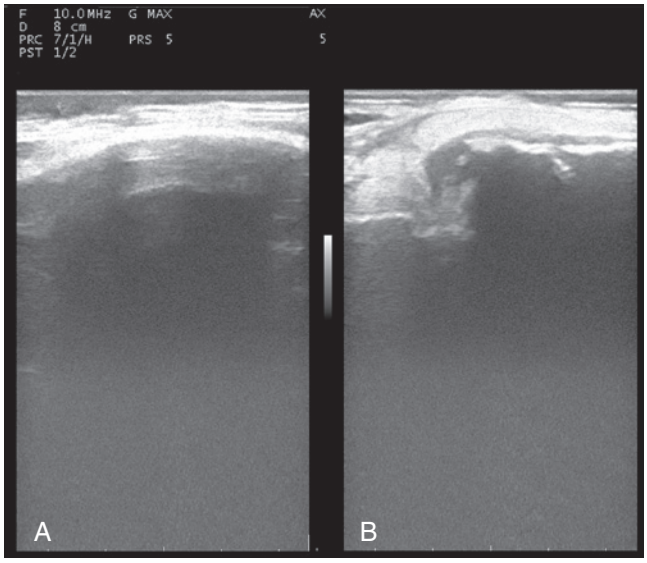


Figure 15-121 Ultrasonograms taken during rectal examination using a 10-MHz linear transducer showing a displaced fracture of the left acetabular region in an 18-month-old Brown Swiss heifer. *A*, Normal right side. *B*, Fractured left ischial crest.

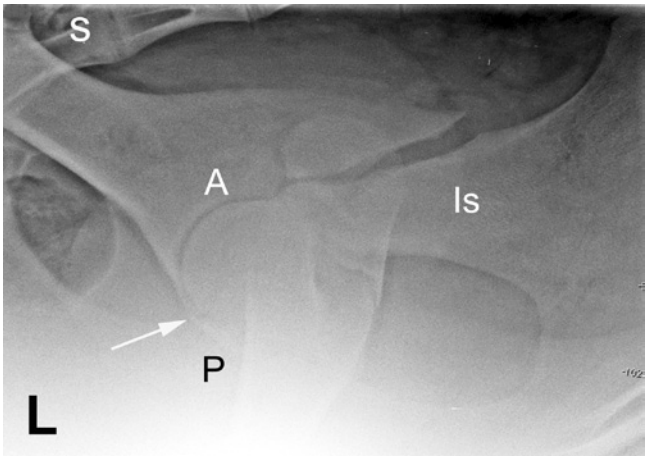


Figure 15-122 Right 25-degree dorsal–left ventral transpelvic radiograph of the left (L) coxofemoral joint area of an 18-month-old standing Brown Swiss heifer. The fracture line runs from the ischial spine of the ischial bone (Is) cranially into the acetabulum (A), where it curves (*arrow*) toward the pubic bone (P). S, sacrum.

therefore small in large animals. Nondisplaced pelvic fractures without acetabular involvement can heal with conservative treatment, but this may be associated with callus formation obstructing the pelvic canal. Owners should therefore be advised not to breed heifers or cows that have recovered from a pelvic fracture unless the pelvic canal has a normal diameter, as confirmed by transrectal examination. Alternatively, elective cesarean section should be considered in pregnant animals.

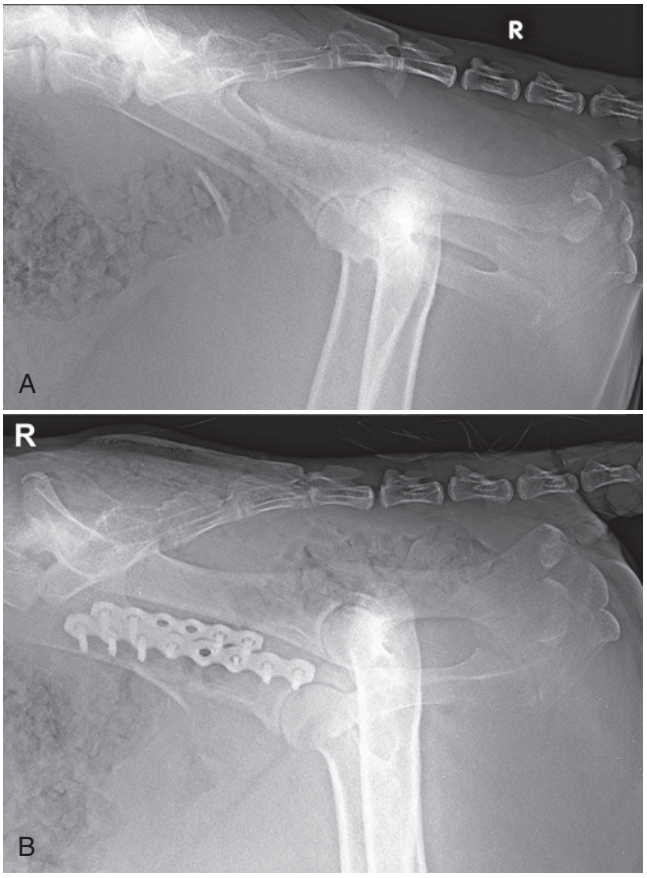


Figure 15-123 *A*, Laterolateral radiograph demonstrating a comminuted fracture of the (left) ileal column in a 92-kg castrated male goat used for trecking. *B*, The fracture was repaired with two locking plates placed laterally. A fracture line in the right os ischium (*arrows*) is visible on the postoperative radiograph. With stall rest, the fracture healed with no gait impairment.

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SACRAL FRACTURE

Norm G. Ducharme

Sacral injuries and fractures are rarely traumatic and are associated with mounting injury during estrus or excessive



Figure 15-124 Loss of normal smooth contour of the dorsal sacrococcygeal area of a heifer with a sacral fracture.

traction on the tail during assisted parturition or restraint. The fracture may result in localized pain and an abnormal contour of the dorsal sacrococcygeal area (Figure 15-124). In addition, depending on the location of the injury, various neurologic deficits may be seen. Fracture to the most cranial aspect of the sacrum may result in damage to the sciatic and obturator nerves; therefore clinical signs may also be seen in the pelvic limbs. Damage to the obturator nerves results in adductor muscle deficit. Finally, deficit to the sciatic nerve results in knuckling at the fetlock. Pelvic and pudendal nerve injuries may result in disorders in micturition and defecation. In addition, flaccidity of the anus and vulva can be seen. Caudal neurologic damage to the coccygeal nerve can lead to deviation of the tail if unilateral damage is present. If bilateral damage to the innervation is present, a decrease or lack of tail tone is seen with soiling of the tail by fecal material because of failure of tail elevation.

Treatment options include the following: conservative management (which allows time for fibrous or bony union of the fracture and restoration of nerve function), antiinflammatory agents, and avoidance of tail manipulation, and placing the animal in a box stall with excellent footing is recommended. If an adductor muscle deficit is present, the hind limbs should be tied together (hobbling—use commercial hobbles or a rope tied just above the fetlock, giving about 2 feet [0.6 m] of movement between each leg). If return of tail function does not occur, tail soiling will cause unsanitary conditions in the milk parlor, thus requiring tail amputation.

A tail amputation can be performed by placement of a rubber ring (3 mm thick, with an inner diameter of 7 mm[13]) at the base of the tail at the level of the vulva. Because more proximal amputation is generally needed for paralysis, surgical amputation is recommended. In the average adult cow, 4 cm^3 of lidocaine hydrochloride is placed between the first and second coccygeal vertebrae, therefore proximal to the intended amputation site. A tourniquet is applied and the amputation area prepared for aseptic surgery. The intent is to transect between two coccygeal vertebrae and close the skin over the defect. The skin is incised 2 to 3 cm more caudal than the intervertebral space to be incised. The intervertebral space is identified and the blade inserted under the skin flap until the space is reached and transected. The coccygeal vein and artery are identified at the ventral aspect of the remaining vertebra and ligated. The tourniquet is temporarily released to identify additional significant vessels. The skin is reapposed over the coccygeal vertebra with simple interrupted sutures.

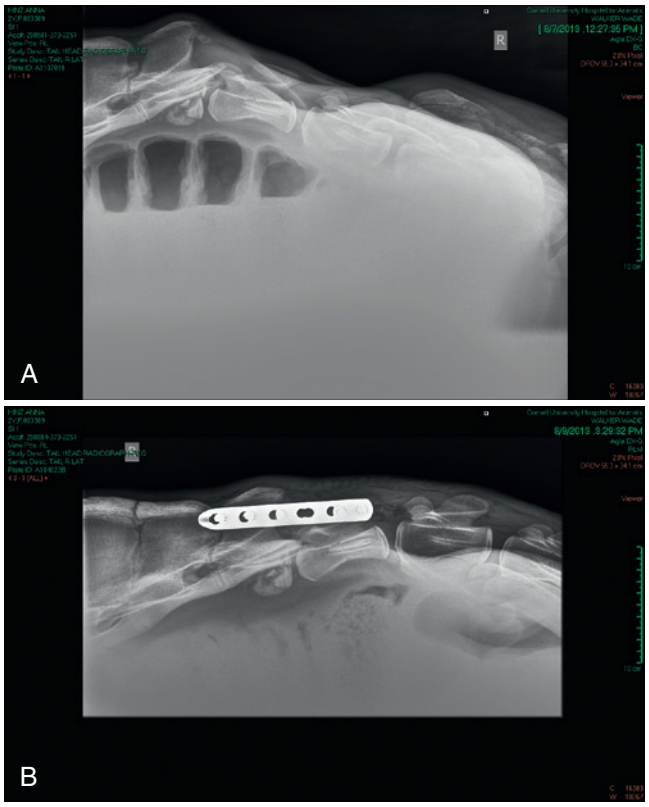


Figure 15-125 *A*, Lateral radiograph showing fracture of the caudal aspect of the sacrum (S5) with ventral displacement of the caudal physeal fracture of a last sacral fragment in a 2-year-old Holstein cow. *B*, Postoperative view after surgical repair with narrow locking plate placed in the dorsal spinous process of the last sacral vertebra and the first caudal vertebra. Note the marked improvement in external conformation without correcting ventral displacement of the caudosacral endplate. (Courtesy of Dr. Alan Nixon.)

Surgical repair of sacral fractures can also be done by using internal fixation (see the Internal Fixation section in this chapter). The fracture is stabilized by using either internal fixation (narrow LC-DCP plate, locking plate) on the vertebral body adjacent to the fracture or by placing a spinous process plate[14] on the spinous process adjacent to the fracture. There is a better likelihood of restoring vertebral body alignment but with a greater potential for morbidity because of the possibility of neural damage to the caudal nerves.

The surgical procedure is performed under general anesthesia, and the animal is placed in sternal or lateral recumbency. The caudal sacral area is prepared for aseptic surgery. An incision with a dorsal midline approach is made until the dorsal spinous process is identified. The incision is extended along either side of the dorsal process; if elected, a spinous process plate is applied to the dorsal spinous process of the sacrum and first coccygeal vertebra (Figure 15-125*A* and *B*).

[13]Ideal Instruments, Schiller Park, IL, USA.

[14]Lubra plate, Lubra Co., Fort Collins, CO, USA.

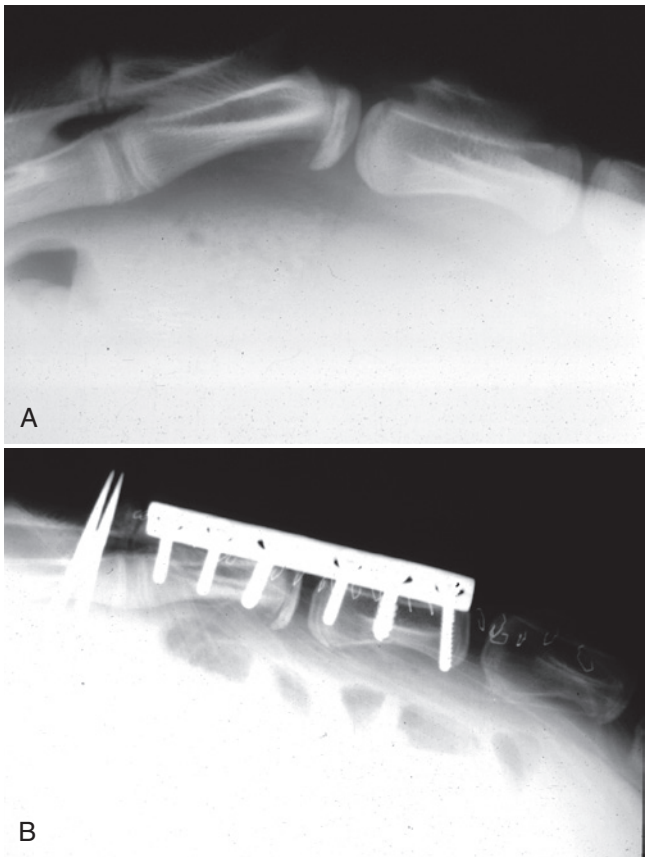


Figure 15-126 *A*, Lateral radiograph of a physeal fracture of the last sacral fragment of a heifer. *B*, Intraoperative view after surgical repair with narrow plate placed in the vertebral body of the last sacral vertebra and the first caudal vertebra. (From McDuffee, et al: Repair of sacral fracture in two dairy cattle, *J Am Vet Med Assoc* 202:1126–1128, 1993 [Reproduced with permission].)

If fixation will be made on the vertebral body, an incision of the sacrotuberous ligament on the appropriate side is made after exposing the dorsal spinous process needed to allow adequate exposure. The ventrally displaced physeal fracture is reduced, and a plate (LC-DCP or locking) is fixed to the vertebral body, taking care not to enter the vertebral canal (Figure 15-126*A* and *B*).

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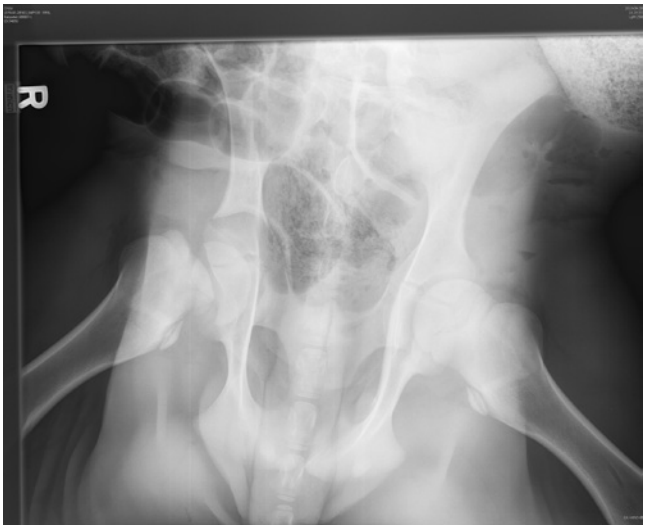


Figure 15-127 Dorsoventral radiograph of a 6-month-old Holstein heifer with a Salter-Harris Type I fracture of the right femoral head.

SLIPPED CAPITAL FEMORAL PHYSIS

Sylvain Nichols

FRACTURE OF THE FEMORAL HEAD

Clinical Presentation

Capital physeal fractures occur in young or juvenile animals. They are caused by forced fetal extraction, direct lateral trauma to the hip joint, or overabduction of the rear limbs. The latest would inevitably cause coxofemoral luxation in older animals. However, in younger cattle, to preserve the unrepairable ligament the bone will often fracture at its weakest point: the growth plate. Young bulls, kept in groups, are more frequently presented with this type of fracture.

Lameness is usually acute. According to the Anderson's lameness scoring system, the animal is moderately lame (grade 2). It is reluctant to walk, but it will use the limb (toe touching) and will have a shortened stride. On palpation, crepitation (bone-on-bone friction) will be felt at a walk. Manual rotation of the hip at rest or with the animal in lateral recumbency will create the same crepitation. Diagnosis is confirmed by taking dorsoventral or standing lateral oblique radiographs (Figure 15-127).

Multiple internal fixation techniques have been described: intramedullary stacked pinning, cortical screws, or cannulated screws placed in lag fashion. Prognosis appeared to be better when cannulated screws were used (70% of bulls serviceable despite mild lameness present in most [80%] of the animals). Age of the animal did not have an effect on the outcome when this technique was used. When stack pinning or cortical screws are used, a positive outcome was obtained in 55% of the animals. Contrary to the aforementioned technique, the age of the animal (less than 12 months had a better prognosis) and the time before the animal resumed walking on the operated limb had an effect on the long-term outcome.

Surgical Approach

A curvilinear incision is created just cranial to the greater trochanter. The incision starts cranially, midway between

the wing of the ilium and the greater trochanter, at the level of the ischial tuberosity. It extends caudally toward the greater trochanter before bifurcating distally toward the distal femur. The tensor fascia lata and gluteobiceps muscles are exposed, and a plane of dissection is created between them. The gluteobiceps muscle is retracted caudally and dorsally to expose the greater trochanter. The insertion of the vastus lateralis muscle, on the greater trochanter, is partially incised to allow retraction of the muscle caudally and ventrally. Alternatively, its fibers can be split to improve exposure of the greater trochanter and the proximal femur (site for screw insertion). The gluteus medius muscle is retracted dorsally. The gluteus accessorius and profondus are retracted dorsally and caudally. If needed, a partial tenotomy of their attachment on the greater trochanter can be performed to improve access to the joint. Finally, the joint capsule is incised (Figure 15-128).

Methods of Internal Repair

The fracture site is digitally explored and the fragments are aligned by manipulation of the limb. A guide wire is first drilled from the proximal femur (just distal to the attachment of the gluteus accessorius on the greater trochanter) to the femoral neck and head. The articulation is explored digitally to ensure adequate placement of the wire. Radiographs can be taken to confirm the position. Ideally, the wire is used to guide a 5.0-mm cannulated drill bit and a partially threaded 7.3-mm cancellous and cannulated bone screw. However, if the cannulated system is not available, the guide wire is used to evaluate the adequate angle to

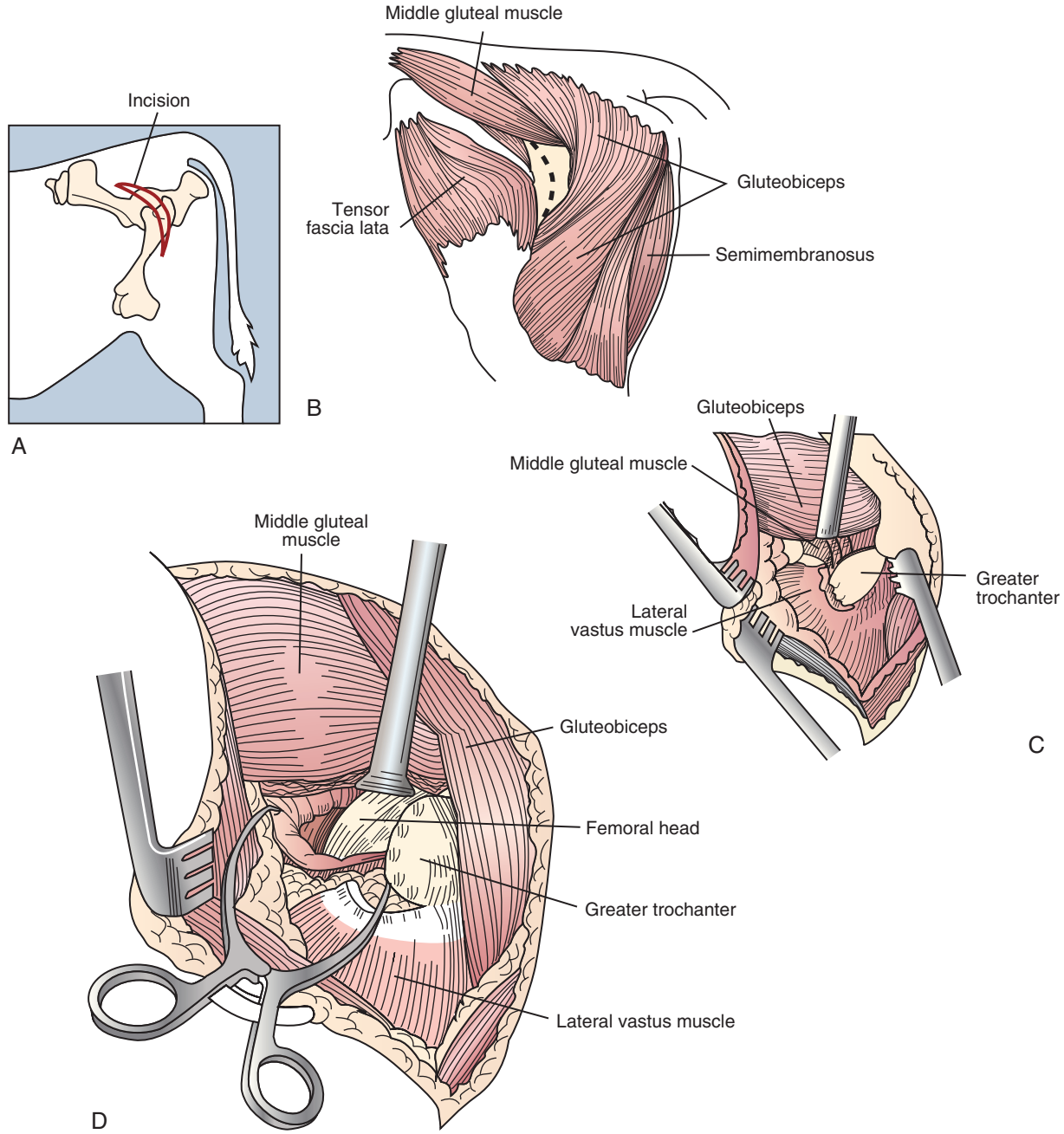


Figure 15-128 Schematic of surgical approach of the coxofemoral joint.

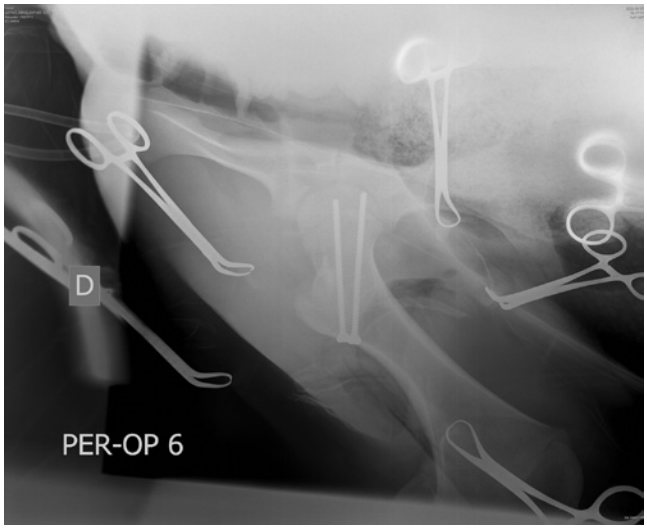


Figure 15-129 Intraoperative radiograph of an open reduction and an internal fixation of a Salter-Harris Type I fracture of the femoral head in a 6-month-old Holstein heifer. Two 4.5-mm screws were placed in lag fashion to compress the fracture site.

reach the femoral head, the depth to drill, and the length of the screw needed to compress the fracture site. If a cortical (5.5 mm) or a cancellous bone screw (6.5 mm) is used, the glide hole is first made according to the depth estimated with the wire minus 10 mm (measured and marked on the drill bit). Then the thread hole is prepared. While drilling, the femoral head is palpated to feel the drill bit catching on it. The length of the hole created is measured and compared with the previous estimation. The threads are created manually. The femoral head is palpated to make sure the tap penetrates the fragment. A screw of the measured depth is inserted. The joint is explored and moved to make sure the screw is not too long. A minimum of two screws are inserted (Figure 15-129).

Alternatively, smooth Steinmann pins can be used. Two to three pins of a diameter of 3⁄16 and 1⁄8 of an inch have been used with reasonable success. The insertion is similar to the technique described above. The use of a guide wire is recommended to avoid missing the head with a large drill bit.

The cannulated screw system has been used without exposing the joint. With this technique, the tensor fascia lata is separated from the gluteobiceps and the fibers of the vastus lateralis are spread at the level of the greater trochanter. From this approach, the wires and the screws are placed under radiographic control. This technique is less invasive but technically more challenging than the open-joint technique. The possibility of easily performing intraoperative radiographs is essential to succeed with this technique.

Surgical Site Closure

The joint capsule is closed with a simple continuous pattern with small-gauge polydioxanone. The tenotomies are repaired with simple interrupted sutures using polydioxanone suture material. The tensor fascia lata is sutured back to the gluteobiceps with a simple continuous suture using absorbable suture material. Finally, the skin is sutured as previously described. A stent bandage is placed over the incision.



Figure 15-130 Femoral head necrosis as viewed on a ventrodorsal radiograph. (Courtesy of Dr. Rylan Edwards III, University of Wisconsin.)

Postoperative Treatments and Complications

Antibiotics are given for 5 days postoperatively. NSAIDs are given as needed. The incision is monitored daily, and the stent bandage is kept in place for at least 1 week. The stitches are removed 14 days after the surgery. The animal is kept in a box stall by itself for the first 8 weeks postoperatively. Then exercise by letting the animal have access to a small nonslippery paddock is allowed for another 8 weeks. Normal activity can be resumed around 4 months postoperatively.

Early postoperative complications include malposition of the implants (migration, impingement of the joint), wound infection, and septic arthritis. With malposition of the implants, a second surgery is necessary to replace the pins or screws.

In the long term, the animal may remain lame from osteoarthritis. Chondroprotective drugs may help to decrease the risk of osteoarthritis.

Femoral Head Ostectomy

Avascular necrosis of the femoral head has been seen (Figure 15-130). With the joint capsule in rough shape and the growth plate compromised, the blood supply to the femoral head relies solely on the ligament of the head of the femur. It is important to avoid traumatizing this ligament during surgery. If avascular necrosis is suspected, a femoral head ostectomy can be performed. This procedure may allow a young calf to reach slaughter weight, but it won't allow it to be functional as a breeding animal. The femoral head ostectomy is performed following an osteotomy of the greater trochanter. The surgical approach is similar to what has been described for the repair of a femoral head fracture. After partial tenotomy of the vastus lateralis, holes (2) are predrilled and pretaped in the greater trochanter to facilitate its reattachment to the femur. A Gigli wire is used to perform the osteotomy. With the greater trochanter removed, the femur is easily rotated to expose the femoral neck. A Gigli wire is then used to perform the ostectomy. The greater trochanter is reattached with bone screws (cortical or cancellous) inserted in the predrilled holes. Wires are used to create a tension band. They are passed through a hole drilled in the femoral diaphysis and around the cortical screws. Alternatively, Kirshner wires can replace the screws to create the tension band.

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FRACTURES OF THE FEMUR

Sylvain Nichols

Clinical Presentation

Femoral fractures more frequently involve the diaphysis and the distal metaphysis. Communition and presence of a large butterfly fragment is frequently diagnosed. Severe overriding of the fragments (Figure 15-131) is noted from the contraction of the quadriceps muscle, making the limb look shorter. Severe swelling is present above the stifle. The femoral artery may be lacerated, causing systemic repercussions for the animal.

Femoral fracture occurs more frequently in newborn calves but can also occur at any age. In neonates, they can be caused by forced fetal extraction (stifle lock position) or by direct trauma. The calf will be recumbent or three-legged lame. In older cattle, the animal may bear little weight on the injured limb. Multiple surgical techniques have been used to repair the femur: bone plates (DCP, LCP, cobra head plate, dynamic condylar screw), intramedullary pins, interlocking intramedullary nail (IIN), rush pins, and external fixator.

The challenges of internal fixation in young cattle are the thin cortices unsuitable for bone screws, the frequent involvement of the distal metaphysis, and the neonate's increased susceptibility to systemic infection. Nowadays, the implants most frequently used to repair femoral fracture in neonate cattle are intramedullary pins with or without a Type I external fixator, and IIN (modified or regular nail).

The challenges of internal fixation in older cattle are the degree of communition and the weight of the animal, which leads to significant stress on the implants immediately after the repair. Double plating is the technique of choice in heavier animals.

Surgical Approach

Under general anesthesia, the animal is placed in lateral recumbency with the fractured limb uppermost. The limb is clipped from dorsal midline to midtibia and aseptically prepared for surgery. The skin is incised from the greater trochanter to the lateral condyle of the femur. The tensor of facia lata muscle is separated from the biceps femoris muscle, exposing the vastus lateralis of the quadriceps muscle. This muscle is separated from the biceps femoris, exposing the femur. The hematoma is evacuated.

Method of Internal Repair

If bone plates are used, they should be applied dorsally and laterally. Both plates should span the femur, but they should be staggered. The smaller fragments are reattached to the main fragments using cortical screws placed in lag fashion. The fracture is then reduced by elevating the fracture ends out of the incision, aligning the fragments, and folding it back into position. During those manipulations, distal traction might be necessary. The fragments are held together with large bone forceps and cortical screws applied in lag fashion or cerclage wires are placed. The bone forceps are removed, and the plates are positioned and secured to the bone, making sure to compress the fragments whenever possible. In neonates, LCPs should be used if plating is attempted.

If intramedullary pins are used, they may be inserted normograde, from the trochanteric fossa, or retrograde. To decrease the chance of migration, positive profile threaded pins can be used. Using multiple pins improves the stability of the construct and decreases the chance of migration (Figure 15-132). IM pins do well under tension and compression forces, but poorly under rotational forces. Therefore they are frequently combined with a Type I external fixator.

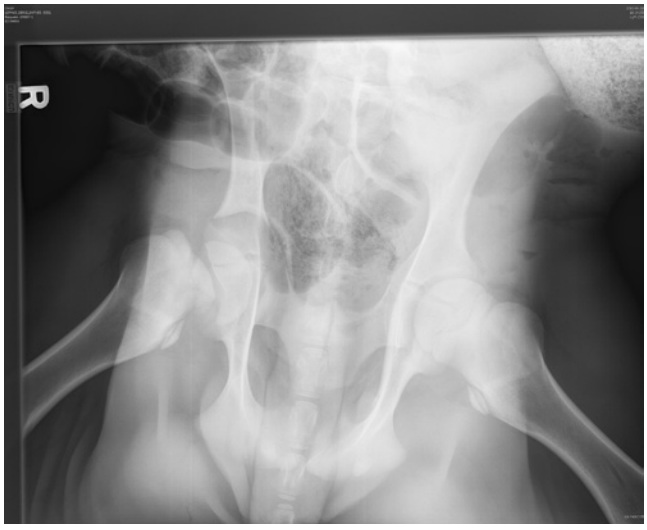


Figure 15-131 Lateral radiograph of a distal physeal femur fracture of a 2-day-old Holstein heifer. Note the severe overriding of the fragment caused by the quadriceps contraction. (Courtesy of Dr. André Desrochers, Université de Montréal.)

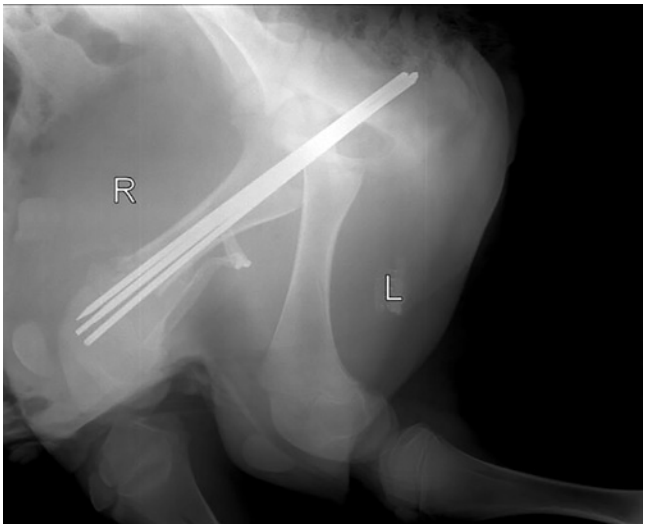


Figure 15-132 Lateral radiograph of a 7-day-old Holstein heifer, following the repair of a distal physeal femur fracture using multiple (stack) intramedualllry smooth pins. (Courtesy of Dr. André Desrochers, Université de Montréal.)

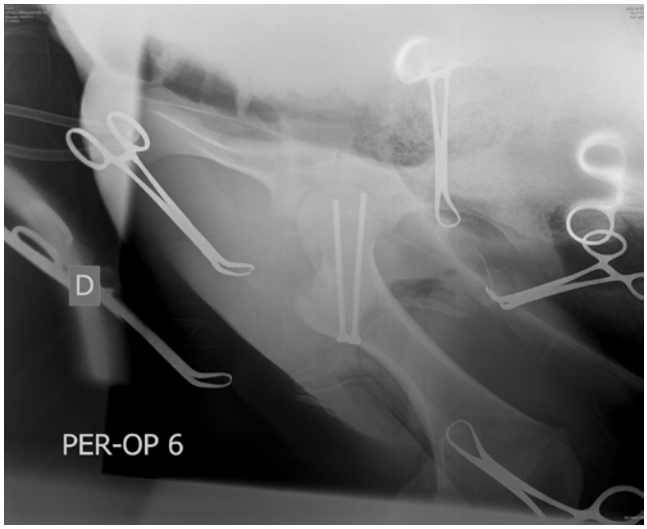


Figure 15-133 Lateral radiograph of a 10-day-old Holstein heifer, 8 days after the repair of a distal physeal femur fracture using cerclage wire and an 8-mm intramedullary interlocking nail. Two proximal screws and one distal screw were used to lock the nail and improve rotational stability. The distal screw will be removed when the fracture is healed. (Courtesy of Dr. André Desrochers, Université de Montréal.)

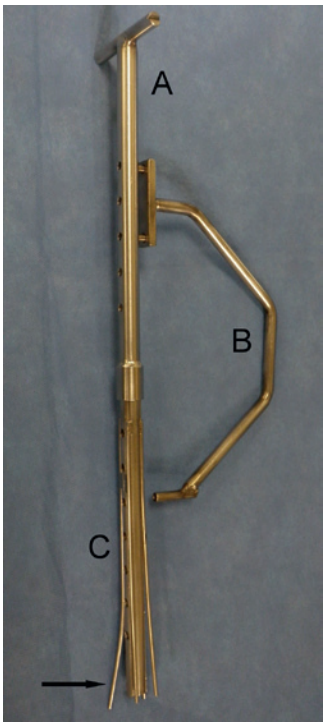


Figure 15-134 Modified intramedullary interlocking nail developed by Dr. Jacques Bellon (Clinique Vétérinaire, Route de Champvert). *A*, Handle attaching to the nail allowing placement of the jig. *B*, Jig allowing insertion of the screws to lock the nail in position. C, Custom-made 302 stainless steel, 190-mm-long, 10-mm-diameter interlocking nail. The nail is grooved dorsally and ventrally to accommodate 4-mm diverging pins (*arrow*).

Distally threaded Steinmann pins with a positive profile are introduced in a lateromedial direction. Two proximal and two distal pins are usually connected to a lateral sidebar. The prognosis for middiaphyseal fracture repair with stack pinning in the neonate is good. However, the prognosis for distal metaphyseal fracture is poor.

When IIN is introduced from the trochanteric fossa into the proximal and distal fragments, the first procedure is to drill an insertion hole into the medullary cavity. Then the hole and the medullary cavity are enlarged with a reaming device to accommodate the nail. With the jig attached to the nail, cortical screws are used to lock the nail in place (Figure 15-133). It can be challenging to place the screws in the small distal fragment of the bone so it is important to make sure that the distal end of the nail does not enter the stifle joint. A large study regarding the prognosis of femur fracture repair with an IIN is lacking. However, the author has had good success with this technique.

An alternative to the regular IIN for the distal metaphyseal fracture is the modified nail developed by Bellon. This nail has four distally located wires that open in the femoral condyle to improve stability (Figure 15-134*A* and *B*). To my knowledge, this nail is not marketed yet. In a recent report, a 60% success rate was achieved in neonatal calves with this nail.

Surgical Site Closure

A four-layer closure is performed. First the quadriceps is sutured back on the gluteobiceps femoris. Then the fascia lata tensor is sutured on the gluteobiceps femoris. The subcutaneous tissues are apposed before the skin is closed. A closed suction drain (multifenestrated Jackson Pratt drain) is placed deep in the tissue to avoid formation of a seroma. A tie-over bandage is placed over the incision and the drain exit.

Postoperative Treatments and Complications

Antibiotics are given for the first 5 days postoperatively or until the drain is removed. NSAIDs are given as needed. The incision is monitored daily and kept under a tie-over bandage for the first week. The stitches are removed 14 days after surgery. The animal is kept in a box stall by itself for the first 8 weeks postoperatively. Exercise is then allowed by letting the animal have access to a small nonslippery paddock for another 8 weeks.

Usually distal femoral fractures require bridging the growth plate to achieve stability. In immature animals, the growth plate has to be released to avoid limb length asymmetry.

Early postoperative complications, after bone plating, are pulling (neonate) and/or fracture (heavier animal) of the implants. After intramedullary stack pinning, distal (within the stifle) or proximal migration causing pain or instability has been reported. Early loss of the external fixator has also been seen. With an IIN, splitting of the distal fragments has been reported. Surgical wound infection leading to osteomyelitis can be diagnosed in the early postoperative period. Persistent swelling and lameness should warrant investigation of the fracture site to evaluate a possible infection.

Long-term complications include nonunion or malunion (usually from infection), deformed fractured limb, and breakdown of the contralateral limb. All complications may lead to persistent lameness.

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FRACTURE OF THE TIBIA

Sylvain Nichols

Clinical Presentation

Tibial fractures are sporadically seen in cattle. They can involve the proximal or distal physis (Salter-Harris), the metaphysis, and more frequently the diaphysis. The latter can have multiple configurations and degrees of communition. They tend to become open on the medial aspect of the bone because of the lack of muscle coverage at this location and the contraction of the lateral musculature, which leads to medial displacement of the fracture ends.

Depending on the fracture type, the location on the bone, the age of the animal, and its value, multiple closed or open reduction techniques have been described in cattle. If a closed reduction is chosen, external coaptation alone or combined with transcortical pins (pin-cast), or a Type II external skeletal fixator can be used. If external coaptation alone is used, a Thomas splint or ideally a Walker splint will be added to a fiberglass cast.

Diaphyseal tibial fractures are difficult to align with closed reduction. Even with traction, the reciprocal apparatus tends to create a craniocaudal displacement of the fragments (Figure 15-135). Depending on the displacement, the bone can eventually heal and remodel. However, to speed up and improve healing, internal reduction and fixation are recommended.



Figure 15-135 Lateral radiograph of a fractured tibia on a 9-month-old Canadienne heifer representing the normal displacement of the proximal and distal fragment because of the reciprocal apparatus. By traction alone, it is difficult to align the fragment.

Surgical Approach

The lack of muscle coverage on the medial aspect of the bone makes this approach tempting to fix a tibial fracture. However, the skin is frequently damaged at this location and, if implants are to be used on the craniomedial aspect of the bone, they will be located under the incision, making this approach less than ideal. Therefore the tibia is usually approached through a craniolateral approach. The animal is placed in lateral recumbency under general anesthesia with the affected limb uppermost. The leg is shaved from the mid femur to the midmetatarsal bones and aseptically prepared. A curvilinear skin incision is created starting craniolaterally to the tibial crest and finishing distally at the lateral malleolus. The caudal branch of the lateral saphenous vein is identified and protected. A plane of dissection is created between the long digital extensor/peroneus longus and the lateral digital extensor muscle. The peroneal nerve and the cranial tibial vein are identified and protected. The group of muscles formed by the peroneus longus, long digital extensor, peroneus tertius, and cranial tibialis are retracted cranially and medially to expose the cranial and lateral aspect of the tibia (Figure 15-136).

From the same skin incision, the craniomedial aspect of the tibia can be reached by creating a plane of dissection medially to the cranialis tibialis muscle. This muscle is then retracted laterally to expose the craniomedial aspect of the bone.

Methods of Internal Repair

The geometry of the bone (hexagonal) makes internal reduction and fixation of tibial fractures difficult. Ideally, diaphyseal tibial fractures, in cattle over 3 months of age, should be reduced using double plating. A lateral plate combined with a craniomedial plate should be used (Figure 15-137). Contouring the craniomedial plate is difficult but can be achieved with plate pliers and a large bending press. When possible, the fragments should be compressed by loading the plate and by placing all the screws, which cross the fracture line, in lag fashion.

In neonates, the thin cortices are not suitable to hold screws. In such cases, an intramedullary interlocking nail can be used. It can be inserted retrograde or normograde through the tibial plateau. The author has also used a combination of internal reduction and external coaptation in younger animals. The fragments are held by a combination of lag screws and/or cerclage wire (Figure 15-138). The animal is then recovered with the leg in a fiberglass cast with a Thomas splint. The implants are used to stabilize the fragments, keeping them properly aligned, which speeds up and improves the healing.

Proximal and distal physeal fractures are very unstable. The proximal fractures are repaired by placing medial plates. At this location, the plate acts as a tension band. T plates or double medial plates have been used successfully (Figure 15-139). The distal physeal fracture does not allow placement of multiple implants in the physis. A hanging limb pin cast combined or not with a transepiphyseal bridge or screws

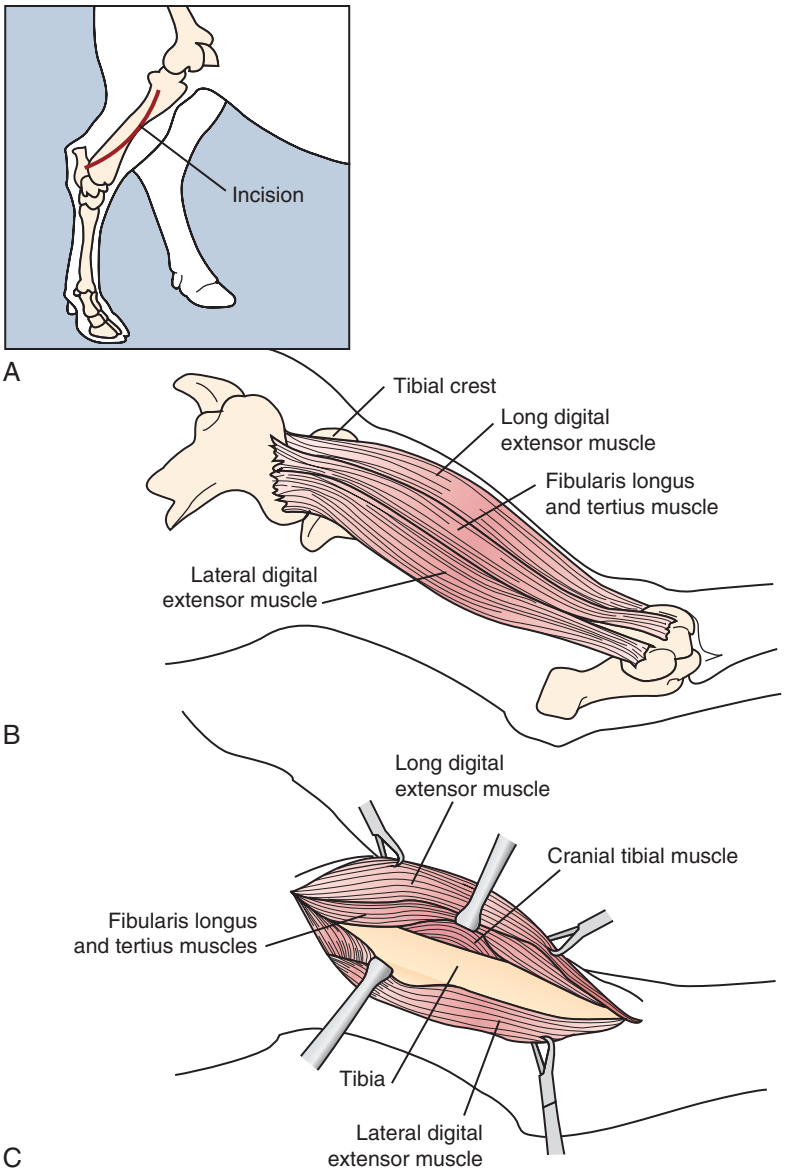


Figure 15-136 Schematic of the lateral approach to the tibia.

has been used successfully to stabilize this type of fracture (Figure 15-140).

Surgical Site Closure

The muscles are sutured back together over the implants. On the medial site, the cranialis tibialis is sutured back to its fascia. A subcutaneous layer is performed before suturing the skin. A closed suction drain can be used. A compressive bandage is placed for the first few days.

Postoperative Treatments and Complications

Antibiotics are given for an extended period of time if internal fixation is used. Tibial fractures seem to be more at risk for postoperative infection than fractures involving other bones. NSAIDs are given as needed. The incision is monitored daily and kept under a compressive bandage for the first 7 days. The stitches are removed 14 days after the surgery. The animal is kept in a box stall by itself for the first 8 weeks postoperatively. Then moderate exercise is allowed for another 8 weeks by letting the animal have access to a small nonslippery paddock.

Early postoperative complications include pulling or fracture of the implants, peroneal nerve paralysis, and surgical wound infection. With the latest, the fracture may still heal, but the implant will eventually need to be removed. Long-term complications include nonunion or malunion (usually from infection), deformed fractured limb (shorter, valgus, or varus), and contralateral limb breakdown.

The prognosis for recovery from a closed tibial fracture is good if internal reduction and fixation are used in lightweight cattle. The prognosis decreases if the fracture is open and if only external coaptation is used. In heavyweight cattle, little information is available regarding fixing this type of fracture.

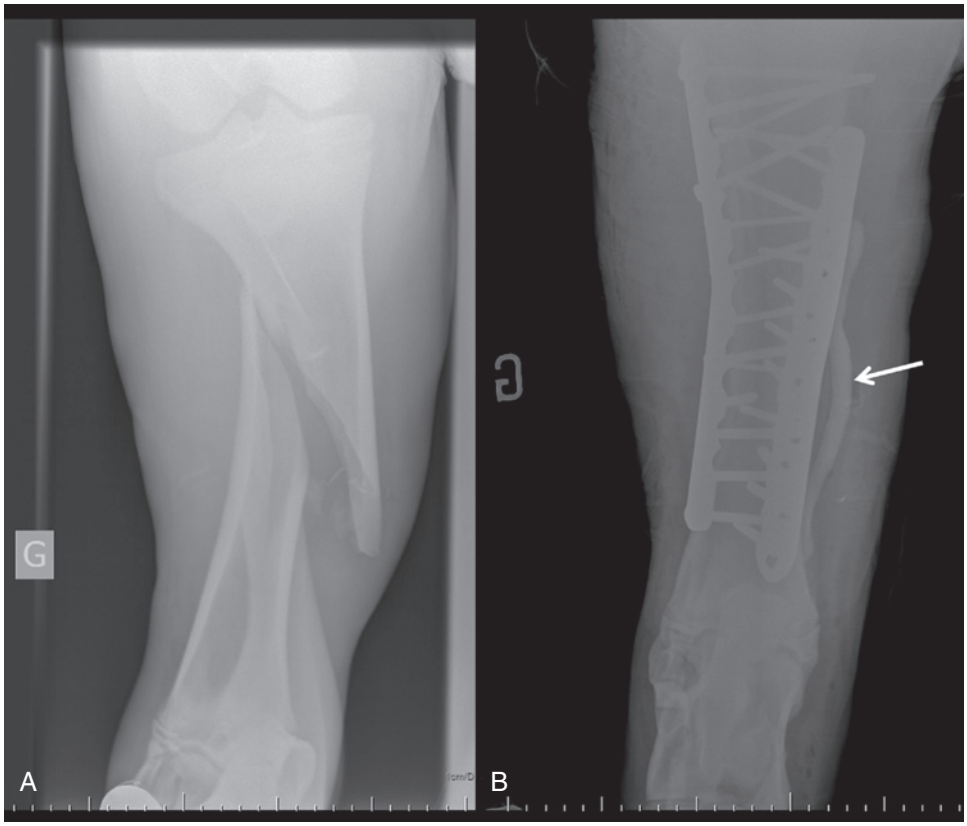


Figure 15-137 Craniocaudal radiographs of a fractured tibia in a 6-month-old Holstein heifer before (*A*) and after (*B*) internal reduction using a lateral and a craniomedial locking compression plate. Polymethylmethacrylate cylinder impregnated with cefazolin was applied along the craniomedial plate (*white arrow*).

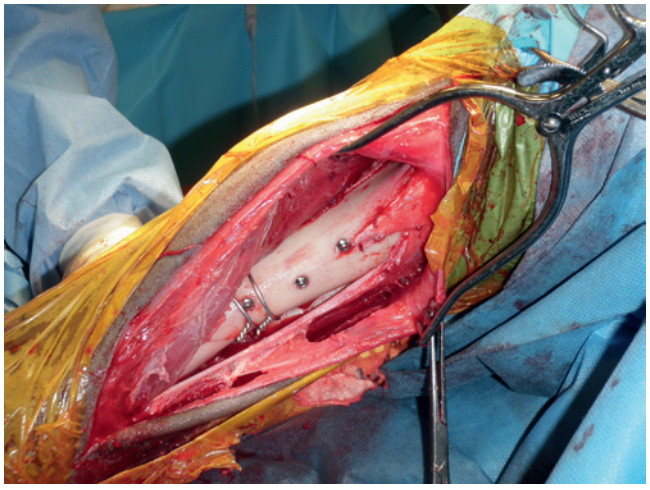


Figure 15-138 Intraoperative view showing reduction and stabilization of a middiaphyseal tibial fracture with two cerclage wires and three lag screws.

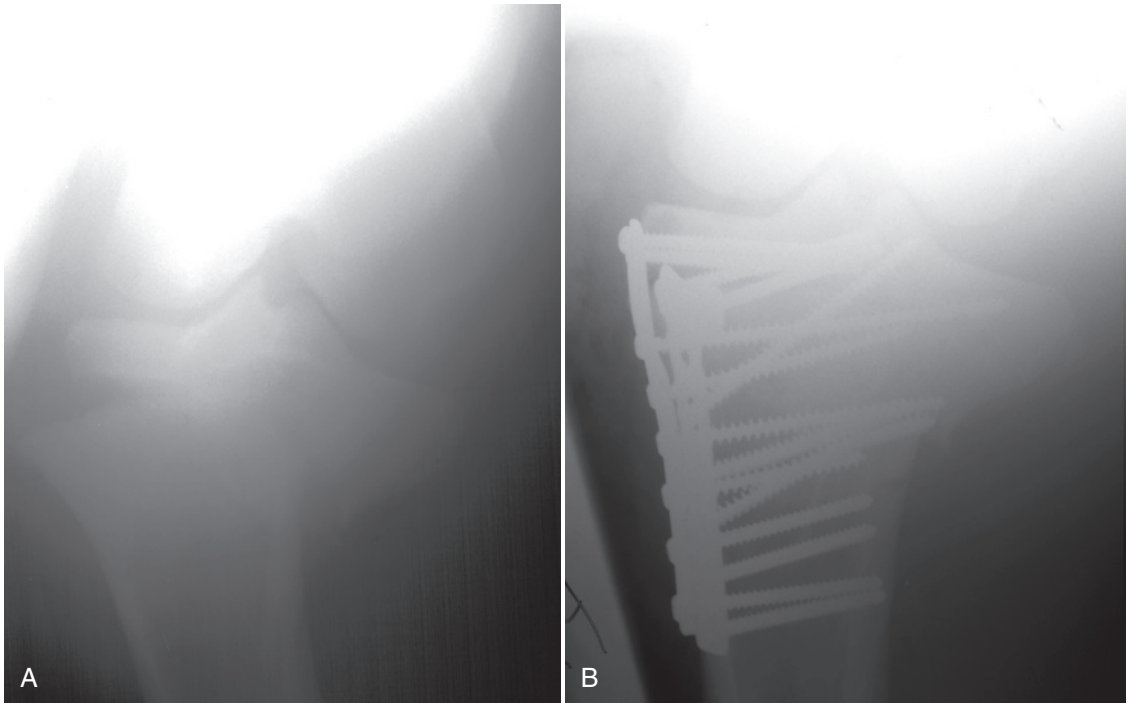


Figure 15-139 *A*, Craniocaudal radiograph of a 16-month-old, 490-kg bull with a Salter-Harris Type II fracture of the proximal tibia. *B*, Previously described fracture repaired with two T-plates placed medially across the physis. (Courtesy of Dr. Ryland Edwards III, University of Wisconsin.)

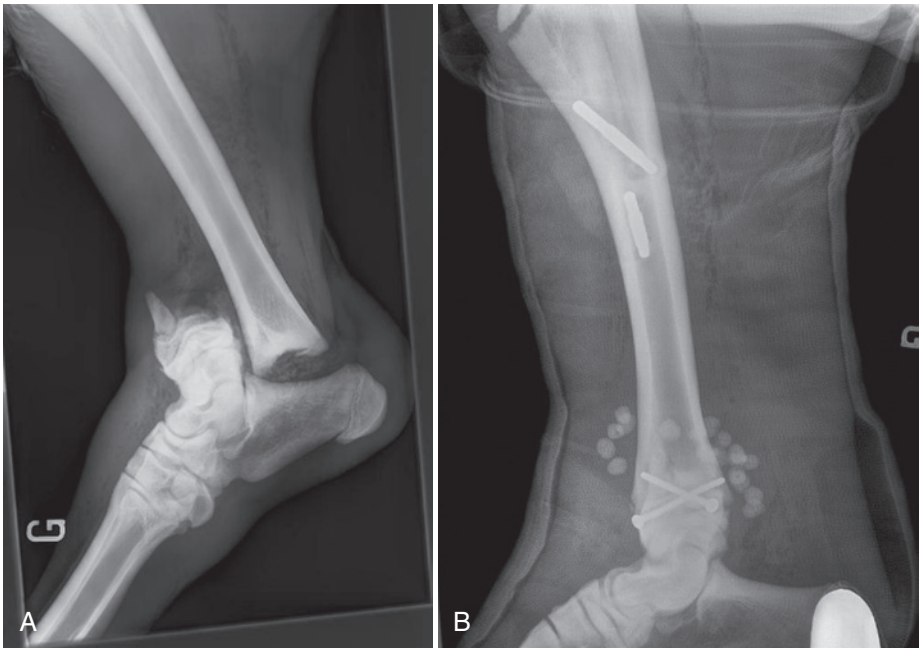


Figure 15-140 Lateral radiograph of an open Salter-Harris Type II fracture of the distal physis of the tibia (*A*) in an 18-month-old camel. The fracture was reduced and stabilized using two transepiphyseal 4.5-mm cortical screws combined with a transfixation pin cast. The round-shape materials around the tibia are polymethylmethacrylate beans impregnated with cefazolin (*B*).

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BONE SEQUESTRUM

André Desrochers

Occurrence and Etiology

A sequestrum is a piece of necrotic bone detached from the healthy tissue, usually secondary to a trauma. Farm animals are more subject to sequestrum due to their contaminated rough environment and lack of soft tissue covering the distal bones. In fact, 66.4% of the sequestrum in cattle are localized on the metacarpal or metatarsal bones.

The proliferation of bone surrounding the sequestrum and the cavity where it sits are called the involucrum. The opening in the new bone is referred to as the *cloaca* (perforation of new bone). The lining of the involucrum is made of granulation tissue and a substance called *glycocalyx*. The glycocalyx is a biofilm made of glycoprotein and polysaccharide produced by bacteria to protect them from phagocytosis and humoral immunity. Finally, the fistula tract from the involucrum to the skin is called the *cloacum*.

There are three common causes to sequestrum formation; most commonly in cattle, a sequestrum is formed following a sharp trauma to the leg exposing the cortical bone and creating an ischemic zone that gets contaminated; a hematogenous septic microthrombus lodges in the cortical bone inducing ischemia; or it is formed from some ischemic bone fragments from a comminuted fracture.

Affected animals are usually moderately lame. The initial complaint is often a chronic wound that is nonresponsive to antibiotics and lavage. Typically, the affected area is swollen and firm with a draining tract (Figure 15-141). Exuberant granulation tissue might be present as well, depending on its chronicity (Figure 15-142).

The definitive diagnosis of a sequestrum is made by radiographic images of the affected limb. Two orthogonal views are essential to determine the exact location and the size of the sequestrum (Figure 15-143*A* and *B*). Additional views are often necessary to precisely evaluate the size and confirm the appropriate surgical approach. The bone proliferation is variable depending on the size, location, and duration of the disease. If the sequestrum edges are not well defined, it is sometimes preferable to repeat the radiographic examination in 2 to 3 weeks before doing the surgery.

Treatment

Medical treatment consisting of systemic antibiotics is rarely efficient. The necrotic bone tissue and the glycocalyx prevent adequate antibiotic diffusion. However, it might contain the infection and control the surrounding soft tissue swelling. Preoperative treatment is indicated if the case is rather acute and the edge of the sequestrum is poorly defined. *T. pyogenes* being commonly isolated, procaine penicillin G is the antibiotic of choice. The surgical procedure is called a *sequestrectomy*. The goal is to remove the sequestrum and debride the cavity to prevent further drainage and promote healing. The owner must be warned that bone deformation might be permanent depending on its location, the volume of new bone formation, and the age of the animal.

Depending on the location of the sequestrum and the size of the animal, the surgery can be done under general anesthesia, high epidural, or brachial block (see Chapter 5). Although the surgical procedure is rather simple, some specific instruments are needed: periosteal elevator, osteotome, orthopedic hammer, bone curette, and rongeur. A rotary burr is a useful tool to debride the involucrum and make the edges smooth.

A C- or S-shaped incision over the sequestrum location will provide better exposure and allow extensive debridement if needed (Figure 15-144*A*). The cloacum or fistula tract is usually at the center of the incision and is resected when closing the skin. The skin is freed from the new bone



Figure 15-141 A mature steer in a feedlot with a chronic fistula tract (*arrow*) at the dorsomedial aspect of the left metatarsi. There is a significant enlargement of the bone diameter.



Figure 15-142 An adult Holstein cow with a sequestrum covered by exuberant granulation tissue.

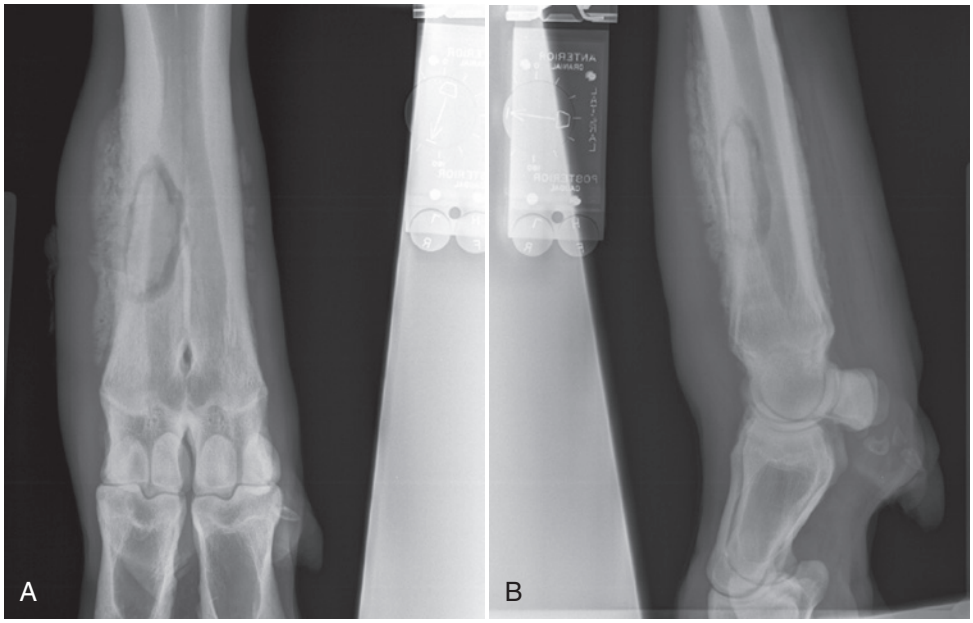


Figure 15-143 Radiographic images of the distal right front limb. *A*, Dorsoplantar view: the sequestrum, the involucrum, and bone proliferation are clearly visible on the third metacarpal bone. *B*, The sequestrum is visible as well but we cannot determine whether it is lateral or medial.

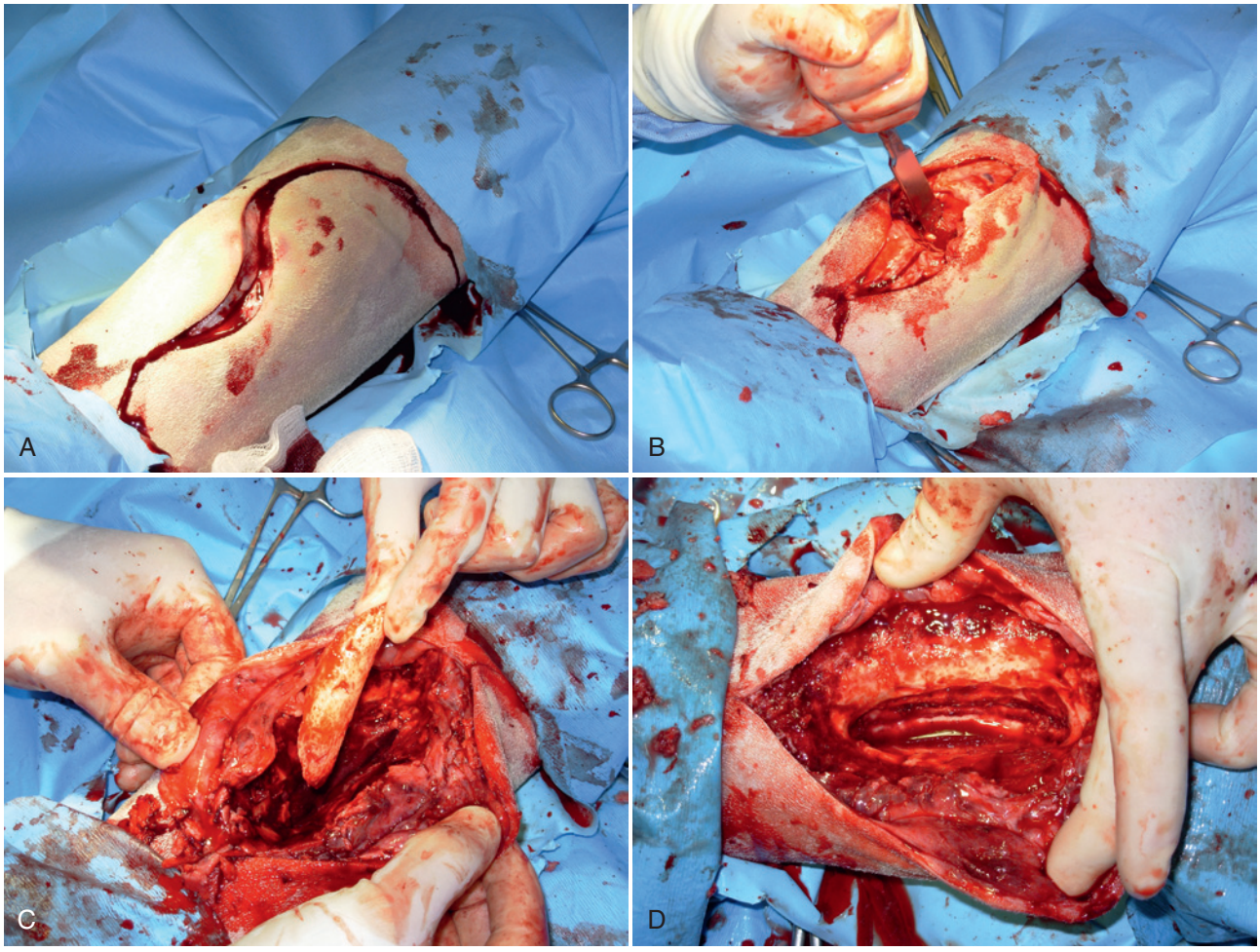


Figure 15-144 Intraoperative view of a sequestrectomy. *A*, S-shaped incision centered on the sequestrum. *B*, An osteotome is used to remove the bone covering the sequestrum; C, The sequestrum is removed from the involucrum. *D*, The involucrum is debrided and the bone edges smoothed.

and the cloacum. The involucrum is invaded starting with the osteotome and progressing along the cavity until the sequestrum is clearly seen (Figure 15-144*B*). The sequestrum can then be gently dislodged from the biofilm (Figure 15-144C). Depending of the size and depth of the cavity, it is possible to split the sequestrum into two pieces so it is easier to remove without extending the bone removal. The biofilm is removed with a curette, the cavity is lavaged thoroughly with saline, and the edges of the remaining involucrum and new bone formation is smoothed (Figure 15-144D). Extensive debridement of the new bone is not necessary and must be avoided to prevent weakening of the bone and subsequent fracture especially with large sequestrum. If the cavity is large and primary closure possible, a fenestrated drain with negative pressure will be kept in place for 48 hours. Primary closure consists simply of skin approximation with simple interrupted or cruciate sutures with nonabsorbable suture material. On rare occasions primary closure cannot be achieved and the surgical wound will be protected with a bandage to avoid secondary contamination.

Postoperative Care

The use of external coaptation is debatable. A fiberglass cast can be applied if debridement was extensive with a large sequestrum on the compression side of the bone. Otherwise a Robert Jones bandage is enough for 10 days after the surgery. Antibiotics are given for 5 to 10 days after the surgery if primary closure could be achieved. The animal must be kept in a stall for 2 months until bone healing is satisfactory. Although radiographic evaluation is advisable for large sequestrectomy, it is unnecessary for small fragments. NSAIDs are given for a few days postoperatively.

Although complications are rare, the most common is surgical site infection and incomplete wound dehiscence. It is left to heal by second intention. Rarely, the bone might fracture and it's usually because the sequestrum removed was very large.

The prognosis is good and the animal should fully return to previous production. Show animals might have deformation that will prevent them from being successful.

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FARRIER HOOF SUPPORT/ MANAGEMENT

Steve Kraus

Occurrence and Etiologies

Hooved animals of different species have similar injuries and diseases. Unlike horses, farm animals have split or cloven hooves. The horny tissue that encapsulates the sensitive and bony structures is similar in composition for cattle, pigs, sheep, and goats. The injuries are similar, as are the diseases that affect hooved farm animals. There are three types of problems that are usually found that require the services of an individual with hoof care experience:

- Penetration injuries of the sole or hoof wall: wounds, abscesses
- Internal diseases or injuries: laminitis, fractures
- Support needs for opposing claws and/or support needs for distorted limbs

The risk factors for developing hoof lesions are

- Lack of regular, proper trimming
- Excessive time for dairy cattle standing in holding areas or on concrete
- Nutritional factors, mineral imbalance
- Postcalving metabolic disorders, such as milk fever or ketosis, in dairy cattle can result in laminitis
- Wet conditions
- Lack of foot baths
- Not recognizing problems early

PENETRATING INJURIES AND ABSCESSES

The sensitive areas of hooved animals are surrounded by the insensitive hoof wall on the sides and insensitive horny sole underneath. In normal conditions the sole and hoof wall provide adequate protection for the internal structures. Excessively wet conditions may weaken the normally resistant hoof wall and sole, making it susceptible to penetration of foreign objects. These objects may be something as small as a piece of grit, a sharp stone, or a stray nail. Although any hooved animal is susceptible to penetration injuries, large sows and boars seem to be particularly susceptible due to their additional weight. Hooves on these animals do not increase in size proportionately to their body mass.

Any penetrating object will carry bacteria into the sensitive hoof areas, which may develop into an abscess often by the infecting organism *Fusobacterium necrophorum* (note: vaccination has not been effective in preventing the incidence of hoof infection in cattle). If the penetration tract stays open, the animal may not appear lame because there is no pressure on internal tissue as pus is able to drain. When the penetration tract closes off, then the pus will develop pressure on tissue, causing lameness. Some hoof problems result from external infections causing dermatitis around the hairline or in between claws. These forms of dermatitis and foot rot can eventually cause structural damage to walls. Any treatment must eliminate the infectious cause.

Management of Penetrating Injuries/Abscess

To treat the problem, one must first locate the penetration tract. Cleaning debris from the sole with a wire brush may be helpful to find the tract. Scrape the suspected area with a hoof knife or loop knife (Figure 15-145). When the tract appears, slowly follow the tract through the horny sole into the sensitive sole. Usually some pus will run out from the tract. Typically a proper draining channel should be 5 to 8 mm. If the animal is restrained or sedated, a small rotary tool like a Dremel brand can be useful to open up the tract. Once the tract is open and debrided, further treatment can be accomplished by soaking the hoof in a solution of betadine and Epsom salt for 15 minutes once or twice a day. An alternative soaking solution consisting of chlorine dioxide[15]

[15]White Lightning, JD Saddlery and sold by Canoga Farrier Supply, Chatsworth, CA, USA.



Figure 15-145 Instruments used for working on hooves: *A*, Large loop knife. *B*, Small loop knife. *C*, Hoof tester. *D*, Thermal scanner.

activated with white vinegar (1 part white vinegar, 5 parts chlorine dioxide, 10 parts water) is also recommended. The cloven hoof is placed in a sturdy bag (i.e., a used 5-L IV bag) containing one of the already mentioned solutions with the neck of the bag taped to the cannon bone or pastern. The debrided area can be treated with iodine solution or a commercial hoof treatment like Thrush Buster.[16] Ideally, after medicating a suitable wrap can be applied. Elasticon or other commercial bandage material is typically used, but gauze wrapped with duct tape can work just as well. Bandage changes should occur every 3 days until the tract is closed. In commercial cattle, bandaging a hoof after debridement has not been effective in improving resolution of foot abscess after debridement.

A hoof block can be glued onto the opposite claw to raise the affected side off the ground.

All glued-on support blocks or plates need proper application to stay in place long enough for healing to occur. These simple steps will insure successful bonding of the appliance (Figure 15-146*A* to C):

- The hoof sole needs to be clean and dry. A small butane torch can be used to completely dry the area to be glued. Just appearing dry is not good enough. Keep the torch flame moving for about 10 to 15 seconds so as to not overheat the foot. Smaller feet take less heat time.
- Small spacers can be applied to the block to ensure that the glue is not squeezed out when putting pressure on the block.
- Using commercial fast-setting hoof adhesives such as Vettec Super Fast®, Bovi Bond®, or Hoof Tight®, apply the glue to the hoof sole and the block. Applying glue to both surfaces insures a good bond.
- These adhesives are a two-part system that mixes with a mixing tip. Once the glue is moving through the mixing tip, you have less than 15 seconds to get the block in place. These adhesives are making their bond at the end of the mixing cycle. The less the block is moved or the glue is manipulated, the better the bond. Setup time is 30 seconds at room temperature.
- Hold the block firmly in place until you feel the glue warming up.

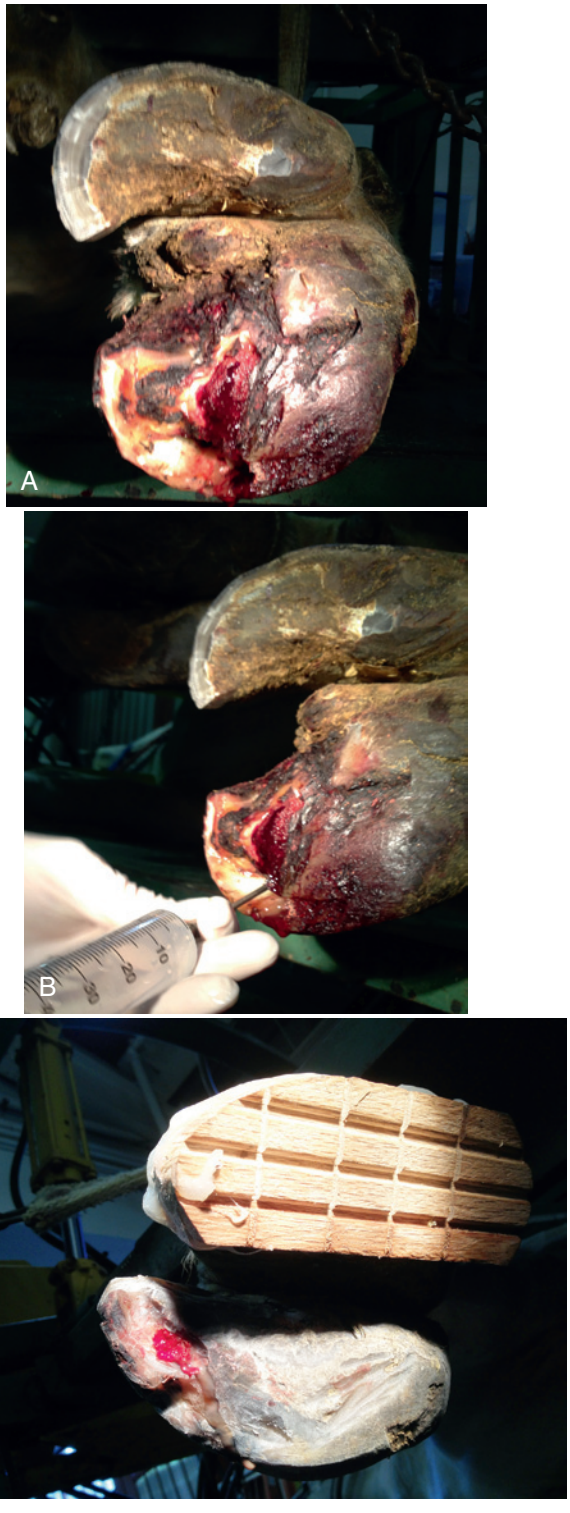


Figure 15-146 Cow with sequestrum in the lateral claw of the left hind limb. *A*, The medial claw has been trimmed to receive a block. *B*, The area is being flushed. C, A block has been applied on the medial claw.

[16]Thrush Buster, Delta Mustad Hoofcare, Forest Lake, MN, USA.



Figure 15-147 Yearling heifer unable to stand for the first 7 months of her life because of bilateral carpal flexural deformity. A pancarpal arthrodesis has been performed but excessive toe extension is observed. *A*, An aluminum plate has been cut to fit both claws with a heel extension. Holes in the plate allow "self-riveting" with the adhesive. *B*, A brace has been secured to the shoe with a bolt. This will be secured to the limb (in this case a bandage cast) with adhesive tape (C) to allow a stronger support for the hoof despite weak flexor tendons.

- A second application of adhesive around the edge of the block that goes up the hoof wall ½ inch to ¾ inch will give more support to the block.
- Colder weather takes more time for complete setup. Warmer weather speeds things up. Keeping adhesive cartridges cool in hot weather extends setup time or warming them in cold weather will shorten setup time.

INTERNAL DISEASES AND INJURIES

Laminitis is thought of as a disease of equines, but any hooved animal can suffer from an inflammation of the laminae. Loss of blood supply to the laminae will create issues such as abscesses, hoof wall distortion, and coffin bone displacement. These problems will cause lameness, resulting in loss of appetite and unwillingness to move about.

Aggressive trimming of the dorsal hoof wall to control hoof distortion will also relieve the abscesses that may occur.

Laminitis often occurs on one side of the foot, so a hoof block can be glued on the opposite claw to take the pressure off the affected side.

Fractures of the coffin bone will usually cause a sequestrum and must be removed. Opening up the horny sole is usually done to remove the bone fragment. After the fragment is removed, the wound area should be treated just like the debrided abscess discussed previously. A hoof block should be applied to the opposite claw.

SUPPORT NEEDS (SEE ALSO THE SECTION ON ORTHOTICS AND SPLINTS)

Conformational and structural issues due to injuries or disuse can create strain on joints, tendons, and ligaments. For example, excessive base narrow conformation can be helped with a glued-on hoof block set with lateral support. Also hooves that are excessively run down on their heels can be strengthened with caudal support using a glue-on shoe with a heel extension. The aforementioned concepts are incorporated in a heifer with very weak flexor tendons such that the fetlock is dropped and the toe is lifted off the ground. A shoe with a heel extension is glued on both claws (Figure 15-147*A*) and its action reinforced using a brace (Figure 15-147*B*). This results in good hoof support (Figure 15-147*C*).

RECOMMENDED READINGS

Checkley SL, Janzen ED, Campbell JR, et al: Efficacy of vaccination against *Fusobacterium necrophorum* infection for control of liver abscesses and footrot in feedlot cattle in western Canada, *Can Vet J* 46:1002–1007, 2005.

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CONSIDERATIONS FOR THE USE OF ORTHOTICS, PROSTHETICS, AND SPLINTS

Jacqueline A. Hill, Steve Kraus, and Norm G. Ducharme

Orthotics, splints, and prostheses are used to support animals before and/or after orthopedic surgical treatments or as an alternative to surgery. Gross deformities of the leg can be helped with a combination of surgical procedures and leg supports or splints. Splints are used temporarily to support a deformity or a fracture, and therefore precise fitting is less important because the splint is placed over a bulky bandage. Orthotics are indicated when long-term or lifetime support is needed. With long-term use, a more precise custom fit is crucial to the comfort of the animal and the prevention of pressure sores on the affected limbs. Limb prostheses are rarely used in adult cattle, and we have more experience with their applications in small ruminants.

Splints

Polyvinyl chloride pipe cut in half and tailored to the appropriate length of the animal is most commonly used to support a limb, especially for emergency stabilization of a fracture or postoperatively to help manage a flexural deformity. To enhance the customization or fitting of the splint, a bandage cast (bulky cotton wrap bandage with cast material applied over it to enhance support) can be made. The bandage cast is then bivalved so that either or both halves can be used as a splint.

To add stronger support, the farrier can bend and weld metal bar and pipe to broadly configure it to fit an animal's size and limb conformation (see Figures 15-99 and 15-100). A higher level of custom fitting can be fabricated from aluminum (which is preferable to other metals because of its lighter weight) (Figure 15-148*A* and *B*). The farrier has been helpful in cases in which the splint needs to be modified by decreasing the degree and location of the support as the animal's condition improves.

Orthotics and Prosthesis

An orthotic is an external device (i.e., custom-made splint or brace) that supports an area (or multiple areas) in the limb. We have used these devices in farm animals from rescue organizations and for pet animals. Orthotics offers an alternative to manage animals with multiple limb deformities (Figure 15-149*A* and *B*) that require bilateral surgery that would be difficult to recommend because of the risk of causing a downer animal. We have also used orthotics to

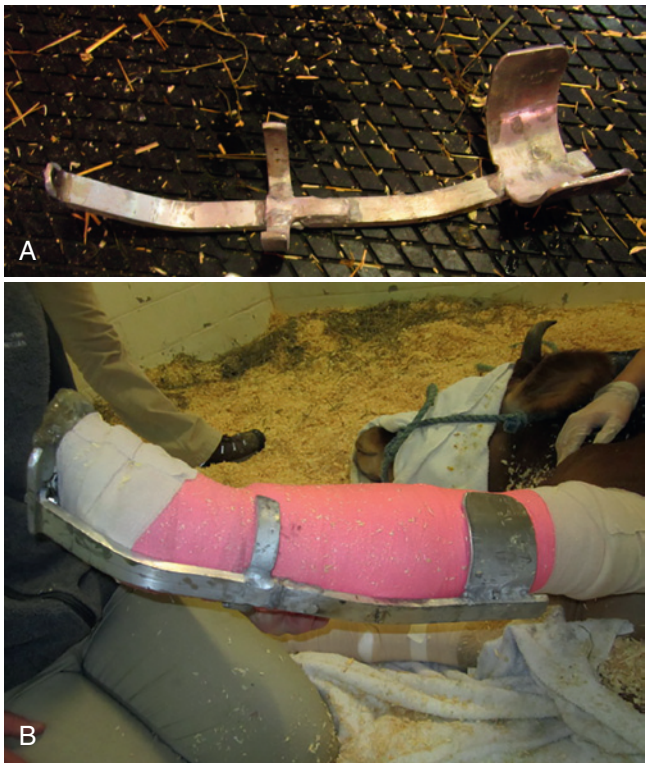


Figure 15-148 A heifer with weak flexor tendon requiring palmar support. A custom-fitted aluminum splint with horizontally welded half ring (*A*) to fit the animal bandage used (*B*). This splint has been modified to be secured to a glue-on shoe using a bolt.

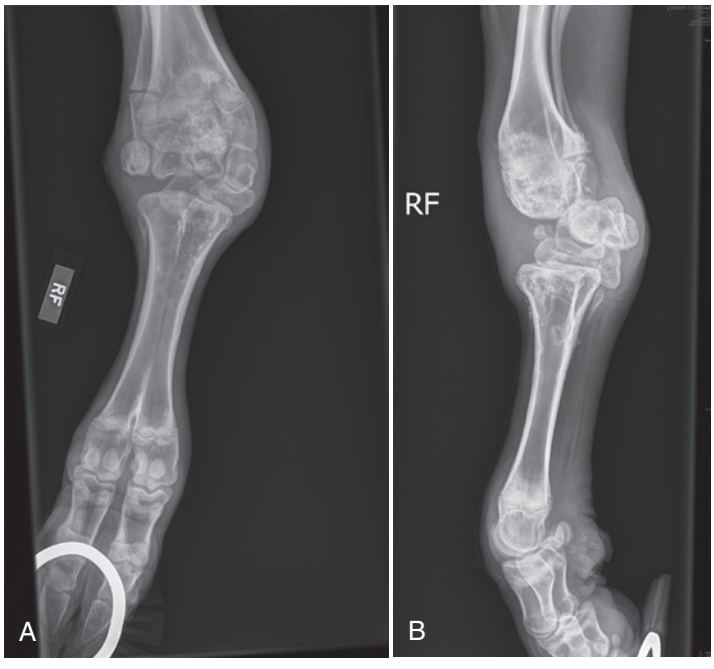


Figure 15-149 Dorsopalmar (*A*) and lateral (*B*) radiographs of a calf born with congenital malformation of the carpal bone. Note the lateral and caudal displacement of the carpal bone.

preserve some degree of motion in a joint that cannot be achieved with a splint (Figure 15-150*A* to *D*).

To develop a properly fit orthotic one must work with a professional orthotist/prosthetist, preferably one familiar with the stress and forces that must be supported in large animals. The first step in creating a proper custom-fitted support is to develop a cast so that a proper mold of the leg can be created. It is preferable that the orthotist make the casting for building the mold. Because of the paucity of orthotists with animal experience it may be that the veterinarian makes the cast to ship to the orthotist and he or she builds the mold to construct the orthotic. Ideally the orthotist can visit the animal for the fitting after construction. If so, here are the general guidelines for that process of getting a well-fitting orthotic.

Casting and Measurements

The orthotist need to know the therapeutic goals (i.e., what and where the support is needed) and what expected adjustments in pressure or animal growth would be needed. Then a cast of the leg is required to make the mold, and the orthotist also needs several limb measurements. The following are guidelines for fitting an animal for an orthotic or brace, but the orthotist should always be consulted beforehand to see if any additional measurements/requirements/radiographs are needed.



Figure 15-150 An orthotic for the bull calf in Figure 15-149. *A*, A lateral view showing a hinge to allow some degree of flexion at the carpus, with lateral support to manage the carpus valgus. *B*, Dorsal view. C, Palmar view. *D*, Bull calf with an orthotic. The device gives lateral support to the carpus but allows the preservation of some movement in the joint. (C, Courtesy of Ronnie N. Graves, VIP Veterinary Inclusive Prosthetics/Orthotics, Prosthetics Research Specialists, Inc.)

To start, measurements should be taken with the animal standing and weight bearing on the limb if possible. For the hind limb, measure the distance from the ground to the proximal aspect of the calcaneus, the ground to the plantar aspect of the fetlock joint, and the ground to the center of the tibiotarsal joint along the dorsal surface of the leg (Figure 15-151*A*). For the forelimb, the distance from the ground to the fetlock joint and the ground to the center of the carpus should be recorded (Figure 15-151*B*).

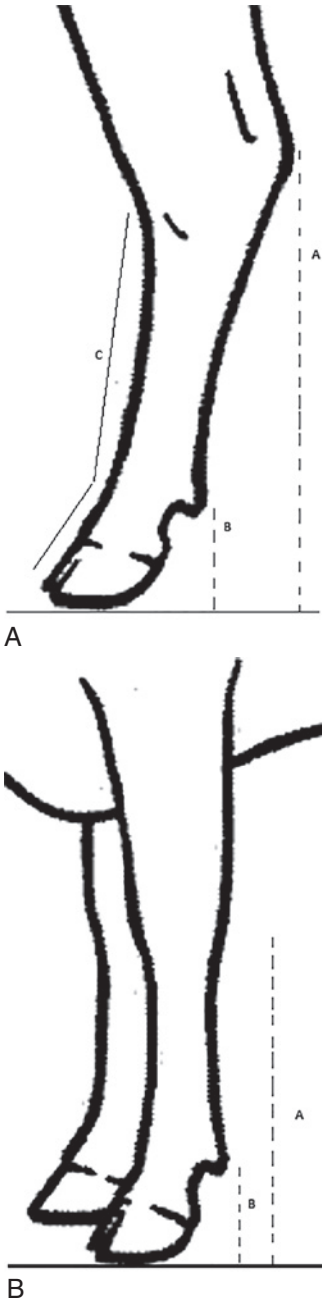


Figure 15-151 Measurements needed for a hind-limb and forelimb brace. The distance from the ground to the proximal aspect of the calcaneus or center of the carpus (*A*), the ground to the palmar/plantar aspect of the fetlock joint (*B*), and in hind limbs the distance from the ground to the center of the tibiotarsal joint along the dorsal surface should be recorded.

To make a mold of the animal's leg, the animal will need to be in lateral recumbency with the leg to be casted up. The animal can either be sedated and restrained or anesthetized. If sedation is used, it is important that the animal be sufficiently sedated to allow manipulation of the leg and that the leg remains still during the cast application. With the leg in a remain position, circumferential measurements of the limb are made at 2-cm intervals, starting distally at the coronary band and extending proximally to above the tarsus or carpus for lower limb braces or to the stifle or elbow for full-limb braces. A hand-drawn sketch or a printed lateral photograph of the leg is helpful to facilitate recording these measurements (Figure 15-152).

To cast the leg, a single strand of Gigli or obstetric wire should be placed along the dorsal midline of the limb, with approximately 8 inches of extra wire at the top and bottom. The wire should be held in place on the limb with white tape. Alternatively, the cast can be cut with appropriate scissors, and the wire is not needed. A single layer of cotton stockinette is placed over the wire and along the length of the leg. The smallest diameter stockinette that will fit around the leg should be used to create the most accurate mold of the leg. No additional cast padding or felt should be applied to the limb. While an assistant holds the limb in the desired position, 3-inch rolled fiberglass cast material is applied to the limb, overlapping by 50% each time to create a two-layer cast. The casting material should go to the level of the elbow/stifle for full-limb braces and to just proximal to the tarsus/carpus for half-limb braces. The entire hoof should also be incorporated into the cast. Additional casting material should not be added as the thinnest cast possible is needed to make the brace. The casting material is allowed to set until it is firm, then cut. If a cutting wire was incorporated, the top and bottom of the stockinette and first 1 cm of cast material are cut over the underlying wire with scissors to create a track for the wire and to stop bunching of the cast when starting to cut. The



Figure 15-152 Example of a photograph of a patient's right hind limb that was printed and used to record measurements taken during fitting.



Figure 15-153 *A*, Mold of a 14-month-old Jersey heifer with bilateral deformity. *B* and *C*, the right-limb flexural deformity needed at first a knee pad protection after pan-carpal arthrodesis on the contralateral limb. Eventually bilateral orthotics were needed (*D*). (Courtesy of Ronnie N. Graves, VIP Veterinary Inclusive Prosthetics/Orthotics, Prosthetics Research Specialists, Inc. and Woodstock Farm Sanctuary.)

wire is used to remove the cast by attaching each end of the wire to a handle and, using a sawing motion, creating a single cut down the dorsal midline of the cast. The cast is removed from the leg, taped back together, and then allowed to fully harden. If tape is insufficient to maintain the shape of the cast, a second roll of 3-inch fiberglass casting tape can be applied to the cast after it has been removed from the animal's leg. Once the cast is dry, the lateral side and the center of the fetlock and tarsal/carpal joints should be marked on the cast with a permanent marker. The mold and measurements are then shipped to the brace manufacturer.

The measurements and the cast are sent to the orthotist, and he or she makes a mold (Figure 15-153*A*) in preparation for the construction of the proper orthotic. This may range from a simple custom-fitted knee protector (Figure 15-153*B* and *C*) to the more completed orthotics (Figure 15-153*D*). The prosthesis is then fitted to the animal. In growing animals, the orthotist may be able to make the prosthesis a little larger and have it fit in an acceptable manner by using multiple layers of stockinette (i.e., socks) underneath it. As



Figure 15-154 A pressure point was noted on the lateral aspect of an orthotic on a bull calf (*red circle*).



Figure 15-155 A pressure point was noted on the proximal medial aspect of an orthotic on a cow (*red circle*).

the animal grows, the socks are removed to ensure proper or acceptable fit.

One should be aware that adjustments may be needed as areas of pressure may develop or be recognized over months of use (Figures 15-154 and 15-155). Those are generally easy to adjust by the orthotist but require good vigilance with the caretaker and veterinarian to recognize possible problem areas.

The same mold may be used for a prosthesis. We have used those in smaller farm animals and have no experience with their use in adult cattle (Figure 15-156*A* and *B*).

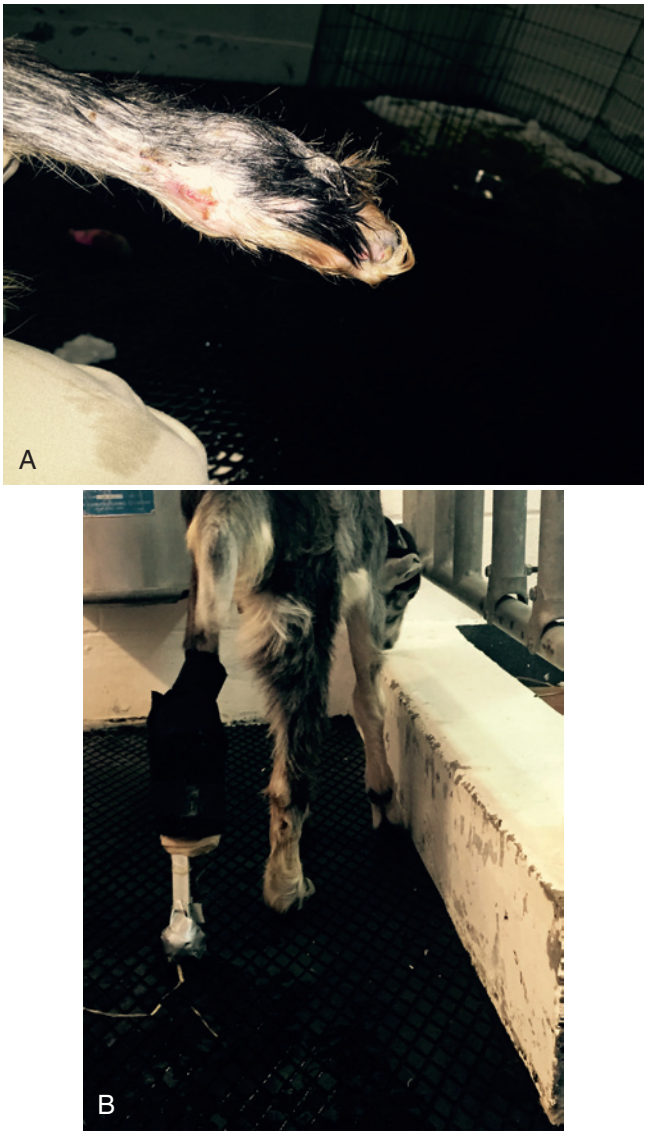


Figure 15-156 A goat that needed a limb amputation in the proximal metatarsal area (*A*). *B*, The prosthesis allowed the goat to ambulate. Heel extension was also needed on the contralateral limb to support the limb.

CHAPTER 16

Surgery of the Bovine Reproductive System and Urinary Tract

Robert O. Gilbert, Christina Cable, Susan L. Fubini and Adrian Steiner

SURGERY OF THE MALE REPRODUCTIVE TRACT

Robert O. Gilbert and Susan L. Fubini

APPLIED ANATOMY AND EXAMINATION OF THE REPRODUCTIVE TRACT

The paired testes of ruminants hang vertically in the scrotum with the caput epididymidis dorsally. They are slightly flattened laterally. Testicular blood supply is via the testicular artery, a branch of the abdominal aorta. Testicular lymph drainage is to the medial iliac lymph nodes and reflects the embryonic origin of the testes caudal to the kidneys. Autonomic innervation of the testes is via the renal and caudal mesenteric plexuses.

The testis is enclosed within two layers of the tunica vaginalis. The inner layer (visceral) is closely applied to the tunica albuginea of the testis. A potential space separates it from the outer (parietal) layer; this space is continuous with the peritoneal space of the abdomen, through the inguinal canal. The sulcus formed by the fold of visceral to parietal layers of tunica vaginalis is occupied by the ductus deferens if approached from the cranial aspect and is attached to the testis along the line of the epididymis if approached from the caudal side. This architecture can be exploited to make midscrotal vasectomy a simple procedure (described later in the chapter).

The testicular artery courses toward the deep inguinal ring of the inguinal canal, where it joins the spermatic cord. The latter structure consists of the testicular artery and vein, the lymphatics, the nerves, and the ductus deferens. Together they pass through the inguinal canal. The testicular artery, once external to the abdomen, becomes extremely tortuous. In this area it is in close apposition to the dilated and contorted veins. This complex is known as the *pampiniform plexus*. It serves multiple purposes. The multiple contortions of the artery help blunt the pulsatility of arterial blood flow. (The fibrous outer surface of the testis, the tunica albuginea, is unyielding and extremely sensitive to distention, which means that arterial pulsatility within the testis would be most uncomfortable.) In addition, arterial blood is cooled by exposure to the effluent venous blood and countercurrent exchange of steroids, especially testosterone, which is produced in the testis and is necessary in high concentrations locally for optimal testicular function. Testicular arterial blood is therefore cooler, is fortified with testicular steroids, and flows with diminished pulsatility.

The testicular artery courses on the surface of the testis in a large S pattern before entering the parenchyma. The surface of the testis is richly supplied with blood vessels. These are sparsest on the craniolateral surface of the testis, in its upper (dorsal) half. This is of practical significance, because this is the optimal site of testicular biopsy (a procedure with a high risk of complications, including hemorrhage and subsequent infarction).

The cremaster muscle is a slip of the internal abdominal oblique muscle. It contributes to testicular thermoregulation by raising and lowering the testis, and this maneuver also functions as a protection mechanism.

The products of spermatogenesis leave the seminiferous tubules (spermatogenic tubules) via tubuli recti into the rete testis. The latter is located in the mediastinum testis, a structure that runs from the proximal to the distal extremity of the testis, and is visible on ultrasonography. Via a number of efferent ductules the newly produced sperm make their way to the epididymal duct at the head of the epididymis. The epididymal duct is a single duct, and multiple connections (efferent ductules) are made to it in the caput epididymidis. It is not unusual for one or more of these connecting ducts to end blindly and leave a palpable pealike nodule in the head of the epididymis. If a large number end blindly, they may become large enough to obstruct normal neighboring ducts. Escape of sperm from these ducts provokes a granulomatous reaction to the foreign material, and further functional blockage may occur. Eventually, the granuloma formation may be sufficient to cause total functional occlusion and render one (or even both) testicular-epididymal unit inoperative. This is occasionally seen in bulls or rams. It is the mechanism of infertility associated with polled goat bucks.

The epididymis is closely applied to the body of the testis. It runs along the caudomedial surface of the testis and ends in the prominent tail (cauda epididymidis). The degree of filling of the epididymal tail is a good indicator of the status of spermatogenesis and an indicator that no blockage of the epididymis exists. The ductus deferens runs medial to the epididymis of its side, enclosed in its own fold of tunica vaginalis, the mesoductus deferens.

The testes and epididymides should be turgid without being hard. Their surfaces should be smooth, and they should be freely moveable within the scrotum.

The ductus deferens enters the inguinal canal, then courses retroperitoneally, medial to the ureters and dorsal to the bladder, where its terminal 10 cm is thickened to form the ampulla of the ductus deferens before it enters the urethra. This thickening is caused by glands in the wall of the deferent duct, not dilation of the lumen as the name might indicate. The paired ampullae (left and right) are contained within a fold of peritoneum, the plica genitalis, or genital fold. An embryonic remnant, the uterus masculinus, may sometimes be found between the two ampullae.

The scrotal skin is thin, and hair or wool is usually sparse on the scrotum. It is richly endowed with glands. These modifications enhance the thermoregulatory capacity of the scrotum but also make it exquisitely sensitive to insult. Scrotal dermatitis profoundly affects scrotal temperature and spermatogenesis. The tunica dartos is a layer of fibroelastic tissue and smooth muscle that by contracting thickens the scrotal skin and raises the testes closer to the body and by relaxing lowers the testes and allows the scrotal skin to

become thinner. In this way it contributes to thermoregulation. The scrotum (in contrast to the testes) receives its blood supply from the external pudendal artery, and its lymphatic drainage is to the superficial inguinal lymph node. The innervation of the scrotum is via the genital branch of the genitofemoral nerve, which arises from the second through fourth lumbar roots.

The vesicular glands lie immediately lateral to the ampullae, dorsal to the neck of the bladder. The vesicular glands and ampullae open into the urethra dorsally near the neck of the bladder, on either side of the colliculus seminalis. Four separate openings are present. Very close to the terminations of the ampullae and vesicular glands and closely applied to the urethra is the body of the prostate gland, which encircles the urethra near the bladder neck. The ampullae actually pass through the parenchyma of the prostate to reach the urethral lumen and open into the urethra via multiple small ducts. In the bull there is also a disseminate part of the prostate gland that is not palpable within the wall of the urethra.

The pelvic portion of the urethra and its surrounding thin layer of spongy tissue are covered by the urethralis muscle. At the ischial arch the spongy tissue enlarges to form the bulb of the penis and then continues along the penile urethra as the corpus spongiosum. As the urethra passes over the ischial arch, it runs between the crura of the penis. The penile crura become fused and continue as the corpus cavernosum penis. In ruminants, the corpus spongiosum and corpus cavernosum do not communicate. The ischiocavernosus muscles cover the crura of the penis, and the bulbospongiosus muscle covers the penile bulb. Both muscles are important in the mechanism of penile erection. Partially covered by the bulbospongiosus muscle are the paired bulbourethral glands. The bulb and the crura of the penis and their covering muscles constitute the root of the penis.

The accessory sex glands are palpable per rectum in bulls. The bulbourethral glands can be felt as smooth structures that protrude from under the cranial edge of the bulbospongiosus muscles. The pelvic urethra, surrounded by the urethralis muscle, is prominent in the midline of the pelvic floor. If any doubt exists, the urethralis muscle can be identified by massaging it per rectum; it will respond by contracting rhythmically. As the urethralis muscle is traced forward, a transverse ridge can be felt at its cranial-most end. This is the body of the prostate. Converging on this point, the fairly soft, pliable ampullae can be felt. The ampullae move as a pair within the genital fold and are separated by less than half an inch. They may be displaced to one or the other side by a full bladder. Also converging toward the body of the prostate are the vesicular glands. These lobulated structures project craniolaterally. In young animals they are smaller and softer than in mature bulls.

In rams, the bulbourethral glands are larger and may be palpated by inserting a finger into the rectum. Wethers that graze estrogenic pastures may develop cystic metaplasia of the bulbourethral glands, in which case they may protrude conspicuously as swellings of the perineal area.

The urethral lumen is small, despite the deceptively large diameter of the urethralis muscle. As the urethra turns over the ischial arch there is a dorsal diverticulum formed by a shelf of mucosa. This diverticulum makes urethral catheterization of the bladder virtually impossible, as the leading tip of the catheter invariably finds the diverticulum.

The ischiocavernosus and bulbospongiosus muscles do not extend beyond the fusion of the crura of the penis. The penis is readily palpated through the skin of the perineum. It extends cranially, then turns ventrally and caudally in the first loop of the sigmoid flexure, and turns cranially again ventral to the penile root. This distal loop of the sigmoid flexure is also palpable through the perineal skin. Also palpable at this point are the paired retractor penis muscles. They arise from the first two or three coccygeal vertebrae, decussate around the anus, and then pass superficially through the perineal region to attach ventrally to the penis just beyond the distal loop of the sigmoid flexure.

In the resting bull, the tip of the penis lies at a level just cranial to the scrotal neck. The skin of the prepuce (lamina externa) is reflected at the preputial orifice to form the lining (lamina interna) of the preputial cavity. The lamina interna of the prepuce is attached to the penis about 12 cm from the tip of the penis. This integument (it has no glands and is not mucosa) is supported by several layers of loose connective and elastic tissue that allow extension of the penis, during which process the lamina interna comes to lie along the body of the extended penis.

In cross section, the penis consists of the ventral urethra (dorsal in the middle of the sigmoid flexure) surrounded by the corpus spongiosum and the larger corpus cavernosum (the fusion of the crura of the penis). The corpus cavernosum is encased in a thick, dense, and inelastic tunica albuginea. The corpus cavernosum is supplied by the deep artery of the penis and is drained by the analogous vein. The artery of the bulb of the penis supplies the corpus spongiosum. The dorsal artery of the penis supplies the superficial structures of the penis. The deep artery of the penis, the artery of the bulb, and the dorsal artery of the penis are terminal branches of the internal pudendal artery.

The penis of mature bulls is about 120 cm in length, with some breed variation, and extends 30 to 50 cm from the prepuce when erect. Near the free end of the penis is a dorsally located thickened fibrous band termed the *apical ligament*. This ligament helps hold the penis straight for intromission. At ejaculation it slips to the side and causes a spiral deviation of the tip of the penis. In some bulls, the ligament slips prematurely and the spiral deviation arises before intromission, making intromission impossible. The penis of the ram and buck is characterized by a urethral process that extends 4 to 5 cm beyond the glans penis.

The pudendal nerve arises from ventral branches of the second through fourth sacral spinal nerves. Its branches provide motor supply to the retractor penis muscle and, via the dorsal nerve of the penis, sensory innervation of the penis. Penile sensation is important for normal function. Afferent impulses from the glans penis, conducted by the dorsal penile nerve, are essential for ejaculation. Bulls that have lost penile sensation are unable to serve and ejaculate, even if an artificial vagina is used. Care must be taken during surgical procedures to avoid damage to the dorsal nerve of the penis. Fortunately, the nerve divides into plentiful terminal branches near the free end of the penis, and the risk of damage to the entire nerve in this area is small.

Blocking the pudendal nerve achieves relaxation and desensitization of the penis and allows surgical procedures on the penis of the standing, restrained bull, provided the animal's temperament permits. The pudendal nerve can be palpated per rectum. The internal pudendal artery serves as a landmark. It is readily palpable (per rectum) as it courses along the medial surface of the sacrosciatic ligament just dorsal to the ischiatic arch. If the artery is followed caudally, the lesser ischiatic foramen can be identified at the point where the artery divides. The pudendal nerve can be felt about 1 cm dorsal to the artery at the cranial edge of the lesser ischiatic foramen. It is convenient to block the nerve at the foramen, remembering that it receives a branch from the caudal cutaneous femoral nerve at that point. The caudal cutaneous femoral nerve runs laterally to the sacrosciatic

ligament. To administer a pudendal nerve block, the rectum is evacuated and the skin of the ischiorectal fossa disinfected. A bleb of local anesthetic agent (e.g., 2% lidocaine) is injected under the skin at the notch between the tailfold and the caudal extent of the sacrosciatic ligament, and a 15-cm, 18-gauge needle is inserted. The needle is guided toward the lesser ischiatic foramen with a hand in the rectum. The left hand is used to guide the needle for injection of the right nerve and vice versa. The authors prefer to inject about 10 to 12 mL at the site of the foramen, near the palpable pudendal nerve and then divert the needle through the foramen to inject about 5 mL on the lateral side of the ligament, thus ensuring that the caudal cutaneous femoral branch is blocked. As the needle is withdrawn, the remaining 3 to 5 mL is injected slowly, in the hope of blocking the caudal rectal nerve. This nerve, although large, is not readily palpable per rectum because it moves with the rectal wall. It provides some innervation to the proximal fibers of the retractor penis muscle. Both pudendal nerves need to be blocked to produce relaxation of the retractor penis muscles and analgesia of the penis. The penis may prolapse out of the prepuce spontaneously after this procedure, but more commonly it is retained within the prepuce by passive mechanisms (loose connective and elastic tissue surrounding the prepuce), and it needs to be extended manually.

The flaccid and insensitive penis should be extended fully by grasping the free end of the penis with a gauze swab. Forceps may be used to secure the penis, with care taken not to penetrate the tunica albuginea. Penetrating towel clamps may be secured to the apical ligament without injury to the penis.

The length of the fully extended penis should be measured from the natural position of the preputial ostium to the tip of the extended penis. For adult bulls of most breeds, this length should exceed 30 cm. An unusually short penis may prevent normal mating, especially in bulls older than 3 or 4 years. Penis extension may be impeded by lesions of the retractor penis muscles (congenital shortness, fibrosis, and calcification). These can be detected by palpating the retractor penis muscles, between the scrotum and the anus, while tension is applied to the tip of the extended penis. Some bulls may be restored to service by myotomy of the retractor penis muscles, performed in the mid- to upper escutcheon.

While the penis is extended—and in particular if any impediment to full extension is encountered—the entire penis should be carefully palpated, with particular attention paid to the presence of swellings or adhesions surrounding the penis. The preputial cavity may be examined in more detail by inflating it with gas or fluid. A metal or plastic catheter with rounded tip is inserted into the preputial orifice, and through it compressed air or water (from a regular hose pipe) is carefully introduced, while the preputial orifice is held closed. The normal prepuce is clearly outlined by this procedure and should appear symmetric and oval in contour. This technique will reveal any irregularity of the preputial lining (scars or adhesions) that may not otherwise be readily detectable.

Another strategy for minor procedures or examination of the free end of the penis is to block the dorsal nerve of the penis. This is especially useful in younger bulls, which are more easily handled. To block the dorsal nerve of the penis, the penis is withdrawn from the prepuce by manual, hand-over-hand action. Working from the left-hand side of the bull, the penis is grasped through the skin of the prepuce and moved forward with the right hand. Then the preputial skin is moved caudally and the penis is anchored with the left hand. With the right hand the preputial skin is moved caudally and the penis is grasped again and moved forward. (It might be possible to push the penis forward by applying pressure at the distal loop of the sigmoid flexure.) This procedure is repeated until the tip of the penis protrudes from the preputial orifice, where it is grasped by an assistant with sterile gauze sponges. This is only feasible in young (yearling) bulls; the force of the retractor penis muscles is not easily overcome in more mature bulls. Once the penis is extended, lidocaine may be injected beneath the lamina interna of the prepuce dorsally near the preputial orifice. The injection should encompass the dorsal half of the penis. This will provide analgesia of the free part of the penis adequate for minor surgery such as removal of fibropapillomata, correction of persistent frenula, or more detailed examination.

The preputial orifice should be closely applied to the ventral midline of the bull. Some breeds or individuals have pendulous prepuces that are predisposed to prolapse of the lamina interna. The orifice should permit introduction of three or four fingers but should not be wider than that. The prolapsed lamina interna is predisposed to injury, which may result in local scar tissue formation and stenosis of the prepuce. These lesions can usually be palpated through the skin. If doubt exists, the prepuce of the sedated bull can be inflated by introducing water or compressed air slowly into the prepuce while holding the orifice shut by hand. As the preputial cavity becomes filled its contour is readily discernible, and any stenotic area is easily identified.

Although the surgeon is principally concerned with the structural integrity of the reproductive tract and its surgical restoration, any surgery of the reproductive tract should, wherever possible, be preceded by thorough breeding soundness examination, including assessment of semen quality, to preclude other, nonsurgical, problems that would persist after surgical intervention.

CASTRATION

Bilateral Orchidectomy

Castration of young ruminants is a common procedure often done by laypeople to improve meat quality and render males more manageable. It is appropriate for veterinarians to educate their livestock owners to minimize complications from this procedure. A clean, dry environment as well as fly control is encouraged to prevent postoperative infection.

The desired age at which the animal is castrated varies and depends on an owner's expectation, facilities, and the intended use of the animal. Younger animals are easier to restrain, have a lesser risk of incisional complications, and have decreased aggressive behavior after castration. However, some livestock owners feel that castration at a later age is preferable for improved carcass characteristics and weight gain. In a review of the literature, castration had a mixed effect on weight gain of cattle.

Castration can be done pharmacologically by using immunization against GnRH or by insertion of an estrogen implant. Other techniques include using surgical and bloodless castration techniques. This chapter will focus on the latter two methods of castration.

All small ruminants that are castrated should receive tetanus prophylaxis (ideally several weeks before the procedure) because tetanus is one of the main complications of this procedure. This can be in the form of colostral protection, tetanus antitoxin (250-500 IU) or two doses of tetanus toxoid (the first one 3-4 weeks in advance of the procedure).

Regardless of the technique used or species involved, it is essential to check that both testes have descended into

the scrotum before surgery is contemplated. This prevents unilateral castration of cryptorchid animals, which would give the misleading external appearance of a castrated male. Fortunately, cryptorchidism is rare in calves, rams, and bucks.

Castration of Calves and Small Ruminants

Lambs and small goats are held, head down, between the operator's knees or head up with the front and hind limbs on each side held together. Calves younger than 1 month of age are usually restrained in lateral recumbency. Typically, older calves are put into a squeeze chute or stocks. Although some stockmen continue to castrate young calves and lambs with physical restraint only, it is now clear that analgesia promotes appetite and weight gain as well as having clear animal welfare implications. Veterinarians should apply and advocate routine use of analgesics for castration. For a standing animal in stocks or head catch, the operator's hand is placed at the base of the tail so that it can be lifted over the animal's back. Lamb or kid sensitivity to local anesthetics necessitates reduction of the concentration of a local anesthetic being administered; lidocaine should be diluted from 2% to 0.5% or 1%. General anesthesia—or heavy sedation (xylazine hydrochloride 0.02 to 0.1 mg/kg intravenously [IV] or 0.04 to 0.2 mg/kg intramuscularly [IM]) and local anesthesia—are commonly used with larger animals and pets. The lower range should be used on goats and debilitated, aged, young, or depressed animals. Another drug combination that works well on goats is midazolam (0.1 to 0.2 mg/kg IV) in combination with butorphanol (0.02 mg/kg IV).

For animals less than 150 kg, the distal portion of the scrotum is grasped and pulled distally, thus displacing the testes proximally (Figure 16-1). The distal third of the scrotum is excised to expose the testes (Figure 16-2). Traction is applied to each testis, and the spermatic cord is freed by stripping the fascia proximally (Figure 16-3). At this point, the cord can be ligated and transected, emasculated, or stretched until the vasculature ruptures. The latter technique results in vasospasm, which is usually adequate hemostasis for smaller animals but could damage the inguinal ring in lambs and lead to a hernia. For this reason, use of a technique that closes (use of emasculator [Figure 16-4] or ligation) the spermatic cord is preferable. The wound is usually left open to heal by second intention.

Another surgical option for calves is to approach the testes by making a vertical incision in the lateral wall of the scrotum with a Newberry knife (Figure 16-5*A*). The Newberry knife blade is placed through the middle of the scrotum (Figure 16-5*B*) and rapidly pulled distally, thus making a cranial and caudal flap of the scrotal skin (Figure 16-5C). The same flaps can also be created with a scalpel. The testes are excised as mentioned previously, either with traction, an emasculator, or ligation and excision. The wound is typically left open.

Older animals are occasionally castrated, with the best results obtained when they are restrained in chutes or on a tilt table. Local anesthetic in the scrotal skin and spermatic cord is appropriate. The operator's preferences dictate the surgical approach. The distal scrotum can be removed (Figure 16-6), or parallel incisions can be made on either

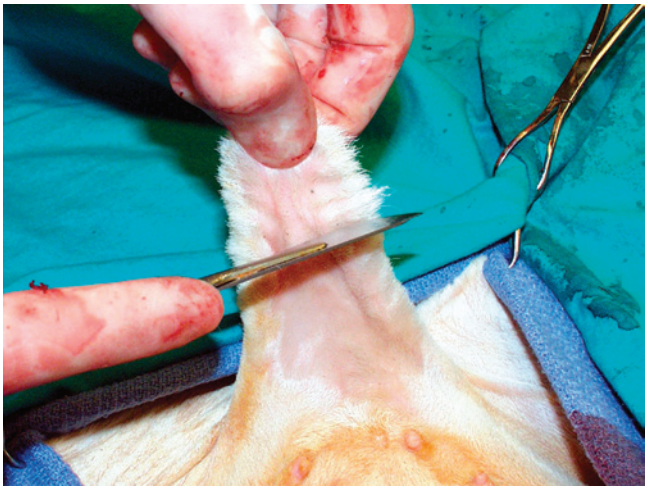


Figure 16-1 The distal portion of the scrotum of a bull calf in dorsal recumbency is grasped and pulled distally, thus displacing the testes proximally.



Figure 16-2 The distal third of the scrotum is excised, exposing the testes.



Figure 16-3 The spermatic cord is exposed by stripping the fascia proximally and applying traction to each testis.

side of the median raphe. Regardless, the testis is identified and freed from its surrounding fascia with blunt dissection. Once isolated, the spermatic cord is ligated and transected or emasculated. Generally, the vaginal tunic is not incised and is removed en bloc with the testis. If the vaginal tunic is incised, the testis and spermatic cord are ligated (or emasculated). Some prefer to split the spermatic vessels away from the pampiniform plexus and ligate (or emasculate) these structures separately. Regardless, the cremaster muscle is ligated with the vaginal tunic, and both are transected approximately 2 cm distal to the ligations. Transfixation sutures help prevent ligature slippage. If primary closure is to be performed, at least a partial resection of the redundant scrotal skin is necessary to minimize dead space. The subcutaneous tissues are closed with a purse string–type suture (superficial and deep bites) using an absorbable suture material. A subcuticular or skin closure should be done with an absorbable suture if primary closure is elected.



Figure 16-4 An emasculator. Note the serrated blade used for crushing the spermatic cord to cause hemostasis. When the emasculator is used, the cutting blade must be placed distal to the crushing blade.

Unilateral Orchidectomy

Injury or illness that involves one testis may detrimentally affect the contralateral testis to the extent that removal of the affected testis provides the best option for returning the bull or ram to fertility. This may be the case in unilateral hydrocele, hematocele, testicular tumor, epididymitis, abscess, varicocele (Figure 16-7*A*), or other conditions. In such cases the contralateral testis may be compromised by pressure or increased local temperature. Careful removal of one testis results in preservation of the remaining testis, and some compensatory hypertrophy and increased sperm production by the remaining testis may be expected.

Abnormalities are usually detected during physical and routine breeding-soundness examination or may be noticed by an astute owner or herdsman. The abnormality can involve the scrotum, testis, epididymis, ductus deferens, vaginal tunic, or vasculature of the testis. Unilateral disease can result in abnormal semen quality as the heat generated by the abnormal testis affects the contralateral testis. Fortunately, studies have shown the effect on semen quality is reversed after the abnormal testis is removed. Care must be taken to limit postsurgical hemorrhage and inflammation and to prevent the detrimental effects of



Figure 16-5 *A*, Newberry knife. *B*, The scrotum is grasped with the Newberry knife. *C*, Photographs taken show the scrotal flaps after the testes were removed.

postoperative pressure or elevated temperature on the remaining testis.

The surgical procedure for unilateral orchidectomy is as follows. The animal is restrained or anesthetized in lateral recumbency. The upper hind limb is abducted and secured in a fixed position; the scrotum may be held by a towel clamp to facilitate preparation (Figure 16-7*B*). After preparation of the surgical site, a vertical incision is made on the lateral aspect of the affected side approximately the entire length of the testis. The initial dissection extends the skin incision through the scrotal fascia, and the testis is bluntly dissected within the vaginal tunic. The vaginal tunic is incised the length of the testis, and the spermatic cord isolated, double-ligated, and transected or emasculated. The tunic can be transected and oversewn with an absorbable suture material. It is usually necessary to remove excess scrotal skin. This will help minimize dead space and prevent postoperative seroma formation, which is important to minimize postoperative pressure on the remaining testis. The scrotal fascia is closed by using a continuous pattern with an absorbable suture. The subcutaneous tissues and skin are closed routinely. Studies have shown that semen quality returned to normal 22 days after unilateral castration in normal bulls. There are other case reports of successful return to production following surgery in several animals with unilateral disease. Currently, surgery is recommended for valuable animals with nonheritable unilateral disorders other than herniation.



Figure 16-6 A yearling bull being castrated. The distal end of the scrotum has been removed, exposing the testes.

Bloodless Castration

Several techniques for castrating farm animals without performing a surgical incision are available. These so-called bloodless techniques create ischemia of the testis with subsequent atrophy or necrosis. In very young animals, the most common technique is to use an elastic band. The band and applicator pliers should be soaked in disinfectant before use. Once the animal is restrained, the band is applied around the neck of the scrotum by using the pliers (Figure 16-8*A* and *B*). Other commercially available tools are designed to place heavy-walled latex tubing around the neck of the scrotum in older animals. The scrotum and testes usually slough within 3 weeks of band application. This technique is used quite commonly in small ruminants less than 1

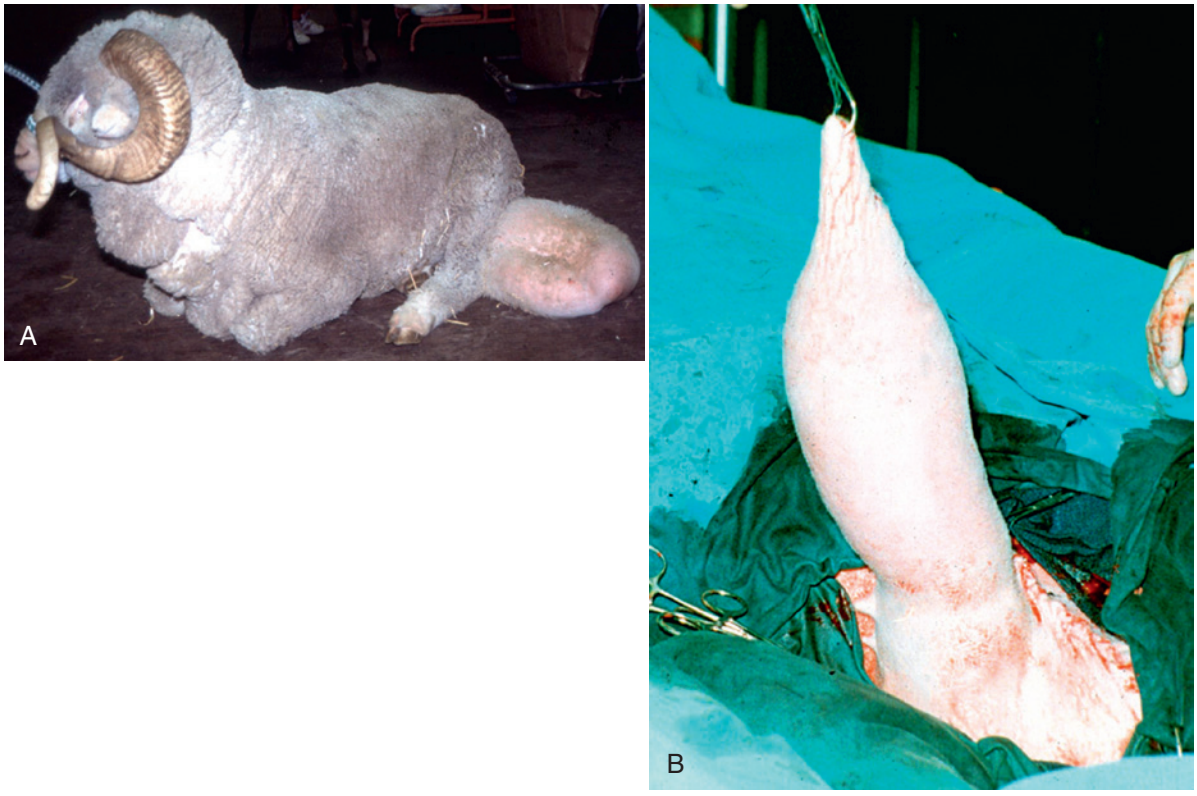


Figure 16-7 *A*, A mature ram with unilateral varicocele. Note the enlarged asymmetric scrotum. *B*, Intraoperative view before resection.

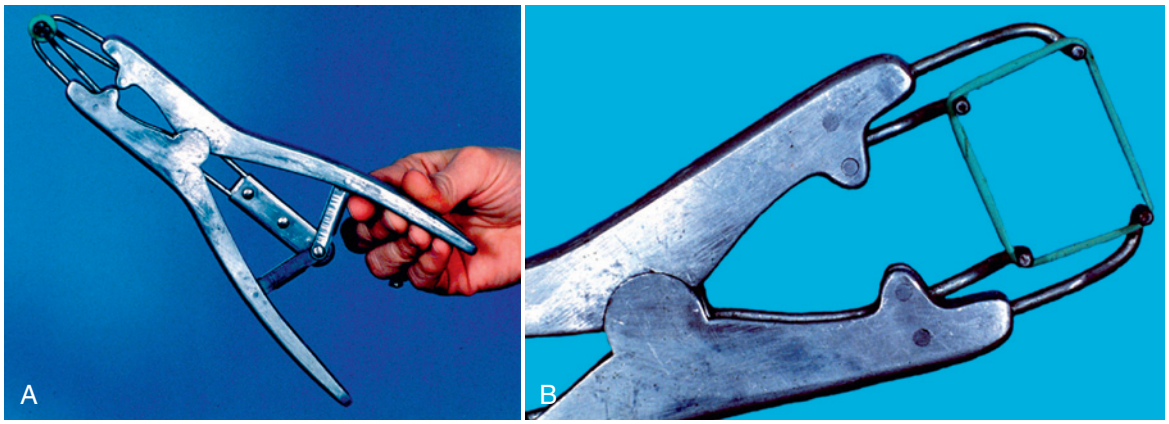


Figure 16-8 *A*, An elastrator used to apply elastic bands when castrating a young kid. *B*, Close-up view.



Figure 16-9 *A*, EZE-Bander. *B*, The tubing is placed around the base of the scrotum. C, Each end of the tubing is then tightened. *D*, After the tubing is cut free, the tightness of the band should be checked.

month of age. Ambulatory clinicians at our institution have been successful with using a callicrate bander[1] in bulls up to 400 kg (Figure 16-9*A-D*). Rare failure has been associated with band breakage. Older, small ruminants should be handled the same as older calves with sedation and surgery; however, one should always be mindful of small-ruminant sensitivity to lidocaine. The callicrate bander has been used successfully on older goats after the long hair was clipped from the neck of the scrotum.

The *Henderson castrating tool* (Figure 16-10) was also developed for larger, more mature males. After the scrotum is opened by a preferred method, the tool is attached to the spermatic cord. An electric drill is placed on the handle of the tool and rotated. This twisting is reportedly very efficient in preventing excessive hemorrhage, even in large mature bulls.

Another bloodless technique is to use a Burdizzo emasculatome (Figure 16-11) to crush the spermatic cord within the scrotum. After this, the testes atrophy but usually do

[1]No-Bull Enterprises, P.O. Box 748, St. Francis, KS, USA. www.nobull.net/bander.

not slough. This instrument is best used by crushing a portion of the scrotum while holding the spermatic cord over the side that is crushed. One can crush the spermatic cord twice while manipulating the cord within the scrotum. These crushes should be staggered without crossing the midline, so no pressure is applied across the entire scrotum, thus minimizing the risk of impairing vascular supply. All animals treated with nonsurgical castration techniques should receive tetanus prophylaxis (ideally several weeks before the procedure) because tetanus is one of the complications of this procedure.

Postoperative Care

After castration, animals should be observed for abnormalities such as excessive swelling, hemorrhage, and signs of infections such as depression, decreased appetite, and abnormal drainage. When castrated animals are older or in an unclean environment, perioperative antibiotics are administered for 5 to 7 days.

Complications

As mentioned previously, tetanus is a worry in small ruminants and may be of concern in bulls that are castrated with the callicrate bander. Minimal complications—including seroma formation, swelling, and inflammation at the surgery site—are typical. These are usually self-limiting and resolve without further treatment. Other castration complications include infection and hemorrhage. With an open wound, any incisional infection or swelling can usually be handled by simply providing adequate ventral drainage and enlarging the incision bluntly. If an appropriate technique is used, hemorrhage is rarely a major problem. If persistent hemorrhage does occur, it may be necessary to pack the scrotum with a sterile towel, laparotomy pad, or gauze roll, with removal in 48 hours. When the sterile packing is removed, any retained blood clot should be gently expressed. If this is elected, antibiotics are appropriate because the packing material can serve as a foreign body in a closed space, thus making a localized infection more likely.

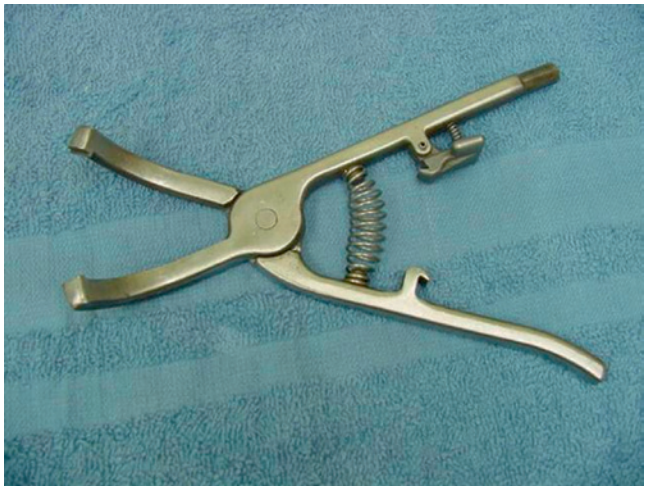


Figure 16-10 Henderson castrating tool.

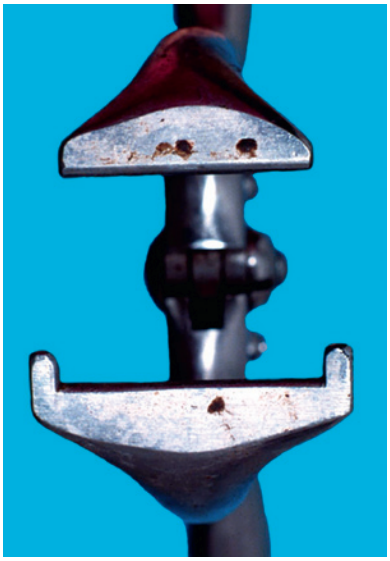


Figure 16-11 A Burdizzo emasculatome.

TESTICULAR BIOPSY

Robert O. Gilbert and Susan L. Fubini

Recently testicular biopsy was performed on six normal bulls to determine whether this would be a useful diagnostic tool for bulls with infertility. The investigators used a 15.2-cm 14-gauge biopsy needle placed through a stab incision in the skin. They determined that there were no long-term changes in semen quality over the course of the 90-day study. Therefore testicular biopsy with histopathological examination may be considered for cases of infertility if time and economic constraints preclude a wait-and-see approach for determining the future breeding ability of a particular bull. It is important to obtain the tissue sample from the lateral cranial aspect of the proximal (dorsal) area of the testis where blood vessels are relatively sparse to prevent excessive hemorrhage and infarction. Severe hemorrhage into the vaginal tunic could necessitate removal of the testis (Figure 16-12). Cultures and sensitivity should be used to assess a testicular condition associated with an inflammatory or infectious process. Even in apparently uncomplicated cases

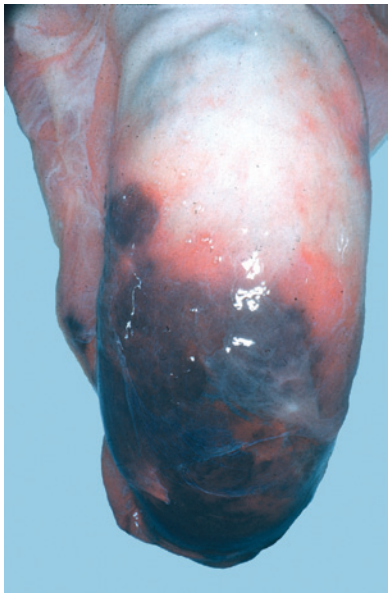


Figure 16-12 Testicular hemorrhage and infarction after testicular biopsy. To minimize the risk of this complication, needle biopsy should be performed at the dorsolateral, cranial aspect of the testis, where there are less superficial vessels.

bulls may be left with a wedge-shaped region of testicular infarction as a complication of needle biopsy.

SURGICAL MANAGEMENT OF SPECIFIC CONDITIONS

Cryptorchidism/Testicular Anomaly

Abnormality of testicular descent results in abdominal, inguinal, or ectopic testes. Cryptorchidism is uncommon in ruminants, has been described to be inherited in polled Hereford bulls, and probably has a genetic component in all cases. Abdominal cryptorchids are rare. Cryptorchidism is usually unilateral, and the left testis is involved about twice as often as the right in cattle; in goats the right testis is more often retained. Most incompletely descended testes are ectopic and may come to lie adjacent to the prepuce and testis. In a subtler form of incomplete descent, the testis is intrascrotal, but instead of its normal attachment to the ventral-most aspect of the scrotum, the ligament of the tail of the epididymis may attach to a point in the midscrotum. In this case the testis may appear normal at first observation. When during examination it is forced ventrally in the scrotum, its midscrotal attachment becomes apparent as the testis rotates about this point of aberrant attachment, instead of sliding smoothly to the ventral portion of the scrotum. Cryptorchid animals should be culled: testicular thermoregulation is impaired and spermatogenesis is rarely normal. It is also likely that the condition is inherited.

The clinical diagnosis of undescended testis is made by physical examination where the absence of a testis in the scrotum is detected. To identify the location of the undescended testis one should palpate for (perhaps also search with ultrasound examination) the testis not only in the abdomen and inguinal canal but also in the subcutaneous tissues in the inguinal region, the fold of the flank, and alongside the penis. In addition, rectal examination may identify an abdominal testis. Furthermore, detection of normal-size bulbourethral glands would indicate the presence of functioning testicular tissue, especially in small ruminants.

With undescended testes the approach is made directly over the testis, if possible. The bull should be restrained appropriately, usually in dorsal recumbency for testes on the ventral abdomen and inguinal canal. Abdominal testes are best removed via a flank celiotomy. In the latter case, closure of the vaginal ring is needed to prevent formation of an inguinal hernia.

Scrotal Trauma

A common consequence of severe scrotal trauma is rupture of the tunica albuginea of the testis. This typically results in profuse hemorrhage and formation of a hematocele. The injury may occur when a herdmate treads on the testis of the recumbent bull or when the scrotum is kicked. The scrotum is immediately swollen and painful. No prospect of recovery of the ruptured testis exists, and the only therapeutic concern is preserving the function of the surviving testis. If the condition is presented and diagnosed promptly, drainage of the hematocele after allowing 3 days for hemostasis helps reduce pressure on the contralateral testis. Hemiorchiectomy may be considered but offers little advantage beyond a better appearance. If the diagnosis is delayed, intervention may offer little advantage. Once the hematoma resolves, the ruptured testis is usually replaced with fibrous tissue if left alone.

Inguinal/Scrotal Hernia

Inguinal hernia occurs mainly in mature bulls. The internal inguinal ring is palpable per rectum and should be examined as part of every routine breeding-soundness examination. The normal inguinal ring permits insertion of one or two fingers. Bulls with internal inguinal rings sufficiently wide to permit insertion of four fingers are predisposed to herniation, and the owner should be warned.

The overwhelming majority of inguinal hernias occurs on the left side of the scrotum, probably as a result of the rumen's weight and mature bulls lying in a sternal position with the left rear leg abducted. Most hernias are indirect (the intestinal component is contained within the tunica vaginalis), but occasionally direct herniation occurs when herniated intestine goes through a rent in the vaginal tunic and is contained within its own peritoneal pouch. The hernia is inguinal as long as the contents are within the inguinal canal (most frequent, Figure 16-13) and scrotal if the hernia extends into the scrotum. A scrotal hernia is rare because anatomic narrowing of the vaginal tunic within the neck of the scrotum normally prevents bowel from descending to the scrotum.

Diagnosis may pose a challenge. Inguinal or scrotal hernia has to be differentiated from excess subcutaneous fat at the neck of the scrotum and from pendulous subperitoneal fat passed through the inguinal canal ("pseudohernia"). In pseudohernia, fat accumulates beneath the peritoneum in overconditioned heavy bulls. It may extend through the inguinal canal on a stalk, but it does so outside the tunica vaginalis, which is important information for performing surgery in this area. Passage of this fat mass through the inguinal canal widens the canal, and a true hernia can occur in conjunction with pseudohernia. Hernia can also result when the bull loses some conditioning, causing the fat pad to reduce and leaving a large vaginal ring. An accumulation of subcutaneous scrotal fat that occurs in the inguinal region but is bilaterally symmetric should not be confused with the presence of an inguinal hernia. This subcutaneous fat usually disappears as the bull loses condition. Other abnormalities that can be confused with inguinal or scrotal hernia include hydrocele, aneurysm, neoplasia, and abscesses.



Figure 16-13 Inguinal hernia in a bull. Note the bulge in the vaginal tunic created by the herniated small intestine, thus resulting in an hourglass configuration. (Courtesy of Dr. David Anderson.)

Beef breeds appear to be predisposed, particularly polled Hereford bulls, suggesting the condition has a genetic component. Hernia surgery may be combined with hemiorchidectomy of the testis on the involved side (a much easier technique), or an attempt may be made to salvage the testis.

As mentioned, hernias in mature bulls can be direct or indirect and acquired or congenital. An indirect hernia has the bowel within the tunica vaginalis that creates an "hourglass" configuration in an adult bull's scrotum. This shape can change, depending on whether the viscera are displaced. The narrowing of the vaginal tunic dorsal to the testis gives the characteristic shape. Inguinal/scrotal hernias are typically chronic and can affect semen quality by altering the bovine scrotal thermoregulatory function.

A true hernia is always palpable per rectum as a mass of abdominal contents that passes through the internal inguinal ring. It may not be possible to clearly identify which tissues are herniating by palpation. The diagnosis is supported if per rectal traction on the mass results in externally visible movement of the herniated mass. Ultrasonography of the scrotum and inguinal region may confirm the presence of loops of intestine. Auscultation of the region with a stethoscope may reveal intestinal sounds in some cases.

Strangulation of an inguinal hernia is not common but may occur rapidly. Affected bulls show signs of intestinal obstruction, including abdominal pain and decreased fecal output, and the condition must be distinguished from intussusception and volvulus of the root of the mesentery. The hernia may be contained entirely within the inguinal canal without visible scrotal swelling. Palpation per rectum of the internal inguinal ring is usually diagnostic.

Given a probable genetic component of the etiology of inguinal hernia, owners may elect not to have surgical repair performed.

Surgical Repair of Indirect Inguinal Hernia—Flank Approach

Preparation is the same as for any flank celiotomy. The approach is on the same side as the hernia. The inguinal ring is identified. Traction is applied gently to the herniated contents. Once the hernia is reduced, the internal inguinal ring is closed with blindly placed simple-interrupted or simple-continuous absorbable sutures. This can be difficult to accomplish. Furthermore, bowel adhesions to the vaginal tunic or the presence of inguinal fat pad remnants can make correction difficult or impossible from this approach.

Surgical Repair of Indirect Inguinal Hernia—Inguinal Approach

The bull is placed in lateral recumbency on the side opposite the hernia. General anesthesia is highly desirable. The uppermost leg is elevated and secured to expose the inguinal area. The inguinal area is prepared for aseptic surgery. A sharp 15- to 20-cm skin incision is made over the external inguinal ring. The subcutaneous tissues are divided by using a combination of blunt and sharp dissection to expose the testis, vaginal tunic, and identified anatomic landmarks of the inguinal canal. At this point, determining whether any adhesions exist between the intestine and vaginal tunic is important. If the bowel slides easily and can be replaced into the abdomen without difficulty, it is unnecessary to open the vaginal tunic. Instead, twisting the testis replaces the bowel into the abdomen (Figure 16-14*A* and *B*). The twisted spermatic cord can be transfixed with No. 2 absorbable sutures and tacked to the sides of the external inguinal ring, effectively occluding the inguinal canal. After this, the testis is emasculated (Figure 16-14C). Adhesions between the bowel and vaginal tunic make it necessary to incise the vaginal tunic to assess the intestine. If adhesiolysis is required, careful attention to hemostasis and asepsis is essential. The hernia is reduced, the testis emasculated, and the external inguinal ring closed. Removing any inguinal fat pad provides better identification of tissue layers for a more secure closure.

Closing the external inguinal ring enough to prevent intestinal herniation without impairing the testis blood supply has been described as a way to save the testis. The authors prefer to sacrifice the testis on the affected side and close the external inguinal ring with substantial bites of No. 2 absorbable suture (Figure 16-14*D*). Subcutaneous tissues and skin are closed routinely in an effort to decrease dead space.

Direct Inguinal Hernia

Direct hernia means the bowel has protruded through a defect in the peritoneum or a tear in the vaginal tunic. The etiology is presumed to be traumatic; less side predisposition occurs and there is no characteristic hourglass shape of the scrotum. If the intestine is incarcerated, the bulls can show signs of intestinal obstructive disease and present as a surgical emergency.

Surgical Repair of Direct Inguinal Hernia—Inguinal Approach

The surgery for direct inguinal hernia is very similar to that described for indirect hernia. However, the status of the bull may indicate the necessity of more intense preoperative care. This would include fluid therapy, nonsteroidal antiinflammatory drugs, and antimicrobials. At surgery, adhesions or devitalized bowel would require resection. A flank laparotomy may be necessary for hernias difficult to reduce or when a large portion of bowel is involved.

Congenital Inguinal Hernia

Repair of congenital inguinal hernia is not recommended unless a bilateral castration is performed. Simple indirect hernias are almost always repaired by twisting the testis as described in the technique described previously (see Surgical Repair of Indirect Inguinal Hernia—Inguinal Approach).

Complications

Considerable postsurgical edema and swelling may occur. This can be controlled with hydrotherapy and diuretics if necessary. If the bull's disposition permits, controlled walking is desirable. If an intestinal resection was performed, antibiotics should be continued for 5 to 7 days.

Epididymectomy

This procedure is performed as the main or supplementary method for producing teaser animals. It may be performed in ruminants of all species in laterally restrained or standing animals. Local anesthesia of the ventral scrotum and testis is achieved, and the surgical site is prepared. A 2-cm skin incision in the ventral scrotum is extended into the relatively conspicuous tail of the epididymis. The tail of the epididymis is separated carefully from the distal aspect of the testis with blunt dissection, ligated with fine absorbable material, and removed. Care must be taken to avoid injury to the testis, which will bleed profusely if inadvertently incised. The tunica vaginalis is not closed, but the skin incision is sutured. The technique should be performed at least 30 days before intended use of the teaser to allow sufficient time to achieve infertility.

Vasectomy

Vasectomy (removal of a segment of the *ductus* (formerly *vas*) *deferens* to render a male animal infertile) is generally a management technique used to produce teaser males or as an adjunct to such methods. Teasers are used to detect or aid in identification of females in estrus to allow them to be

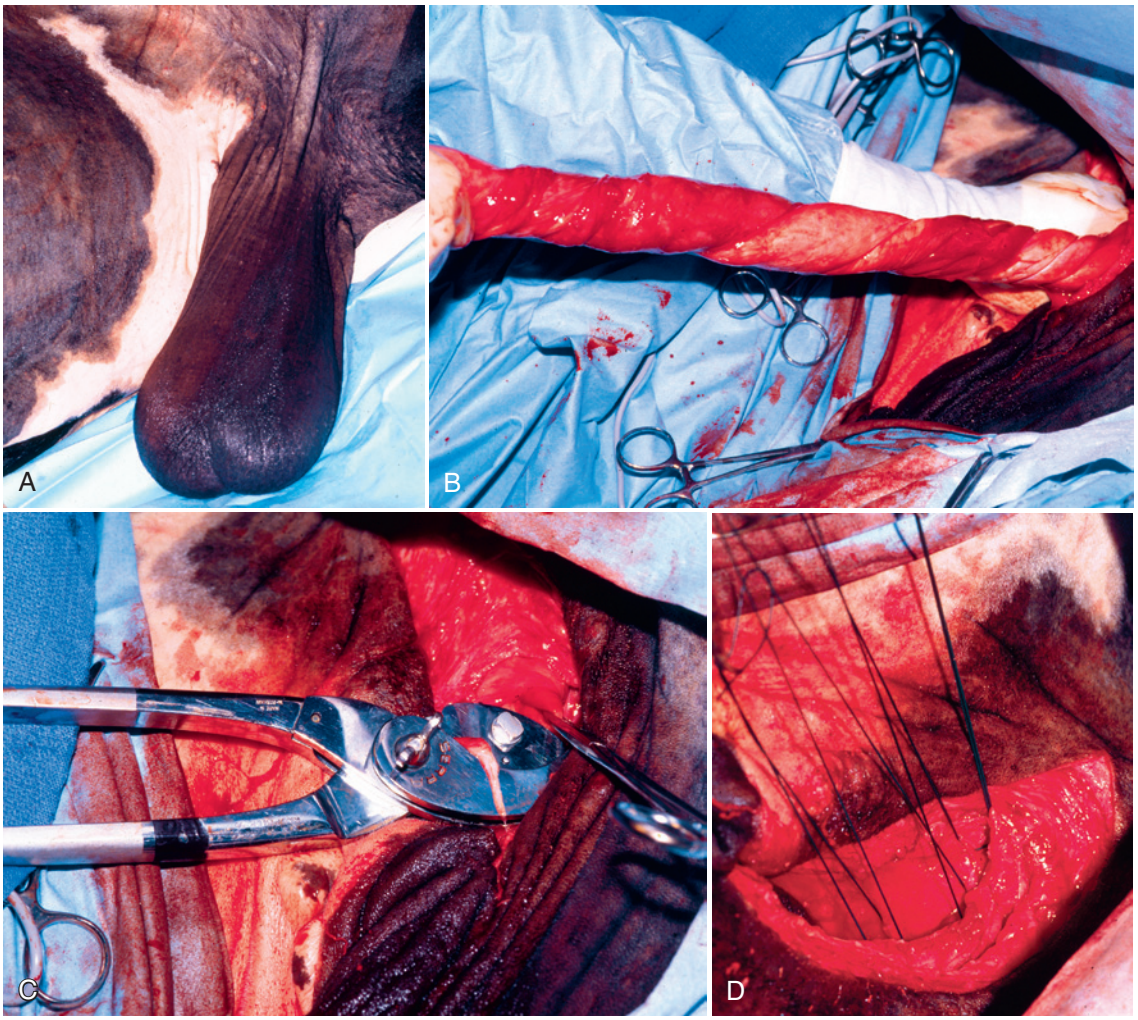


Figure 16-14 *A*, Bull in lateral recumbency with affected limb abducted. The inguinal area is prepared for aseptic surgery. *B*, Twisting the vaginal tunic to reduce an indirect hernia. *C*, Use of an emasculator. *D*, Placement of sutures in the external inguinal ring (Courtesy of Dr. David Anderson.)

bred by natural or artificial means to males of greater genetic merit than the teasers. Ideal methods for creating teaser animals (see later) involve rendering the teaser both infertile and incapable of mating (to prevent spread of venereal diseases). Vasectomy achieves infertility but does not alter the ability or desire of males to mate; it is best to combine vasectomy with a procedure that precludes mating to prevent spread of infectious agents.

Vasectomy is usually performed with the aid of a local block at the surgical site. It can be done with the animal standing or restrained in lateral recumbency. Rams can be operated on in a sitting position, restrained by an assistant. The conventional technique involves incision of the neck of the scrotum cranially, caudally, or even laterally. Some surgeons prefer a single incision in the median raphe to allow access to both spermatic cords. In bulls and rams, the incisions need to be about 2 cm in length to allow exteriorization of the cord. The skin and parietal layer of the vaginal tunic are incised in a vertical fashion. The ductus deferens is located by palpation because it is firmer than the surrounding vasculature and membranes. It is usually located at the caudomedial aspect of the cord. The ductus deferens also lies within its own fold of vaginal tunic. The cord consists of a mass of arteries, veins, and nerves enclosed by the visceral layers of the vaginal tunic. Incision of the vessels of the cord leads to considerable hemorrhage that is difficult to control and can obscure the other structures of the cord. Care should be taken to identify the ductus deferens, isolate it via delicate blunt dissection, and remove a 3-cm piece of it after 3-0 absorbable ligatures have been placed on each end (Figure 16-15). The procedure is repeated on the opposite side. For additional security, it is wise to fix and label the removed components to document the removal of the appropriate structure with histopathology. More simply, the excised ductus deferens may be examined under a dissecting microscope to confirm the presence of the characteristic star-shaped lumen. The vasectomized animal should also be permanently identified (e.g., by notching the ear or tattooing) to guard against later confusion of intact and vasectomized animals (particularly important in rams).

Because vasectomy is a common procedure in animals as well as human males, it tends to be regarded as simple. Surgeons who perform few vasectomies may find positive identification of the ductus deferens among the structures of the spermatic cord unexpectedly difficult, especially in fat, meat-breed rams. Fat surrounding the cord may impede identification of the ductus deferens with a conventional (high) approach from the cranial or caudal direction. A novel approach to the procedure, proposed by Lofstedt (1996), is considerably easier to perform, especially for those who do not regularly vasectomize ruminants. The animal is restrained as described previously. The scrotum is clipped, scrubbed,

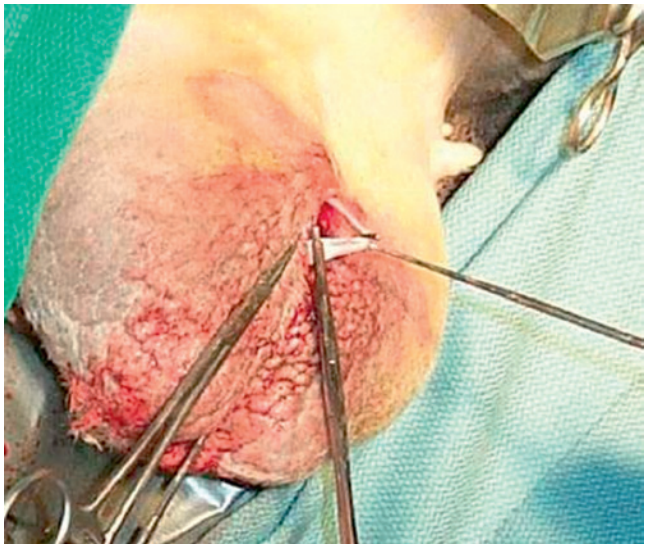


Figure 16-15 Ductus deferens isolated with Allis forceps. (Courtesy of Dr. Carlos Gradil.)

and draped appropriately, and local analgesia is administered. A vertical skin incision is made in the cranial aspect of the scrotum in the middle of the sac. The incision is extended to reach the left or right parietal vaginal tunic, and the cranial aspect of this incision is grasped with Allis forceps. Although the testis is stabilized with one hand, a second pair of Allis forceps is inserted in a caudad direction toward the medial reflection of the vaginal tunic (at the body of the corpus epididymidis). The ductus deferens is the only structure in the cul-de-sac created by the reflection of the vaginal tunic (mesorchium), and it is easily identified and grasped with instruments. A section of at least 3 cm is removed to prevent the possibility of reanastomosis. The procedure is repeated on the opposite side. Postsurgical swelling is remarkably limited, and few complications arise from this approach. Administration of tetanus toxoid is wise after vasectomy, especially in rams. Antibiotic therapy is optional.

SURGERY OF THE ACCESSORY GLANDS

Seminal Vesiculectomy

Vesiculitis (also called *seminal vesiculitis* or *vesicular adenitis*) is characterized by palpable changes in the vesicular glands, ultrasonically visible hypoechoic areas in the glandular parenchyma, and leukospermia (semen contaminated with leukocytes, particularly neutrophils). During the acute stages, pain may be evident, spontaneously or upon palpation of the gland, but most cases are presented later in the progression of the disease. It occurs most commonly in pubertal bulls or in older bulls. Both types defy treatment with antibiotics. In the pubertal form, spontaneous recovery is quite common. The presence of large numbers of leukocytes impairs fertility, probably by increased oxidative damage to sperm, although most affected bulls are not completely infertile. Commercial use of the semen for cryopreservation is not possible. Younger (1- to 2-year-old) bulls in which the condition does not resolve spontaneously or valuable mature bulls with vesiculitis are candidates for vesiculectomy, particularly if the condition is unilateral. The presurgical examination should also seek to confirm that the inflammation is limited to the vesicular gland. Involvement of the ampullae may prevent resolution of the leukospermia after surgery and therefore prevent return to normal semen production.

Surgery is performed in the standing bull, confined in an appropriate chute, under epidural analgesia. Prophylactic antibiotic therapy should be administered for 2 days before surgery. Sedation is not usually needed but should be dictated by the temperament of the bull. The rectum is evacuated, preferably before administration of the epidural analgesic, to prevent rectal ballooning. A purse-string suture is inserted in the anus to prevent contamination of the surgical field (Figure 16-16, *A*). The ends of the suture material are left long to facilitate later removal and to remind the surgeon to remove the suture. A crescent-shaped incision is made in the ischiorectal fossa, curved around the anus. The incision is continued through the skin and subcutis by sharp dissection. With blunt dissection, the loose connective tissue is separated between the rectum medially and sacrosciatic ligament laterally until the vesicular gland is reached. The temptation to use sharp dissection should be resisted once the skin and subcutis are penetrated, or profuse hemorrhage may ensue. The inflamed gland is invariably encased in tough connective tissue. The peritoneal reflection covers the cranial-most portion of—and always firmly adheres to—the gland. Inflammation in and around the vesicular gland increases the amount of dense fibrous tissue that needs to be broken down blindly with the fingers of one hand. This process takes many minutes—and is tiring—but should be completed patiently and gently. Damage to the rectum or to major blood vessels could be catastrophic. The nerves, vessels, and muscles associated with erection and ejaculation lie close to the operative field. It is important to completely free the vesicular gland as close to its base as possible. Care is taken not to damage the ipsilateral ampulla. In fact, the base of the vesicular gland extends virtually to the urethra, but only the portion of the gland external to the urethralis muscle is freed up and ultimately removed. Experience suggests that the remaining tissue seldom presents a problem; either it is not usually involved in the inflammatory process or postsurgical induration renders it inactive. Once the vesicular gland is completely freed from surrounding adhesions, a sterile écraseur is inserted and the chain is carefully placed around the freed gland (Figure 16-16*B*). The gland is held to ensure the chain is snugly applied to the base of the vesicular gland without encroaching on neighboring structures, and the gland is removed (Figure 16-16*C*). Multiple simple interrupted absorbable sutures are used to close as much dead space as possible. The skin is closed routinely (Figure 16-16*D*). The purse-string suture is removed from the anus. Postsurgical antibiotics and antiinflammatories should be administered for 3 to 5 days. The skin sutures are removed in 10 days. The bull should be sexually rested for 4 to 6 weeks. Initial postsurgical semen quality may be disappointing, commonly with numerous detached sperm heads, but gradual improvement in semen quality is the rule.

After unilateral removal of a vesicular gland, the prognosis for return to normal service and fertility by natural service or artificial insemination is excellent. Postsurgical complications may include perirectal hematoma in the area of blunt dissection. This usually resolves spontaneously, but occasionally infection sets in and an abscess develops that requires drainage. Although success after bilateral vesiculectomy has been reported, the authors have had disappointing results with simultaneous or sequential removal of both glands and do not recommend it. Intractable dilation of ampullae with sperm accumulation has been reported as a complication of bilateral vesiculectomy.

Although the surgical method described previously has been very successful, it does require blind operation and profuse bleeding is a risk. These factors have prompted a search for a method of surgery that allows clear visualization of the operative field. Hull (2001) has described an approach

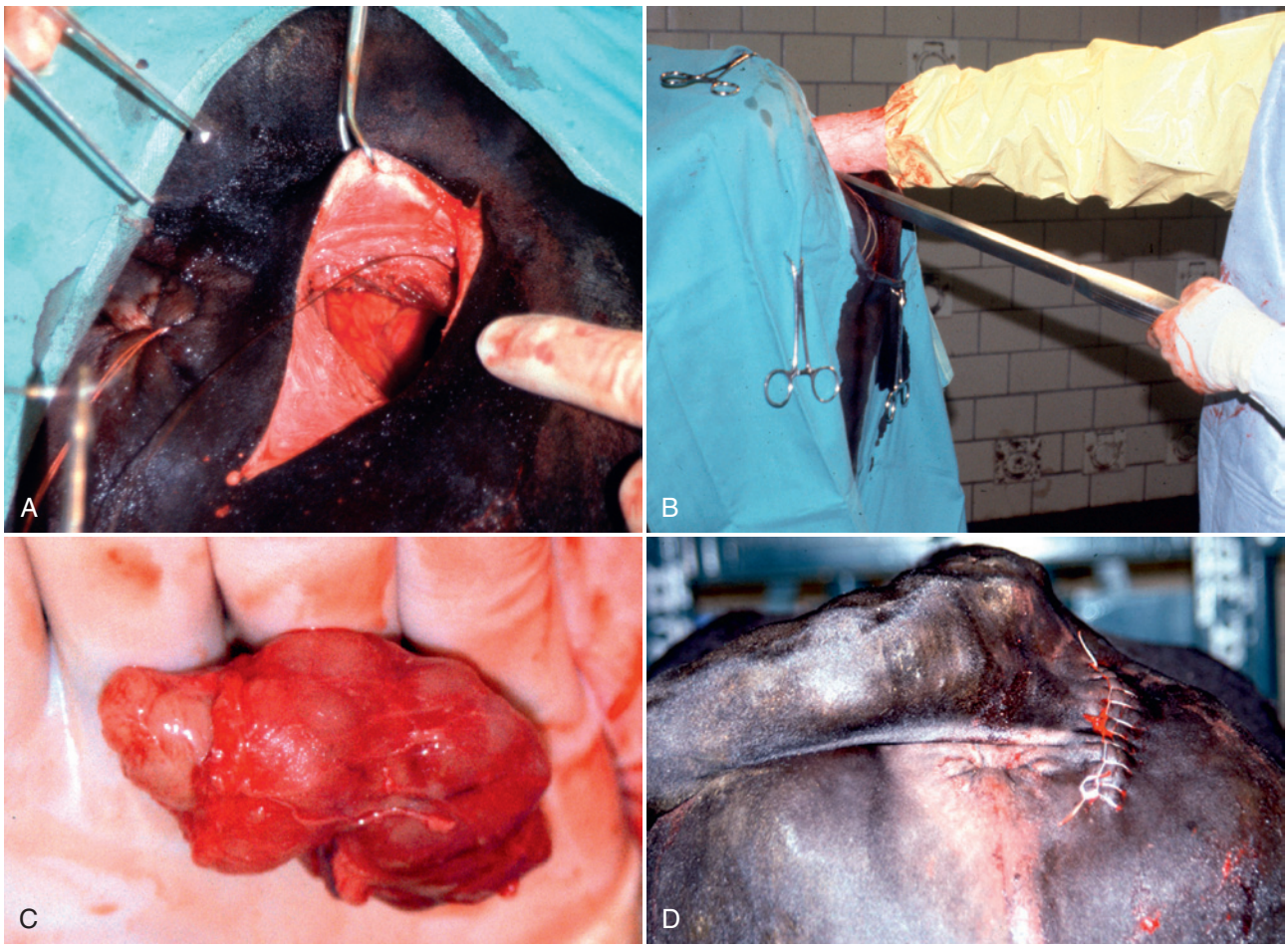


Figure 16-16 *A*, View of incision site for vesiculectomy. Note purse-string suture in the anus (*arrow*). *B*, Use of an écraseur to remove the dissected vesicular gland. *C*, The vesicular gland after removal. *D*, Surgical site after skin closure.

through the floor of the rectum. This procedure is also performed on the standing bull under epidural anesthesia, with sedation if indicated. Again, surgery should be preceded by antibiotic therapy for a day or two. In preparation for surgery the rectum is evacuated, and a tampon made of gauze is inserted about 25 cm into the rectum. The rectum caudal to the tampon is lavaged with an antiseptic solution such as dilute Lugol's iodine. The perineal area is clipped and prepared for surgery. A vertical incision is made in the ventral aspect of the anus and through the connective tissue ventral to the rectum until the level of the urethra is reached. The ventral rectal wall is divided cranially with blunt dissection as much as possible to minimize hemorrhage until the vesicular glands are visible. The incised or separated edges of the rectum are retracted to allow visualization of the surgical site. The affected gland is freed from its peritoneal attachments, and any periglandular adhesions are ligated and removed. The rectal floor is restored by suturing the rectal submucosa and serosa with absorbable inverting sutures in a continuous Lembert pattern, with care taken not to penetrate the rectal mucosa or to leave exposed suture material within the rectum. After removal of the rectal tampon, the anal sphincter is repaired with absorbable suture in a horizontal mattress pattern, and the skin is closed with nonabsorbable sutures. Alternatively, the tampon may be left in situ until closure is complete to maintain pressure on the surgical site and prevent hemorrhage until it is removed an hour or two later. Antibiotic coverage is maintained for 3 days after surgery.

It is not unusual to encounter a high proportion of morphologically abnormal sperm in the period immediately after vesiculectomy; detached heads usually predominate. A slow return to normal sperm motility and morphology over about 4 to 6 weeks can be expected. Most bulls recover well and return to natural or artificial service. Sperm retain their ability to survive cryopreservation after unilateral vesiculectomy.

PENILE SURGERY (FOR UROLITHIASIS SEE CHAPTER 23)

Robert O. Gilbert

Examination of the Penis

Any factor that causes inability to mate is called *impotentia coeundae*. The cause of such impotence may lie outside the genitalia. It is therefore necessary to exclude poor libido or lesions of the neuromusculoskeletal system before exploring the possibility of lesions of the penis or its adnexa. Note that any lesion that causes *impotentia coeundae* may eventually result in loss of libido, so absence of libido does not guarantee that the original lesion is not one of the penis or other genitalia.

The examination is designed to detect lesions of the penis, retractor penis muscles, prepuce, or connective tissue surrounding the penis, all of which may interfere with the ability to mate successfully. Visual inspection, palpation, special examinations, and observation of mating attempts may be required to acquire a comprehensive understanding of the state of the ruminant's penis.

A general physical examination should be done to rule out lesions of the neuromusculoskeletal system that may prevent normal mating or mating behavior. The bull or ram is examined in motion, and particular attention should be paid to the feet, joints, sensation of the skin, muscular development and symmetry, or any other lameness or neurologic deficit in the restrained animal.

Visual inspection of the external genitalia and initial palpation do not require any special physical or chemical restraint beyond those readily available in most circumstances. If no cause of impotence can be established, the bull or ram should ideally be observed in one or more mating attempts. For this purpose females in estrus are ideal, but restrained animals may suffice. Some males, especially those of certain breeds (zebu breed bulls), are shy and may not mount or mate readily while under observation. This need not imply a lack of libido or mating ability.

Further examination requires exteriorization of the penis, preferably under pudendal nerve block (as described earlier). Anesthesia of the pudendal nerves achieves sensory block of the free end of the penis as well as relaxation of the retractor penis muscles. It is ideal for penile examination as well as surgical procedures of the penis that can be undertaken in the standing animal.

Penile Hematoma

Perhaps the commonest penile lesion is hematoma or its sequelae (abscessation or adhesion). A hematoma results from sudden or forceful bending of the erect penis. During the peak of erection, blood pressure within the corpus cavernosum penis rises to astronomical levels. Deviation of the penis at this point (by sudden movement of the cow or by thrusting of the bull against the thigh of the cow before intromission is achieved), results in rupture of the tunica albuginea and hemorrhage. The hematoma may be exacerbated by repeated mating attempts by the bull. The site of the hematoma is almost always on the dorsal or lateral aspect of the penis, distal to the distal curve of the sigmoid flexure (Figure 16-17*A*). At full erection, this part of the penis comes to lie at the preputial orifice, which acts as a fulcrum against which the bending force is exerted. Furthermore, this is the site of attachment of the retractor penis muscles. The ventral attachment of the retractor penis muscles allows only ventral or lateral movement of the penis, resulting in dorsal or lateral rupture.

Diagnosis of penile hematoma is usually uncomplicated. The bull may exhibit signs of pain such as an arched back or altered gait, but this is uncommon. The lamina interna of the prepuce may protrude, indicating that the penis is not withdrawn fully to its normal resting position. In some cases paraphimosis (inability to withdraw the penis itself back into the prepuce) may be seen. The swelling is almost always just cranial to the scrotum, reflecting the position of the site of rupture on the partially withdrawn penis. It may not be obvious on inspection, requiring palpation to appreciate its full extent.

The prognosis and clinical approach are both influenced by the size of the hematoma. In cases where the swelling is less than 15 cm in diameter, surgery is not usually required. Most of these bulls have a good prognosis for return to normal service behavior with conservative therapy. The bull should be removed from cows for 6 weeks. Daily hydrotherapy with cold water in the acute stage after the injury (about 4 days) and warm water thereafter, coupled with vigorous massage in a deliberate attempt to move the skin, intervening layers of fascia, and the penis to minimize formation of adhesions between these structures, is recommended. The hydrotherapy and massage should be continued for 3 weeks. Nonsteroidal antiinflammatory drugs may be beneficial during the first week. The bull should be reexamined before being returned to service, and his initial mating attempts should be observed to ensure return to copulatory function.

Complications include abscessation or extensive adhesions. These can be corrected surgically, but the prognosis is usually poor. If the dorsal nerve of the penis is damaged, the free end of the penis may lack sensation, in which case intromission may be impaired and normal ejaculation is impossible. Semen may be collected from these bulls by electroejaculation for artificial insemination.

When the initial hematoma is over 15 cm in diameter, more extensive damage to the penile adnexa (telescoping fascia) results, making restrictive adhesion formation more likely. Risk of abscess formation is also increased. These factors account for the poorer prognosis and the preference for surgical therapy. Surgery may be performed in the standing animal, but general anesthesia is preferable. The skin covering the area of swelling is clipped and prepared for surgery. The skin incision should be as small as practical, as a larger incision allows more opportunity for firm adhesions to form between the skin and the underlying tissues. Blood, blood clots, and serum are gently removed, with attention paid to hemostasis. The penis is examined (Figure 16-17*B*), the area debrided (Figure 16-17C), and any detectable rent in the tunica albuginea sutured with absorbable material, with care taken to avoid penetrating suture bites full thickness through the tunica albuginea that might later become a source of leakage and failure to maintain erection. Dead space is occluded as much as possible and the skin closed routinely. Postsurgical treatment should parallel the conservative approach to smaller hematomas.

Most penile hematomas occur in young (3-year-old) bulls, which reflects their inexperience and copulatory exuberance. Recurrence of the injury is common, which suggests that these bulls may have underlying copulatory habits (clumsiness) that predispose them to damage.

Penile hematomas may become infected (probably hematogenously) and develop abscesses. These should be drained surgically and can be left open to drain and heal by secondary intention.

Deviations of the Penis

Spiral deviation of the penis (*corkscrew penis*, Figure 16-18) is the most commonly encountered form of penile deviation. It results from slippage of the apical ligament of the penis when the penis is erect, but before intromission occurs, and thereby prevents intromission. Formation of a spiral in this way is normal at the point of ejaculation, once the penis is within the vagina. Bulls that suffer from corkscrew penis do not demonstrate this deviation at every service attempt, but it may prevent intromission in 50% to 100% of attempts. This condition is therefore more appropriately regarded as premature spiral formation. Whether the predisposition to this condition is inherited is unknown. The only way spiral deviation of the penis can be diagnosed with confidence is by observation of serving attempts. Reproduction of the corkscrew form during electroejaculation is not diagnostic.

Treatment

Surgical repair of spiral deviation of the penis involves anchoring the apical ligament of the penis so it cannot slip

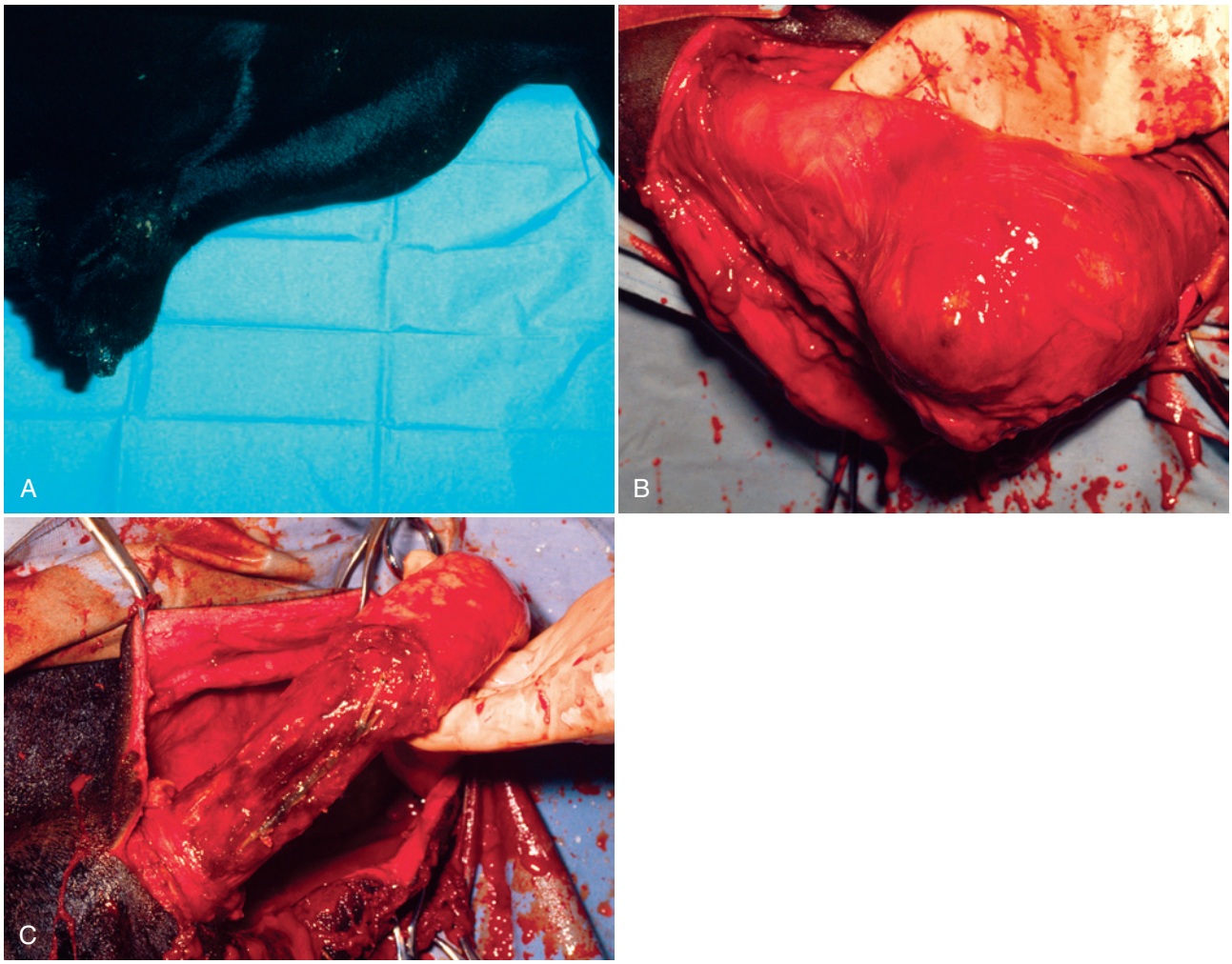


Figure 16-17 *A*, A bull with penile hematoma. Note swelling caudal to the prepuce. *B*, After incision over the site of the swelling, the hematoma can be seen on the penis. *C*, Surgical site after resection of the hematoma. (Courtesy of Dr. David Anderson.)



Figure 16-18 Spiral deviation of the penis (*corkscrew penis*).

laterally and pull the free part of the penis into a spiral or augmenting the apical ligament with an implant. For implantation, one large (Figure 16-19*A*) or multiple thin strips of fascia lata may be used; alternatively, synthetic fibers may be implanted.

Surgery to anchor the apical ligament can be performed in standing animals, under pudendal nerve block, although general anesthesia is preferable. The preputial hairs are clipped. The penis is extended and held in place with penetrating towel clamps carefully placed into the distal part of the apical ligament to avoid penetration of the tunica albuginea (Figure 16-19*B*). A longitudinal incision is made along the dorsal aspect of the penis for about 10 cm, starting 3 cm from the tip of the penis. (This incision will traverse the preputial reflection.) The incision is deepened until the apical ligament is exposed (Figure 16-19*C*). The free edges of the apical ligament are identified, and these edges are carefully tacked to the underlying tunica albuginea, using multiple simple interrupted sutures of synthetic absorbable material. The skin incision is closed with absorbable material. The surgical site is covered with antimicrobial ointment to provide lubrication. Postsurgical care requires inspection to ensure adhesions are not forming; most bulls move the penis a great deal during normal daily activities, and adhesion is a rare problem. The bull should be housed alone for 4 to 6 weeks after surgery and not be allowed to be sexually excited.

For implantation of the apical ligament, the bull must be under general anesthesia and in lateral recumbency. The area of the uppermost thigh (usually left) is prepared for

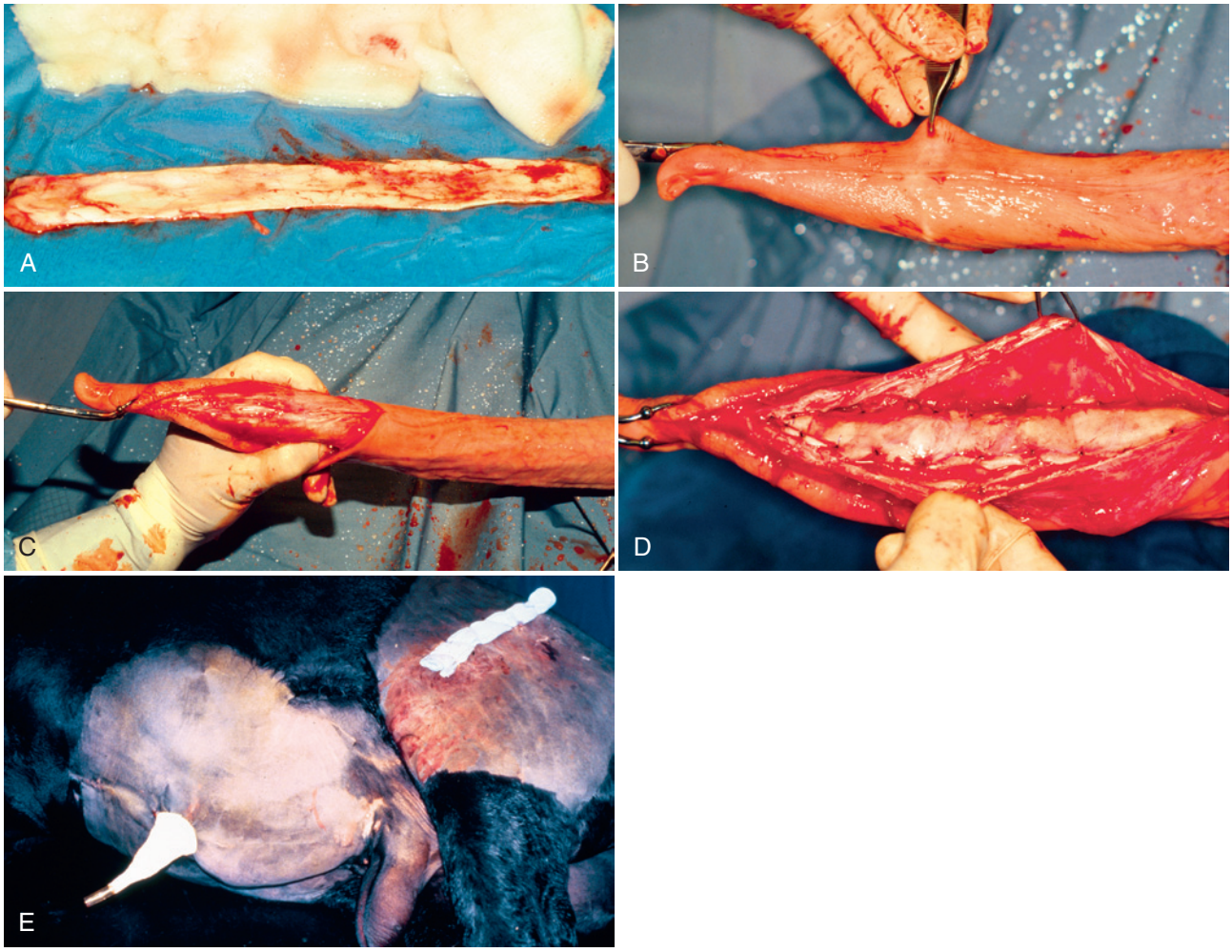


Figure 16-19 *A*, Strips of fascia lata used for reinforcement of apical ligament. *B*, The penis is held with a penetrating towel clamp placed in the apical ligament. *C*, The penile integument is incised before placement of the graft. *D*, Surgery site after placement of the fascial graft. *E*, A stent is placed at the site from which the fascial graft was harvested. (Courtesy of Dr. David Anderson.)

surgery. A 15-cm skin incision is made midway between the tuber coxae and a point about 15 cm caudal to the patella and the fascia lata identified (Figure 16-19*E*). Three or four strips of fascia lata, each about 10 cm long and 0.5 cm wide, are harvested and placed on moistened cotton sponges. Alternatively, a single strip of fascia lata about 10 cm long and 1.5 cm wide is obtained (see Figure 16-19*A*). The defect in the fascia lata is closed with absorbable sutures, and the skin incision is closed in a continuous pattern with nonabsorbable material and a stent sutured in place (see Figure 16-19*E*).

The penis is extended and prepared for surgery. Open or closed methods can be used for inserting the fascia strips. The authors prefer the closed method for its simplicity. A 2-cm longitudinal incision is made 3 cm from the tip of the penis on the dorsal aspect. A fascia strip is threaded through the eye of a blunt needle probe, which is then inserted into the incision and directed proximally along the dorsum of the penis. A small incision is made over the tip of the probe proximal to the preputial reflection and it is withdrawn, leaving the fascia strip in place. This is repeated for each strip, and the surgeon should try to spread them evenly across the dorsal aspect of the penis. The incisions in the penile integument are closed with fine absorbable material after cutting off excess lengths of the fascia implants. The fascia strips need not be sutured in place. Care must be taken to ensure that the fascia strips are not exposed to air because exposed ends may result in local granuloma formation.

For the open method, a longitudinal incision is made along the dorsal aspect of the penis, exposing the apical ligament (see Figure 16-19*C*). The ligament is carefully incised and the tunica albuginea is exposed. The fascial strips are laid carefully on the tunica albuginea, the defect in the apical ligament closed, and the skin incision closed. Alternatively, one large strip is sutured in place (see Figure 16-19*D*).

Use of synthetic materials, such as carbon fibers, has been described for each of these procedures. Implantation of fascia lata strips may also be effective for treatment of ventral deviation of the penis.

ERECTION FAILURE

Erection failure caused by leakage from the corpus cavernosum penis is a well-described cause of impotence in bulls. In this species, the normal circulation of the corpus cavernosum penis is a closed system. Blood enters the corpus cavernosum penis via the paired deep pudendal arteries at the level of the crura penis and leaves via the homologous

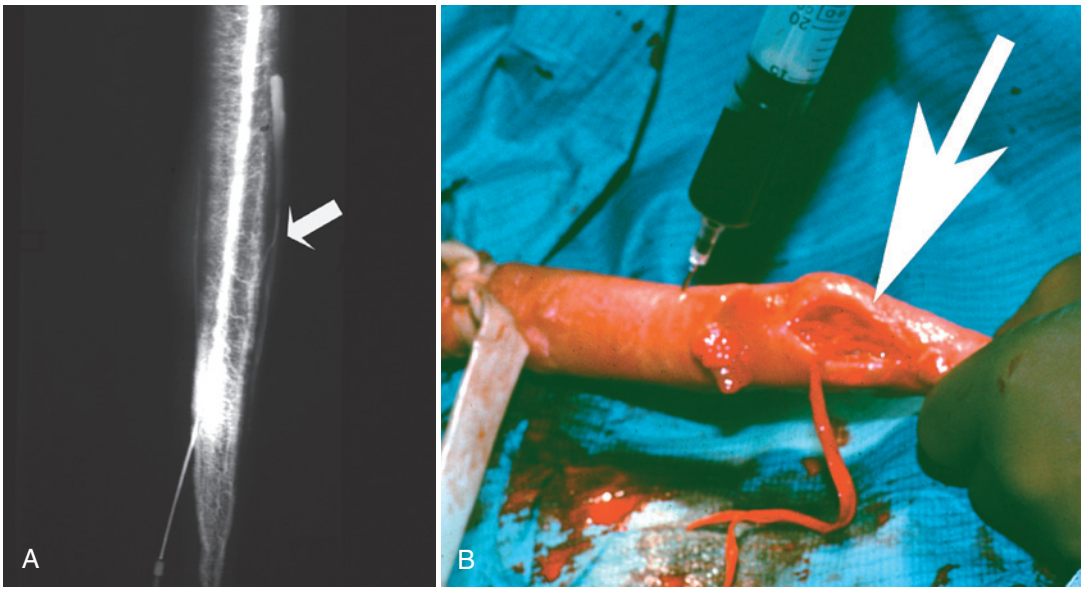


Figure 16-20 *A,* Contrast cavernosogram that shows contrast medium escaping from the corpus cavernosum penis (*arrow*). In normal bulls, the contrast medium remains entirely within the corpus cavernosum penis. *B,* Intraoperative view of correction of cavernosal shunt. *Arrow* indicates site of leakage from the corpus cavernosum penis. Syringe containing methylene blue is inserted into the corpus cavernosum; injection of a small volume confirms correct identification of the leaking vessel by its blue discoloration.

veins. The corpus cavernosum penis communicates neither with the corpus spongiosum penis nor with the superficial vasculature of the penis. In the first stage of erection of the bovine penis, musculature that retains the normal resting position of the penis is relaxed. Arterial dilation allows passive filling of the cavernous spaces of the corpus cavernosum penis, and the penis is extended in response to sexual stimulation. During and immediately before mounting, contraction of the ischiocavernosus and bulbospongiosus muscles produces a short-lived but dramatic increase in blood pressure within the corpus cavernosum penis. Full erection is therefore achieved by the addition of very little blood volume but a great increase in blood pressure. Any leakage of blood from the corpus cavernosum penis can therefore impede erection. Vascular shunts usually communicate with the superficial penile vessels, but in some cases communication between the corpus cavernosum penis and corpus spongiosum penis occur.

Cavernosal vascular shunts must be differentiated from ventral deviation of the penis (*rainbow penis*), which is attributable to a defect of the apical ligament of the penis. In ventral deviation, the penis does not achieve its full length while straight, and it remains rigid. In the case of cavernosal shunts, the penis is usually extended normally, but erection is maintained only momentarily before the penis becomes flaccid and droops. Careful observation is required to make the distinction. Definitive diagnosis depends on contrast cavernosography. For contrast cavernosography, the bull is anesthetized and positioned in lateral recumbency. An 18-gauge needle, attached to an extension set, is inserted into the corpus cavernosum penis 10 cm from the tip of the penis. Sterile saline should flow freely when injected. A survey (plain) radiograph is taken to confirm suitability of exposure factors. Following this, 10 mL of water-soluble contrast medium is injected into the corpus cavernosum penis and a series of radiographs—ventrodorsal, lateral, and oblique—taken. It may be advantageous to place a tourniquet around the base of the penis to achieve elevated pressure of the contrast medium and thereby more closely simulate the normal physiology. In normal bulls the contrast medium remains confined to the corpus cavernosum penis. In the case of shunts, contrast medium can be seen outside of the corpus cavernosum (Figure 16-20*A*). With care, the position of the leakage can be identified. If there is communication between the corpus cavernosum and the corpus spongiosum, surgery is impossible. If the communication is with a superficial vessel, this vessel can be identified at surgery and firmly ligated at its point of emergence from the corpus cavernosum penis (see Figure 16-20*A*), including superficial bites into the tunica albuginea of the penis with fine absorbable suture material. If doubt exists during surgery as to the correct identification of a communicating superficial vessel, a small (2-3 mL) volume of dye (e.g., methylene blue) can be injected slowly into the corpus cavernosum penis; it will be seen escaping from the corpus cavernosum penis via the communicating vessel (Figure 16-20*B*). The bull should be allowed 6 weeks of sexual rest.

Cavernosal shunts are believed to arise from the congenital presence of communicating vessels. Some cases may follow traumatic or iatrogenic penetration of the corpus cavernosum. At surgery, the communicating vessels appear normal, and similar vessels can be found upon dissection of slaughterhouse material from presumably normal bulls, leading this author to favor an explanation that leakage constitutes a functional aberration rather than an anatomic one.

PENILE TUMORS

The most common tumor of the bovine penis is fibropapilloma (Figure 16-21). These are usually encountered in young bulls. In bulls that are group-housed, as, for example, in a beef bull performance test, penile fibropapillomata may occur in large numbers of animals. Although there is some controversy about this, this author's experience strongly suggests that commercial wart vaccine diminishes the incidence of the condition.

Penile papillomata interfere with breeding by making intromission impossible in some cases or uncomfortable in



Figure 16-21 Penile fibropapilloma. The tip of the penis is held by a sponge.

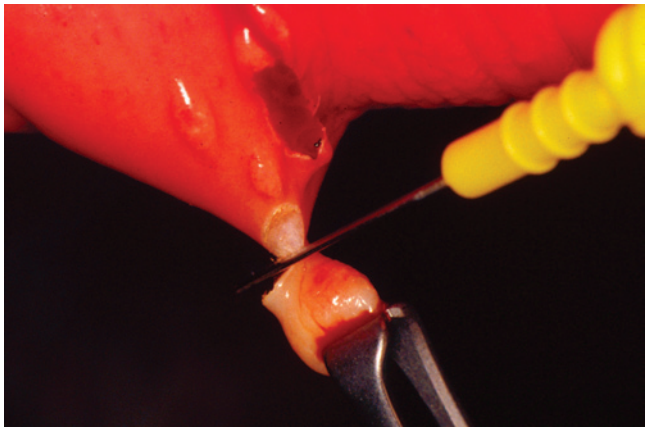


Figure 16-22 Removal of penile fibropapilloma with electrocautery. (Courtesy of Dr. David Anderson.)

others. Bleeding interferes with semen quality. The papillomata generally regress spontaneously with time but are usually removed to provide a rapid and certain return to use.

Removal is usually done in the standing bull with appropriate restraint, sedation if necessary, and local (dorsal penile nerve) or regional (pudendal) nerve block. Most penile papillomata are pedunculated. They may be removed by sharp dissection, electrocautery (Figure 16-22), or cryosurgery. The integumentary defect is sutured if necessary. The bull should be sexually rested for 3 weeks.

When papilloma-like lesions are encountered in mature bulls, histologic confirmation of the lesion type by biopsy is indicated; rarely, aggressive, malignant fibrosarcomata may be encountered in the bovine penis. Culling is indicated in these cases.

PENILE PROCEDURES FOR TEASER BULLS

Several methods are used for producing teaser bulls for identification of cows in estrus. These include vasectomy, epididymectomy, and preputial relocation or obliteration, discussed in this chapter. Ideally, teaser bulls should be young, virile, and healthy, and the procedure should cause sterility and prevent intromission to limit any potential spread of disease.

Young bulls are generally most active and make the most desirable teasers. With any procedure, particularly those that make intromission impossible, most teaser bulls usually lose interest after a variable time—1 or 2 years. Alternatively, they may become frustrated and very aggressive. It is good practice to use teaser bulls for only 1 year—or at most 2—and plan on regular replacement before bulls become very large or unmanageable.

Penile tie-down (phallopexy) is a procedure that creates a permanent adhesion between the penis and the ventral body wall. With the patient in dorsal recumbency, the ventral abdomen is prepared for sterile surgery. A 5-cm longitudinal incision is made midway between the scrotal neck and the preputial orifice, at the level where the prepuce meets the abdomen. The incision is deepened until the linea alba is exposed. Loose connective tissue is dissected from the penis, and the urethra is identified by palpation. The dorsal aspect of the tunica albuginea of the penis (opposite the urethra) is attached to the linea alba by multiple interrupted sutures of heavy nonabsorbable suture material placed approximately 1 cm apart and penetrating 1 cm into the body wall and a similar distance into the penis. The skin is closed routinely.

The penis may be attached to the skin of the escutcheon more simply. In the standing bull under epidural analgesia, the skin of the escutcheon, from the scrotal neck to the anus, is prepared for surgery. A skin incision is made over the area where the distal loop of the sigmoid flexure is palpable and is deepened until the penis is identified. Sutures of heavy, nonabsorbable material are placed in the tunica albuginea of the penis and through the skin adjacent to the skin incision. This is done on each side of the incision. Care must be taken to identify and avoid the urethra (closest to the incision) by placing the sutures in the penile tunica albuginea on the (lateral) sides of the penis. It is convenient to include the distal portion of the retractor penis muscles in the sutures, and this helps stabilize the penis.

Penectomy, or phallectomy, may be performed at the same surgical site dorsal to the scrotal neck. A skin incision is made as described previously and is deepened until the penis is identified at the level of the distal loop of the sigmoid flexure. The distal portion of the penis can be removed from its abdominal attachments by blunt dissection and firm traction and exteriorized through the incision. The penis is transected about 3 cm ventral to the ventral level of the skin incision. The transection is done at an angle, to provide a ventral flap that can be used to cover the corpus cavernosum to control bleeding. The dorsal artery of the penis is ligated. The urethra is spatulated to provide a suitable aperture for urination and to prevent stricture. The penile stump is attached to the skin with nonabsorbable suture material. A good mucosa to skin seal is essential. The bull must be observed after surgery to ensure that it is able to urinate.

An alternative method of phallectomy is performed with the bull in dorsal recumbency. The preputial cavity is irrigated with a weak disinfectant solution before surgery and the ventral abdomen prepared for surgery. A longitudinal skin incision is made, beginning 5 cm cranial to the scrotal neck and extending cranially for about 15 cm. The penis is identified and freed by blunt dissection, until it can be exteriorized through the incision. The sigmoid flexure is straightened, and a tourniquet is applied near the caudal aspect of the skin incision. The penis is transected obliquely (longer ventrally than dorsally) at a point 10 cm from the preputial attachment. The dorsal penile artery is ligated, and the ventral flap of the penile stump is folded dorsally to cover the corpus cavernosum and sutured in place. The urethra is spatulated and its edges sutured to the penile stump to ensure an adequate orifice for urination. The tourniquet is removed, and adequate hemostasis is ensured by ligation or electrocautery. Then the cranial (free) end of the penis is

removed from its preputial attachments and discarded. The prepuce is sutured to the stump previously created with multiple interrupted sutures of fine absorbable material. The skin is closed with nonabsorbable sutures. This method has the advantage that the bull urinates into the prepuce. The bull must be observed after surgery to ensure that urination is possible.

PERSISTENT FRENULUM

At birth, the integument of the penis is continuous with the lamina interna of the prepuce. Separation occurs at the time of puberty, starting from the tip of the penis and progressing caudally (Figure 16-23). The last area of separation is the penile raphe, along the ventral edge of the penis. In some bulls this separation is incomplete. Although separation of the penis from the lamina interna of the prepuce is usually complete by about 9 months of age, some incomplete separation will be encountered among yearling bulls; this is usually seen as a circumferential zone of pale integument that can be separated with gentle traction. With time, this form of delayed separation usually develops normally. However, some bulls (or rams) retain one or more discrete bands of tissue that connect the free end of the shaft of the penis to the lamina interna of the prepuce (Figure 16-24*A*). These connections prevent straight extension of the penis. As



Figure 16-23 A pubertal bull with ongoing separation between penis and lamina interna of the prepuce (*arrow*). This is normal. If separation is incomplete, a persistent frenulum results. Compare with Figure 16-24*A*.

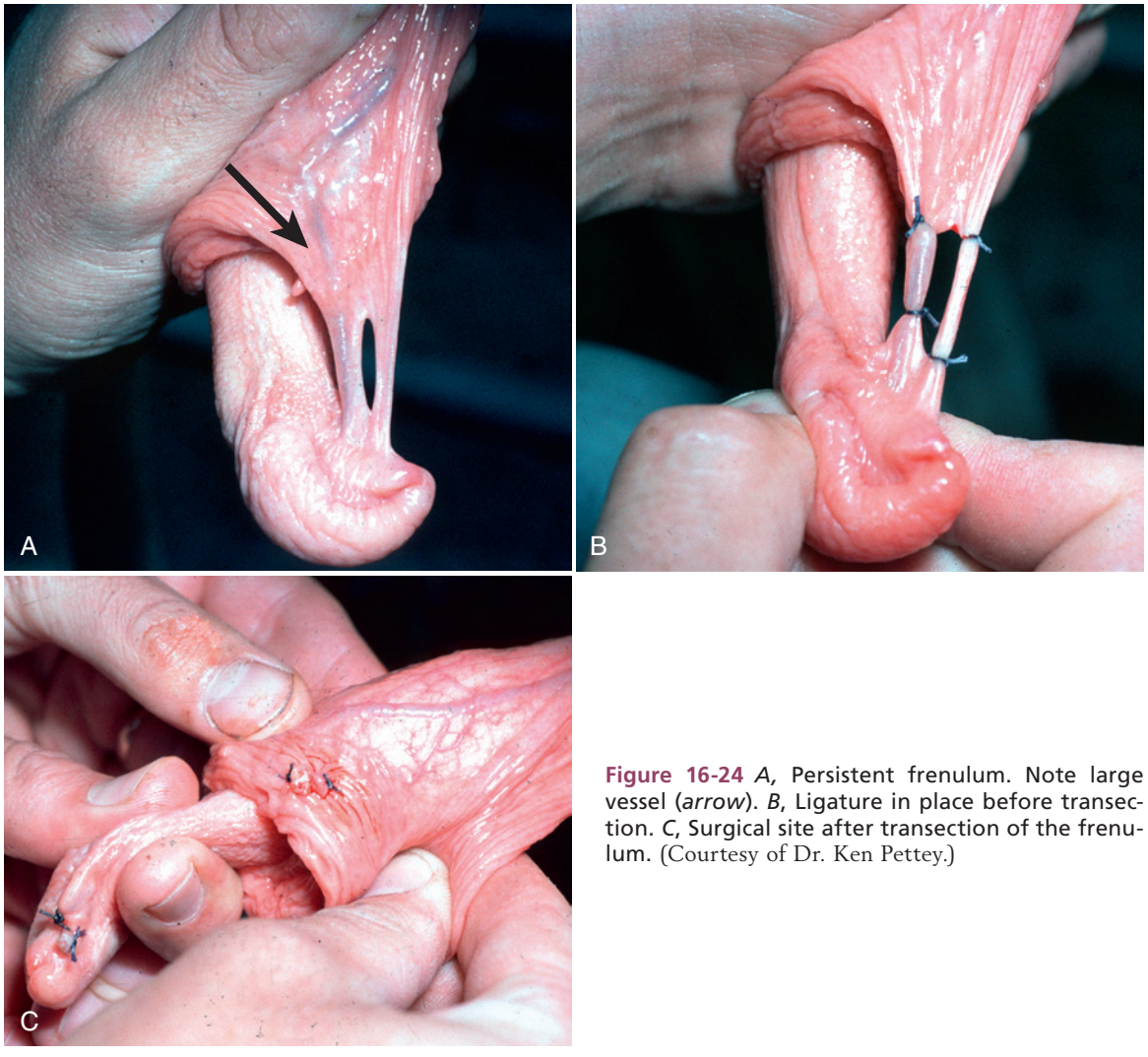


Figure 16-24 *A,* Persistent frenulum. Note large vessel (*arrow*). *B*, Ligature in place before transection. *C*, Surgical site after transection of the frenulum. (Courtesy of Dr. Ken Pettey.)

erection is achieved, the elongated penis is pulled into a bow shape by the persistent frenulum. Should an entire curtain of tissue persist along the raphe, the condition is called *persistent frenum; frenulum* is a diminutive form of *frenum*.

Persistent frenulum is an inherited disorder that can be passed on to progeny. Although it is easily repaired, this should be borne in mind. If all progeny are destined for slaughter, the surgery is justified. Otherwise, the owner should carefully evaluate the risks and benefits before electing to use the bull.

In young bulls the penis can often be extended manually with no or little sedation. Application of a dorsal nerve block is often sufficient to perform this procedure. With the penis extended as far as possible by traction on its free end, a fine needle is inserted through the lamina interna at the dorsal aspect of the preputial orifice. Lidocaine (2%) is injected under the lamina interna and is deposited in a semicircle to cover the dorsal aspect of the penis. This will render the free end of the shaft of the penis insensitive by blocking the dorsal penile nerve before it splits into its terminal branches. Alternatively, pudendal nerve block and administration of xylazine and butorphanol can be used to achieve adequate exposure and anesthesia of the site.

The site of the persistent frenulum is prepared for surgery and then the structure is split between two absorbable sutures (Figure 16-24*B*). Although the persistent frenulum is usually a small structure and can be cut quickly without much preparation, this should be avoided, both for the bull's comfort and because it is often endowed with a generous vein and artery that can be the source of disconcerting hemorrhage (see Figure 16-24*B*). Repair of a persistent frenulum provides instant cure of this condition (Figure 16-24C), and bulls may be used a week after surgery.

PREPUTIAL SURGERY

Robert O. Gilbert

Relocation of the Prepuce and Penis

Relocation of the preputial orifice—and therefore the prepuce and penis to the flank of the animal—allows extension of the penis without intromission and is a common method for production of teaser bulls. The procedure can be performed on bull calves as young as 1 month old or on more mature animals.

The animal is restrained in dorsolateral recumbency to allow access to the midline and to one flank. Heavy sedation and local block or general anesthesia can be used. A generous area from the umbilicus to the scrotum and extending laterally to beyond the flank fold is clipped and prepared for surgery. The initial incision is circumferential around the preputial orifice, with a radius of about 2 to 3 cm. While this incision is made, the skin remaining around the preputial orifice is notched or marked with a colored suture to preserve the correct orientation and prevent later torsion of the prepuce. The skin incision is extended caudally along the midline to within 5 cm of the scrotal neck. By careful dissection, the preputial lamina interna is freed from the surrounding connective tissue and larger vessels are ligated as necessary. The operator must be careful not to incise the prepuce. The lamina should be completely freed from underlying tissue for the entire length of the incision. Some surgeons prefer to insert a sterile glass or plastic speculum into the prepuce to facilitate its dissection. It is important to preserve some connective tissue with the prepuce to ensure sufficient blood supply. Without stretching the prepuce, one moves it to the side and marks a spot lateral to the flank fold to which it can be relocated. A circular piece of skin with a diameter 1 inch smaller than the freed preputial orifice is resected; note that the removal of the skin leaves a bigger defect than the size of the skin removed. A tunnel toward the base of the scrotum is created by means of blunt dissection with a Knowles cervical forceps or similar large forceps. Once a tunnel of suitable size has been made, the free preputial orifice—covered with a sterile surgical glove and lubricated with antimicrobial ointment—is grasped and withdrawn toward the newly prepared site, with care taken not to twist the prepuce in the process or to allow sharp bends or kinks. The new preputial orifice, former site of the preputial orifice, and the longitudinal skin incision are all closed with an appropriate suture pattern.

The prepuce must be relocated to a site lateral to the flank fold. Placement of the preputial orifice more medially allows bulls to achieve intromission in a large number of cases (Figure 16-25). Some bulls are sufficiently motivated to learn to achieve intromission in spite of correct preputial relocation. This makes it prudent to perform vasectomy or epididymectomy at the same time.

After surgery, the area surrounding the newly relocated preputial orifice should be covered with petroleum jelly to prevent urine scald. This should be reapplied twice daily for the first week. Systemic antibiotics should be given for 3 days after surgery. The bull is observed carefully to ensure that he is able to urinate freely. There is often some swelling of the relocated prepuce, and it may take a day or two before it assumes a normal skin color, which indicates reestablished circulation. Complications are rare.

Preputial obliteration is an alternative method for producing teaser bulls. In this procedure, the preputial orifice is permanently closed and a fistula created for drainage of urine. The patient is restrained in lateral recumbency and the penis extended. A 1-inch Penrose drain is sutured over the tip of the penis with fine absorbable suture material. A 1- to 2-cm-diameter circle of skin is removed ventrally, about 5 cm caudal to the preputial orifice. A corresponding amount of subcutaneous tissue is removed, and the lamina interna of the prepuce is identified and similarly incised. (Insertion of a blunt probe into the prepuce helps identify it.) The preputial lamina interna is sutured to the skin with simple interrupted sutures, thus creating a fistula, and the free end of the Penrose drain is passed through the fistula. The end of the prepuce is removed by cutting through skin, subcutaneous tissue, and preputial lamina interna. These structures are then sutured in three layers. The Penrose drain carries



Figure 16-25 A bull with laterally translocated prepuce. Ideally, the newly created preputial orifice should be adjacent to the fold of the flank.

urine past the fresh incision and helps prevent stenosis. The skin sutures and Penrose drain are removed after about 3 weeks.

Individual preference guides the choice of methods for producing teaser bulls. This author prefers preputial relocation combined with vasectomy.

Preputial Avulsion

Avulsion of the lamina interna of the prepuce from its attachment to the penile integument at the fornix, or point of reflection (Figure 16-26*A*), is the most common injury to the penis and prepuce of bulls managed for the collection of semen for cryopreservation. It is observed only in bulls whose semen is collected by artificial vagina and is only very rarely an injury of natural service bulls. This form of injury is costly when it causes temporary suspension of semen collection from extremely valuable artificial insemination bulls that are under considerable pressure to produce semen. These injuries may be left to heal by second intention, but convalescence is prolonged. Surgery, preferably on the same day as injury, is preferred for the bull's more rapid return to use with fewer complications. The etiology of preputial avulsion is not fully understood. This form of injury occurs most often in young bulls newly introduced to semen collection, or reintroduced after a period of layoff (to accumulate progeny data), but has been recorded in all breeds and age groups of bulls.

The semen collector or attendant will usually notice bleeding after semen collection. The diagnosis is confirmed by extending and examining the penis. Particularly in young bulls, the penis can be manually exteriorized after administering 5 mg of xylazine. The penis can then be grasped with dry gauze or held by towel clamps placed into the apical ligament (after anesthesia of the penis is established with a dorsal nerve block or pudendal nerve block (see Figure 16-26*A*). Surgery may be performed on the standing restrained bull or with the bull in lateral recumbency on a tilt table. The penis, prepuce, and ventral abdomen are thoroughly cleansed for surgery. Dorsal nerve block or pudendal nerve block is performed. The extended penis is held in place by an assistant, who uses sponges or a towel clamp placed in the apical ligament. Ligation of any hemorrhaging vessels is performed before closure of the integument. The integument is sutured with absorbable material on an atraumatic needle, with a simple interrupted pattern (Figure 16-26*B* and *C*). The bull should be withheld from service and housed individually until healing is complete. Ideally, the bull should be isolated from cows or other bulls to prevent sexual stimulation. Spontaneous erection may provoke dehiscence of the surgical site, which is usually indicated by bloodstained bedding. If promptly detected, it may be resutured; otherwise it should be left to heal as an open wound.

The bull is examined approximately 30 days after surgery by extending the penis manually or after sedation. The bull should not be allowed to mount a teaser as this provokes full erection. Return to service is allowed after a further 20 to 30 days, provided the surgical site is fully healed and pliable. Although the etiology is not clear, suspicion that atrophy of the preputial lamina interna with subsequent rupture upon stretching may play a role, suggesting that it would be wise to avoid false mounts upon reintroduction to semen collection. In addition, use of a short artificial vagina appears preferable, and its use at a temperature a few degrees cooler than usual may temper the vigor with which a young bull thrusts into the artificial vagina. Most bulls can be returned to service in about 40 to 60 days—a considerably shorter interval than may be expected if surgery is not performed (which may range up to or beyond a year).

Preputial Hair Ring

A ring of preputial hair may occasionally entrap the penis (Figure 16-27). Although this condition is usually spontaneously resolved, the hair may strangulate and damage the

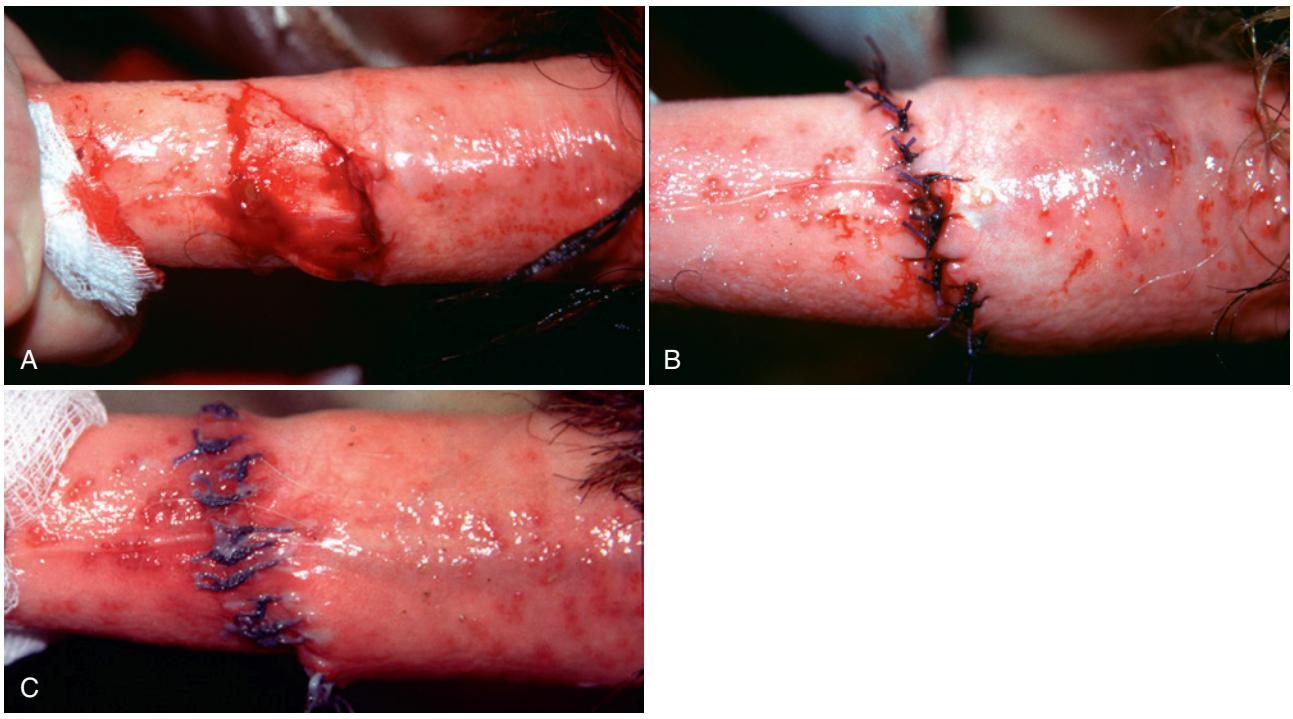


Figure 16-26 *A*, Preputial avulsion. *B*, Immediately after repair of the avulsion. *C*, 2 weeks after surgical repair of the avulsion.

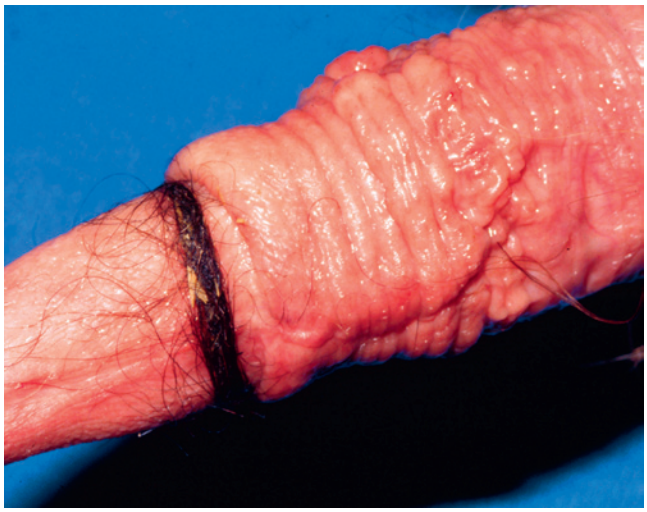


Figure 16-27 A ring of preputial hair. (Courtesy of Dr. David Anderson.)

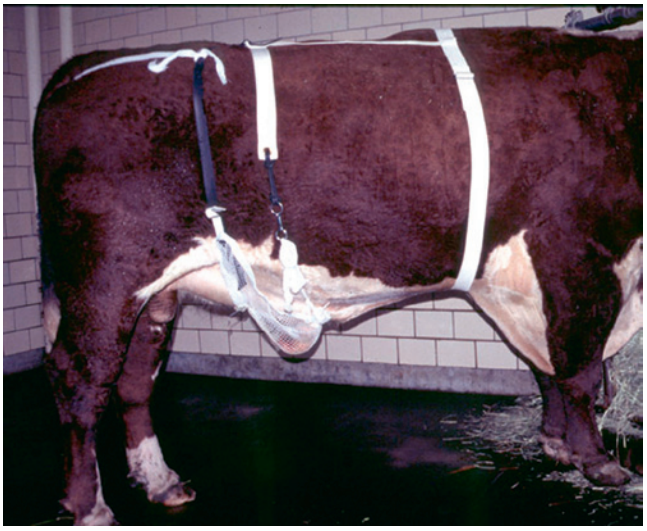


Figure 16-29 A bull with preputial prolapse supported by a truss.



Figure 16-28 A Santa Gertrudis bull with preputial prolapse.



Figure 16-30 Narrow collar of fibrous tissue causing paraphimosis. Final appearance after a longitudinal incision is made through the collar followed by a transverse closure.

penis. Treatment of the resulting lesion must depend on the judgment of the surgeon, but many cases can be sutured as for preputial avulsion.

Preputial Prolapse

Preputial eversion is common in some breeds of bulls—particularly polled breeds and Brahman-influenced breeds. This is thought to result from absence or lack of development of the protractor preputii (cranial preputial) muscles. These muscles are believed to stabilize the lamina interna during movement of the penis and therefore to be instrumental in the prevention of prolapse or eversion. Prolapse of the lamina interna may be constant or may be seen only intermittently, especially during urination and immediately before mating attempts. Prolapse is more common when bulls are stressed. The everted membrane is subject to injury or desiccation. It may become scarred, abscesses may form, and these lesions may be severe enough to prevent penile extension (paraphimosis).

Diagnosis of preputial prolapse is self-evident (Figure 16-28). Early management includes supporting the prepuce until surgical treatment can be performed (Figure 16-29). In some cases, preputial damage and scar tissue may be internal and only diagnosable when the entire prepuce is carefully palpated or inflated with air or water. Sometimes strictures may be located only at the preputial orifice.

If a simple stricture occurs at the preputial orifice, it should be incised longitudinally, beginning at the ventral aspect of the preputial orifices and extending caudally for a few centimeters. The incision is deepened to the lamina interna, which is then sutured to the skin with simple interrupted sutures of nonabsorbable material.

Stricture caused by a narrow (less than 2 cm) band of connective tissue can be treated by making a longitudinal incision in the affected part of the lamina interna, extending 2 cm into normal tissue on each side of the stricture. The incision is then sutured transversely by first suturing the cranial and caudal ends of the incision to each other. The resulting dog ears can be trimmed slightly while suturing, but this is not necessary, and tissue remodeling soon takes care of them (Figure 16-30). This procedure results in a wider lumen and free movement of the penis. The procedure can usually be performed in the standing bull, preferably with a pudendal nerve block.

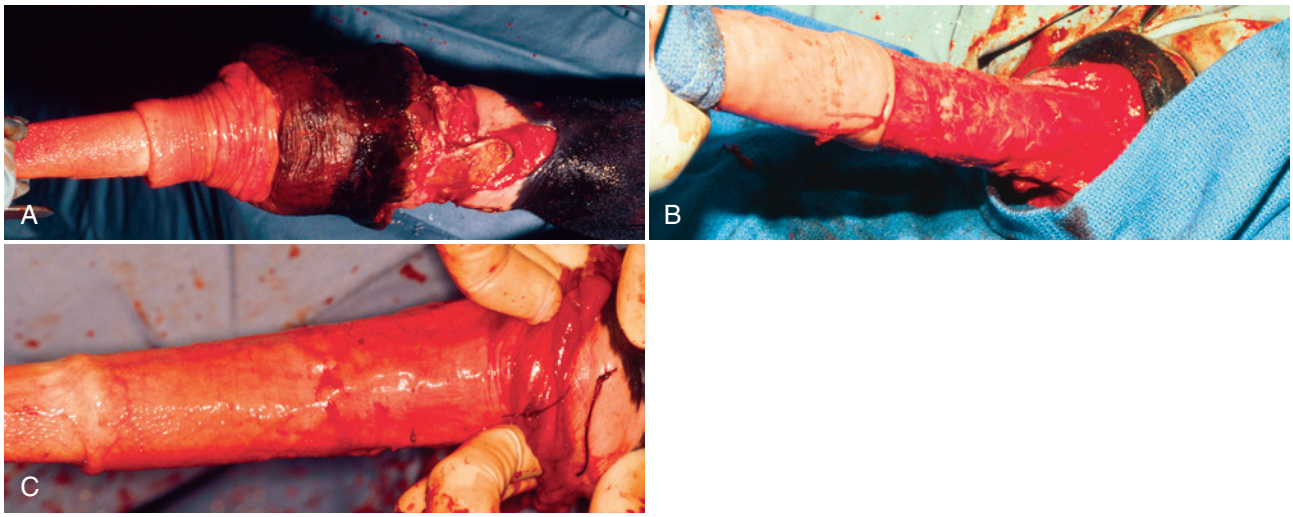


Figure 16-31 *A*, A preputial mass in a bull. *B*, Circumferential incisions are made at each end (cranial and caudal) of the connective tissue collar and it is removed. *C*, The edges of the lamina interna are then sutured together. (Courtesy of Dr. David Anderson.)



Figure 16-32 A bull urinating through a Penrose drain sutured over the tip of the penis. (Courtesy of Dr. David Anderson, The Ohio State University.)



Figure 16-33 A dorsal preputial ulcer in a ram.

More substantial collars of scar tissue (Figure 16-31*A*), whether in the prolapsed part or internal to the prepuce, must be removed by excision (reefing). This surgery is best performed under general anesthesia, with the bull in lateral or dorsal recumbency. Circumferential incisions are made at each end (cranial and caudal) of the connective tissue collar, and it is removed (Figure 16-31*B*). The edges of the lamina interna are then sutured together (Figure 16-31C), with care being taken to preserve their original orientation and prevent twisting of the lamina interna. Attaching a Penrose drain over the tip of the penis with a single absorbable suture and passing it through the preputial orifice allow the bull to urinate without irritating the sutured site (Figure 16-32). Occasionally, this procedure will result in restricture along the suture line. Strategies to prevent this include making the original incisions obliquely if there is sufficient preputial tissue to work with or making a zigzag incision to allow expansion after suturing. When these strictures do recur after surgery, they usually consist only of a narrow band of scar tissue along the incision site. This lesion can usually be treated by longitudinal incision and transverse suturing as described previously. Bulls should be given 6 weeks of sexual rest after surgery.

In rare cases strictures such as those described previously prevent retraction of the penis after erection (phimosis), rather than extension of the penis. They are treated in essentially the same way, except that relief of the phimosis is urgent, to allow urination, and to prevent aggravation of tissue damage and swelling of the penis, which complicate subsequent surgery.

Preputial Erosions

In rams a unique form of decubital lesion occurs dorsal to the preputial orifice (between the prepuce and the abdominal wall) (Figure 16-33). This occurs only in heavy show rams that are confined in small pens. Because the rams are recumbent much of the time, pressure of the preputial orifice on the body wall results in a chronic ulcer. This lesion is resistant to conservative treatment, and the only successful approach is surgical resection.



Figure 16-34 A retropreputial abscess drained through the skin of the prepuce.

Preputial Abscess

Retropreputial abscess may follow injury to the lamina interna of the prepuce (i.e., preputial avulsion or penile hematoma). It is preferable to drain these abscesses into the preputial cavity. Swelling often prevents exteriorization of the penis and access for drainage into the preputial cavity. In these cases, the abscess must be drained by skin incision (Figure 16-34) in spite of the risk of adhesions, which might prevent normal extension of the penis.

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SURGERY OF THE FEMALE REPRODUCTIVE TRACT

SURGERY OF THE OVARY

Susan L. Fubini

Unilateral ovariectomy is performed in cattle for ovarian pathologies such as cystic ovaries, neoplasia, abscess formation, and adhesions. The remainder of the urogenital tract must be normal for a successful return to reproductive performance. Bilateral ovariectomy prevents pregnancy in feedlot heifers, eliminates estrus, simplifies interstate movement of animals from areas of endemic brucellosis, and may enable superior fattening of feedlot heifers in conjunction with growth promoters. Because blood supply to the corpus luteum is substantial, the morbidity of ovarian surgeries, such as ovarian pedicle hemorrhage, can be minimized by performing surgery only when the ovaries are in the follicular or early luteal phase. The ovary is approached by abdominal celiotomy through the body wall or colpotomy through the vagina before performing an ovariectomy. Abdominal laparoscopy can also be used.

Surgical Approaches

Celiotomy

Most unilateral ovariectomies are accomplished via a flank celiotomy. The cow is restrained in standing stocks or a chute, and the appropriate flank is prepared for surgery. General anesthesia may be especially useful for removing very large (>20 cm) ovaries or those with adhesions to the uterus, omentum, or other gastrointestinal viscus. An incision in the caudal paralumbar fossa gives the best access to the ovary. For small ovaries, it may be possible to grid the incision in the internal abdominal oblique muscle by incising the muscle in the direction of its fibers and bluntly extending the incision. This minimizes the incisional defect in the musculature but also limits the manipulations that can be performed. For larger ovaries, a sharp incision through all muscle layers is essential. The ovary is identified and exteriorized (Figure 16-35). If difficulty is encountered when bringing the ovary out of the abdomen, it may be useful to have an assistant hold the ovary in place while the surgeon pushes the body wall around the ovary. If the animal becomes uncomfortable or agitated during manipulation of the ovary, infusing the ovarian pedicle with lidocaine may decrease the painful response as well as increase the risk of hematoma formation because swelling in the vascular pedicle makes individual vessels harder to identify. Alternatively, lidocaine-soaked gauze temporarily placed around the pedicle may

provide sufficient analgesia. Accessibility to the ovarian vasculature is highly variable. An ovary enlarged for a long period of time may have stretched the broad ligament, permitting easier access. Once the ovary has been identified, the vascular pedicle must be ligated. Rarely can each vessel within the ovarian pedicle be individually ligated. Instead, overlapping bites of No. 2 absorbable sutures are placed across the ovarian pedicle. The author prefers No. 2 polyglactin 910,[2] which permits use of sliding half-hitches when the surgeon is placing wide suture bites for hemostasis. Both sides of the pedicle should be examined to ensure ligation is adequate across the whole pedicle. Alternatively, or in addition to sutures, a surgical stapler[3] can be used to place staples across the pedicle. Laparoscopic loop sutures or a vessel sealing device[4] (the LigaSure, Covidien Surgical) can provide a secure ligation of the vascular pedicle. Adequate hemostasis in a smaller ovary may be obtained with an écraseur or emasculator.

If the cow's temperament or medical condition does not permit standing surgery, a caudal flank, ventral midline, or ventrolateral celiotomy can be done in the recumbent cow.

[2]Vicryl, Polyglactin 910, Ethicon, Somerville, NJ, USA.
[3]TA90 surgical stapler, United States Surgical Corp., Norwalk, CT, USA.
[4]Ligasure, Covidien Surgical, Mansfield, MA, USA.

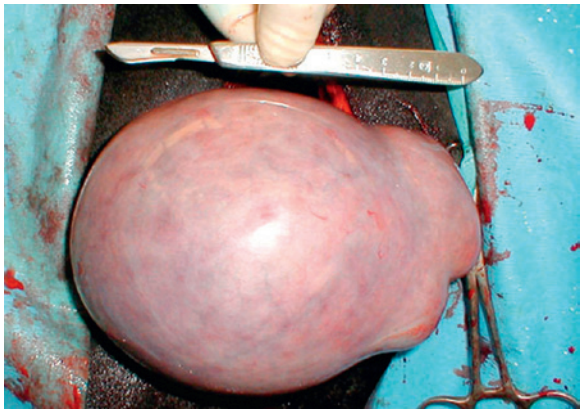


Figure 16-35 Granulosa cell tumor being removed from the right-paralumbar fossa.

The ventral midline approach should be considered in cows with medical conditions that result in chronic ovarian enlargement because it is easy to extend the incision if necessary. The ventral abdominal approach allows good laparoscopic access to the ovary.

In cases where bilateral ovariectomy is desired, consideration should be given to colpotomy and laparoscopic ventral midline approaches that allow access to both ovaries. Another option would be to perform a bilateral celiotomy to access each ovary and ligate the vasculature on each side. Use of an umbilical clamp across the ovarian pedicle has been suggested in animals intended for slaughter.

Colpotomy Approach

Because of the risk of hemorrhage and evisceration, a vaginal approach is only recommended for spaying heifers with small, normal ovaries. In all instances, the animal should be healthy and not pregnant. The animal's size must be adequate for rectal and vaginal manipulation. Withholding feed for 24 to 30 hours may improve access to intraabdominal structures. The heifer should be adequately restrained. The ovaries are identified (one at a time) per rectum to ensure their position and size are as expected, and all feces are evacuated. If the urinary bladder is full, the cow should be stimulated to urinate or be catheterized. The perineal area is cleansed with appropriate aseptic technique, and the vagina is lavaged with a dilute antiseptic solution and rinsed with sterile saline. This helps create a pneumovagina, which may aid manipulations. The hand and arm are ensheathed in a sterile, impervious sleeve. The vaginal wall is incised adjacent to the cervix at the 10- or 12-o'clock level with a scalpel blade or instrument designed for an ovariectomy. If a scalpel blade is used, it should be placed on a handle or secured to the surgeon's hand with umbilical tape or rolled gauze in case it is inadvertently dropped. The blade is held between the thumb and forefinger with 2 to 3 cm of blade protruding. Entry into the abdominal cavity and avoidance of the retroperitoneal space should be confirmed. The incision is digitally enlarged to first permit entry of several fingers and then the hand and arm.

The surgeon locates the ovaries and uterus before palpating once again for any abnormalities. It may be useful, especially in a fractious animal, to place lidocaine-soaked gauze around the ovarian pedicle before the ovariectomy.

Ovaries can be removed via colpotomy with different commercially available or hand-made instruments. These include a chain écraseur (Figure 16-36*A* and *B*), a

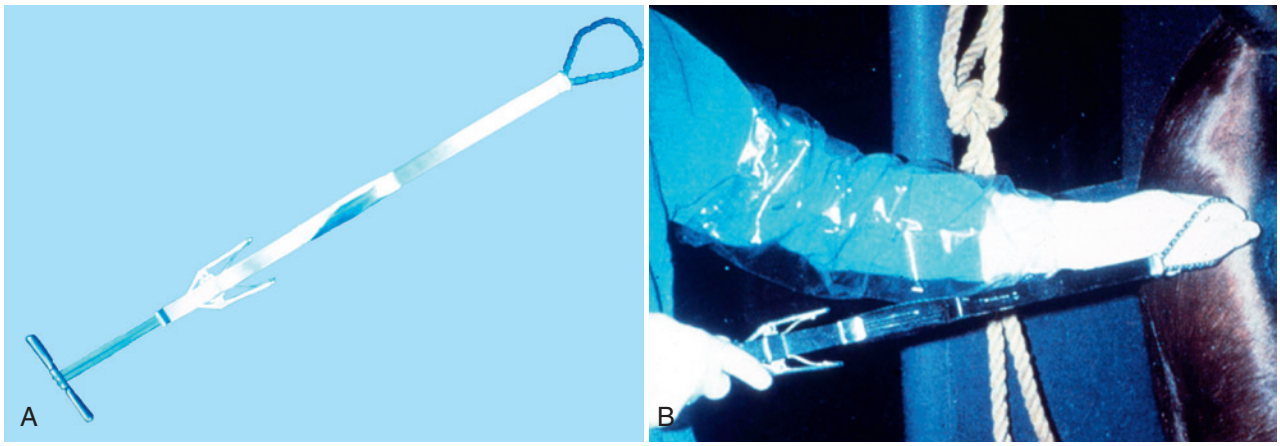


Figure 16-36 *A,* Chain écraseur instruments designed for an ovariectomy. *B,* Positioning of the écraseur on the surgeon's hand.

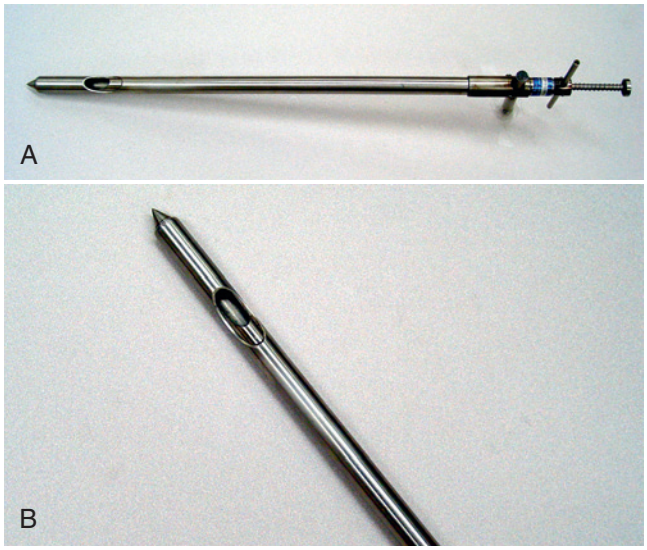


Figure 16-37 *A,* Kimberling-Rupp instrument designed for an ovariectomy. *B,* Close-up view. (Courtesy of Dr. Carlos M. Gradil.)

Kimberling-Rupp[5] spay instrument (Figure 16-37*A* and *B*), a modified emasculator, or a Willis rod.[6]

To use a chain écraseur, a gloved hand is passed through the chain loop to grasp the ovary. The chain is then slipped over the ovary and the hand withdrawn. The chain is gradually ratcheted down tightly around the ovarian pedicle. It is essential that the surgeon check that only the ovary is ensheathed by the chain and that all other intraabdominal structures are free. Once the loop has closed, the ovary and écraseur can be removed. The other ovary is removed in a similar manner through the same vaginal incision. The vaginal incision is left to heal as an open wound.

The Kimberling-Rupp instrument is a long narrow instrument with a trocar point on a tube within a tube. Windows in the tubes are used to introduce the ovary into the inner tube. To use the instrument, the surgeon has one arm in the rectum and the other gloved hand directs the instrument at the 10- to 12-o'clock range through the vaginal wall into the peritoneal cavity with a short, moderate, anterior thrust. As soon as the peritoneum is penetrated, the near handle is released to retract the trocar point. The instrument is positioned dorsal to the hand manipulating the reproductive tract. The ovary is palpated to be sure it is free from other structures before it is pressed firmly into the indented cutting area on the instrument while the inner cutting tube is rotated. When the ovary passes into the chamber, the inner tube is reversed, thus entrapping the ovary in the chamber. Once it is certain the rectum is not caught in the instrument, the cutting chamber is closed, thereby excising the ovary. The ovary can be pushed forward on the instrument for temporary storage by depressing the plunger with a thumb. The procedure is repeated for the second ovary.

Another instrument used for ovariectomy is the Willis rod. This is a single flat rod with a keyhole opening for ovary removal. The procedure is initially the same as described previously. Once in the abdomen, the ovary is placed, via rectal manipulation, into the keyhole opening on the spay instrument. The instrument is then forcefully retracted to sever the ovarian pedicle. The procedure is repeated for the opposite side. This technique leaves the ovaries in the peritoneal cavity. It has been reported anecdotally that an ovary with a functional corpus luteum removed in this fashion may have the capacity to revascularize from peritoneal surfaces and maintain a pregnancy.

[5]K-P spay instrument, Lane Manufacturing Co., Denver, CO, USA.
[6]Willis ovariectomy instrument, Willis Veterinary Supply, Chamberlain, SD, USA.

Outcome

A 1992 paper by Drost et al details for research purposes unilateral ovariectomy in 17 cattle, bilateral ovariectomy in 9 cattle, and removal of corpora lutea in 11 beef cows via colpotomy. They used either a Kimberling-Rupp instrument, a 70-cm plexiglass rod with a 2-cm diameter and a 45° pointed end, a 65-cm-long piece of polyvinyl chloride pipe with a 50° beveled end, a bloat trocar, or scissors to make the vaginal incision. The ovaries or corpora lutea were removed with an écraseur. They described adhesions in 24.3% of cows examined, although none would have caused any life-threatening problems. The sharp trocar and scissors were not recommended for the colpotomy incision because the resulting incision was too difficult to find. The two rods worked well and were a less expensive alternative to the Kimberling-Rupp instrument.

With all ovariectomy procedures, the biggest risks are hemorrhage, adhesions, and peritonitis. Perioperative antibiotics and analgesics are indicated.

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SURGERY OF THE UTERUS

Susan L. Fubini

Relevant Surgical Anatomy

The cow has a tortuous 20- to 28-cm-long uterine tube with a fimbriated infundibulum, which is large and may completely envelop the ovary. A nonpregnant adult cow has 35- to 45-cm-long uterine horns that are united closely at the body of the uterus but diverge and spiral ventrally, caudally, and finally dorsally. The horns are joined just before their divergence by an intercornual ligament. The body of the uterus is only about 3 cm long. With repeated pregnancies, the uterus becomes thicker walled and the spiral of the horns becomes flatter. The broad ligaments that suspend the

uterus from the lateral wall of the pelvic cavity are extensive and become thickened with multiple pregnancies. The round ligaments of the uterus arise from the lateral surface of the broad ligaments. They serve to elevate and lower the uterus.

The cervix is a substantial barrier to the uterine lumen. In addition to the normal layers of viscus, the ruminant cervix is infiltrated with collagenous fibers that make it exceedingly tough. The number and regularity of the annular rings varies with the species: the cow has three to five, the ewe five to six, and the doe five to eight. The cervix rarely dilates except under hormonal influences. Injury to the bovine cervix (often subtle) may occur at parturition, resulting in prolonged inflammation and associated infertility, but is not amenable to surgical repair.

Cesarean Section

The goal of cesarean section in cattle is to relieve dystocia when vaginal delivery is not possible or is unlikely to produce live offspring. The indications for surgery include maternal reasons such as a relatively oversized fetus (particularly in heifers that are immature or recipients of embryo transfer calves), inadequate cervical dilation, abnormal pelvic conformation, prepubic tendon rupture, uterine rupture, uterine torsion, uterine inertia, hydrops of the amnion or allantois, and congenital or traumatically induced vaginal constriction. Fetal indications include fetal malposition that is not correctable per vagina, absolute fetal oversize, fetal monsters, and emphysematous fetuses. Other, ancillary indications include elective cesarean section for the delivery of embryo transfer calves, the production of gnotobiotic calves, or terminal cesarean sections.

A general physical examination should be performed on the cow, including assessing the animal's attitude, appetite, and hydration status. The mammary gland should be checked for mastitis, and it is appropriate to check ear temperature and rumen motility as indicators of hypocalcemia. More sophisticated laboratory tests, such as determining plasma electrolyte concentrations, are rarely indicated. After a physical examination, a reproductive examination consisting of a rectal examination to assess the uterus and position of the calf and a vaginal examination to determine whether the cervix is dilated and calf presentation is normal should be performed. Ballottement of the abdomen from the right and left sides may indicate the side of the abdomen where the calf is located.

Surgical Approach

Many factors are weighed to determine the best approach for cesarean section, including the experience and preferences of the surgeon, temperament of the cow, available facilities, and whether assistance is available. It is also useful to ascertain if the calf is dead or alive. If the calf is dead, it is helpful to determine the state of the uterus, whether it feels normal or contracted down around the calf, or—even more important—whether the calf is emphysematous. Finally, the vascularity of the cow's ventral abdomen also enters into the decision making.

A rule of thumb is that the rumen is easier to manipulate than the rest of the intestinal tract. In most instances, it is easier to deal with the rumen on the left side of the abdomen than manipulating around the intestinal tract on the right side.

When preparing for cesarean section, one should consider the available facilities. A chute or stocks are ideal restraint for a standing celiotomy. For recumbent procedures, sedation and a local anesthetic should be used, and there should be a place to secure the head and limbs of the cow. These authors prefer to sedate only animals that are being positioned in lateral or dorsal recumbency because of the risk of the animal becoming recumbent when tension is applied to the uterus and its ligamentous attachments. If the cow is straining, an epidural is appropriate for either standing or recumbent approaches. No more than 5 cm^3 of local anesthetic should be used in the standing cow to avoid the risk of the cow becoming recumbent. Perioperative antibiotics should be administered depending on the cow's value and condition of the fetus. Intravenous fluids are seldom necessary. In most instances, the surgical site can be desensitized with a local anesthetic, and it may be appropriate to administer analgesics (such as flunixin meglumine) to increase the likelihood the animal will stay standing. If nonsteroidal antiinflammatory drugs are used, withdrawal times for milk and meat must be considered, as must potential postpartum complications such as retained fetal membranes and uterine disease, the incidence of which may be increased by use of nonsteroidal antiinflammatory drugs. Appropriate preparations include an assistant to aid in delivery of the calf, saline lavage of the uterus, chains for delivery of the calf, and oxytocin to administer postoperatively for uterine contraction.

Standing Paralumbar Fossa Celiotomy

The abdominal cavity can be approached via a standing paralumbar fossa celiotomy on the right or left side of the abdomen. The incision should be made in the caudal third of the fossa (Figure 16-38) to facilitate exteriorization of the uterus (Figure 16-39). The celiotomy should be large so that delivery of the uterus is more easily accomplished. If the right side is elected, the incision should not extend too far ventrally so there is no problem with intestines prolapsing out of the surgical incision. A sharp skin incision approximately 40 cm long is made in the skin and continued through the subcutaneous tissue as well as the internal and external abdominal oblique muscles. The peritoneum and transversus abdominis should be tented with a forceps and incised with scissors. A finger should be inserted into the abdomen and the peritoneum should be swept for any adhesions before the incision is extended. The peritoneum can be left open or closed with the transversus abdominis. The external and internal abdominal muscles are closed next, followed by the skin. A simple continuous pattern using an absorbable suture material can be used on all muscle layers. The skin is usually apposed with an interlocking pattern by using a nonabsorbable suture. It is recommended the most ventral portion of the skin incision be closed with interrupted skin sutures, so the incision can be drained ventrally if necessary.



Figure 16-38 A cow with a caudal left-paralumbar fossa celiotomy. The calf has been delivered and the uterus closed, and drapes are being changed before closing the abdomen.

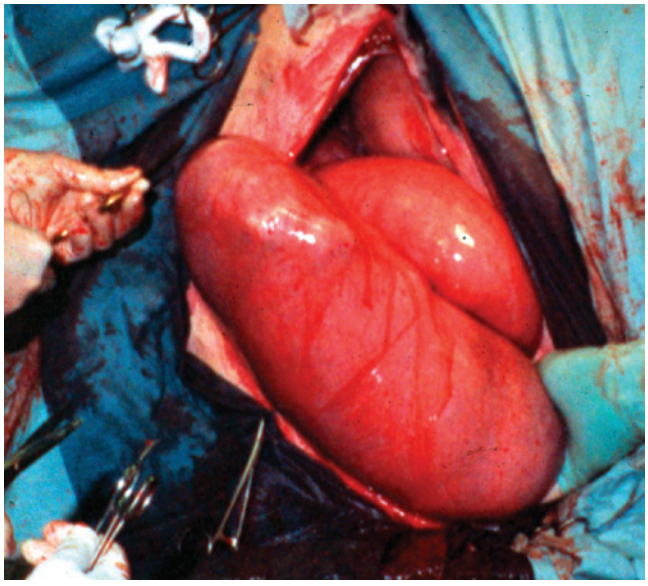


Figure 16-39 Appropriate left-paralumbar fossa celiotomy, allowing exteriorization of the portion of the pregnant horn containing the hind limbs of the calf.

Ventral Midline Celiotomy

Restraint and positioning of adult cattle in dorsal recumbency for a ventral midline approach can be labor intensive. Cattle restrained in this position suffer from cardiovascular and respiratory compromise. Therefore it is ideal to complete surgery as quickly as possible. A 40-cm skin incision is made starting at the udder and extended toward the xiphoid. The subcutaneous tissues and linea alba are sharply incised. The peritoneum is tented and incised with scissors. Some individuals perform the midline celiotomy and then have the cow tilted, so the uterus delivers more easily to one side or the other. Some surgeons feel this approach allows better exteriorization of the uterus and subsequent prevention of abdominal contamination. The midline approach is very useful for beef cattle or fractious range cattle that may not tolerate a standing flank laparotomy. A disadvantage in dairy cattle is the large amount of ventral vasculature and udder that may be in the way. To avoid incising a major vessel, it is advisable to trace the vasculature with a marker while the cow is standing and the vessels are distended with blood. A major transverse vein often runs across the abdomen just cranial to the udder and may be inadvertently incised if the incision is made too caudally.

Paramedian Celiotomy

A ventral paramedian celiotomy for cesarean section also requires restraint in dorsal recumbency. It is a multiple-layer incision in the caudal abdomen, which may result in more hemorrhage and a poor holding layer for closure. This procedure offers very few advantages and is rarely recommended.

Ventrolateral Celiotomy

For this procedure, the cow is restrained in lateral recumbency and the up hind leg is elevated and secured (Figure 16-40). The skin incision parallels the superficial mammary vein before cutting up at an angle by the udder (Figure 16-41). Tracing the vein or marking it with an indelible pen or suture before the animal is cast will prevent inadvertent incision of the vessel because it is no longer prominently distended with blood after casting. Sharp incision is continued through the subcutaneous tissues and abdominal oblique muscles, which are mostly aponeurotic at this level. The



Figure 16-40 A cow positioned for ventrolateral cesarean section.



Figure 16-41 A ventrolateral incision 48 hours after cesarean section. Note the typical postoperative edema.

transversus muscle and peritoneum are tented and incised in the same direction as the incision, perpendicular to the direction of the muscle fibers. Because this incision is long and in a vascular area, it is difficult to open and close. However, it allows excellent exteriorization of almost the entire horn of the uterus. If it is hard to move the uterus, the incised edges of the body wall can be grasped on either side and pushed down around the uterine horn. Our hospital reserves this approach for a cow with an emphysematous fetus because the incision length and difficulty in restraining the animal make it more time consuming and difficult. Closure requires multiple layers, which is also time consuming. Furthermore, the surgery must be performed by the surgeon kneeling beside the cow so the incision is close to the ground, increasing the chances of postoperative wound infection (Figure 16-42).

Left Oblique Celiotomy

A left oblique celiotomy was described by Parish et al for a standing cesarean section. The skin incision begins 8 to 10 cm cranial and 8 to 10 cm ventral to the cranial-most aspect of the tuber coxae. It extends cranioventrally at a 45-degree angle to end 3 cm caudal to the last rib (Figure 16-43). Subcutaneous tissues and the external abdominal oblique muscle are sharply incised. The internal abdominal oblique and transversus muscles are opened along the direction of their



Figure 16-42 An infected ventrolateral incision.



Figure 16-43 *A,* Left oblique celiotomy for cesarean section outlined by white arrows. *B,* Close-up view of incision.

fibers, and the peritoneum is tented and incised. These investigators felt this approach permitted better exteriorization of the uterus than a paralumbar fossa celiotomy. Three of 18 cows did develop incisional complications, and persistent anesthesia of the ventral body wall was apparent.

Delivering the Calf

Regardless of the surgical approach chosen, a large celiotomy should be made. Once entry into the abdomen is accomplished, the position and condition of the calf should

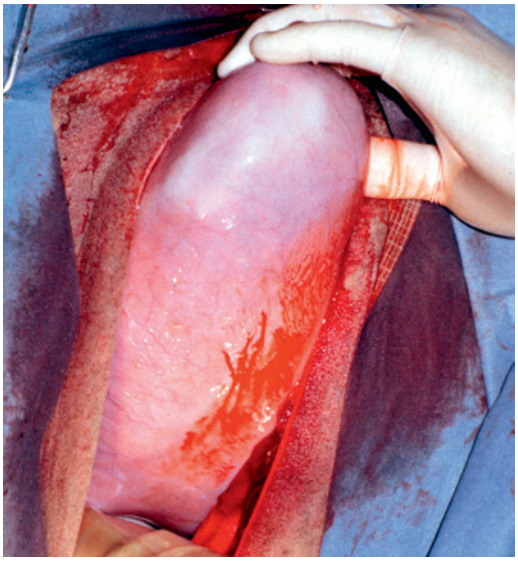


Figure 16-44 The hind limbs of the calf are delivered through a left-paralumbar fossa celiotomy and locked in the incision, which helps keep the uterus exteriorized.

be determined. With the exception of the ventrolateral approach, it is very difficult to manipulate the entire uterus. Instead, the surgeon should attempt to manipulate a limb of the calf to the incision. Ideally, the surgeon is able to lock a limb in the celiotomy incision (Figure 16-44), which essentially holds the uterus in place so the hysterotomy is made outside the abdomen and the calf delivered with minimal contamination of the abdomen. If the vertebral column is presented to the incision and it is difficult to reach a limb of the calf, the surgeon should attempt to rotate the uterus. If a clockwise rotation does not bring the limbs within reach of the surgical incision, then a counterclockwise rotation should be attempted. This is rarely unsuccessful, so another surgical approach normally would not have to be made. Usually it is possible to grasp the limbs, apply traction, and rock them up into the incision. If the calf is in anterior presentation, a hind limb is elevated and the foot and hock are wedged in the incision (see Figure 16-44). For a posterior presentation, the carpus and flexed fetlock are exteriorized. Once this is done and people are in place to aid with the delivery of the calf, a large uterine incision is made, with care taken not to injure the calf. The limbs of the calf are identified, the placenta incised, the feet delivered, and chains applied around them. While the surgeon stabilizes the uterus, the assistants deliver the calf. If there is no or little assistance available, noncrushing uterine clamps (vulsellum forceps) can be used to hold the uterus in position. It is important that the uterus incision be large enough to deliver the calf without tearing the uterus. Once the calf is delivered, whatever placenta comes easily is removed, and the remainder is replaced into the uterus. The surgeon should always check for uterine tears, another calf, and proper positioning of the uterus before closing the abdomen. If it is impossible to deliver a limb to the incision and there is adequate help, the surgeon can grasp a foot of the calf, get it as close as possible to the abdominal incision, then make a small hysterotomy opening, deliver the hoof, and place an obstetric chain around the pastern. Then the chain can be handed to a nonsterile assistant who can help to exteriorize the calf while the surgeon enlarges the uterine incision.

The surgeon's preference dictates the manner in which the uterus is closed. A popular choice is a simple, continuous pattern incorporating all layers into the closure with a No. 2 absorbable suture material. Care is taken to avoid

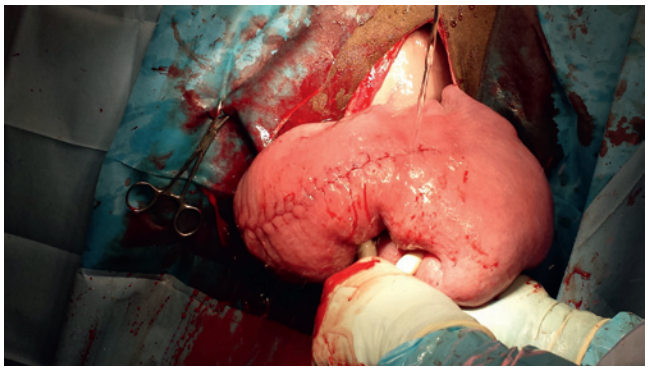


Figure 16-45 Utrecht pattern used to close the uterus. The surface is being lavaged before being replaced into the abdomen. (Courtesy of Dr. Cheong.)



Figure 16-46 An emphysematous calf necessitated a ventrolateral approach to the abdomen.

incorporating placental membranes. This is oversewn with an inverting suture pattern, usually a Cushing or Lembert, with a No. 2 absorbable suture material. Others advocate a Utrecht inverting pattern (Figure 16-45). As long as appropriate technique is used, any inverting pattern is acceptable. The sutures should be placed tight enough so the closure remains intact when the uterus contracts. This helps to prevent peritonitis that can result from leakage of uterine fluid. Minimizing exposed suture material may decrease postoperative adhesions. The uterus and surrounding area are rinsed copiously with fluids and replaced in the abdomen in its normal position. Oxytocin (20 IU) should be given intravenously (tail vein) by an assistant upon completion of the uterine closure. The integrity of the uterine incision is then reevaluated. Gloves should be changed.

The abdominal wound should be lavaged and the incision closed routinely. Before the last suture is placed in the first layer, an attempt should be made to eliminate as much air as possible from the abdomen. This decreases pain from pneumoperitoneum and reduces the development of subcutaneous emphysema if the cow continues to strain. For flank incisions, the ventral aspect of the skin incision should be closed with interrupted sutures to permit drainage should a localized wound infection develop. After surgery, oxytocin is administered to encourage uterine involution, 20 IU qid until the membranes are passed or for 24 hours. The cow should be monitored to be sure the placenta is passed intact and should receive general medical support, including analgesics if necessary, exercise, and udder care, with fresh water and electrolytes available at all times. Antibiotics are usually continued for 3 to 7 days or until the placenta is passed.

Complications of cesarean section include peritonitis, metritis, and abdominal adhesions. In cattle that have signs of endotoxemia, postoperative sepsis can be life threatening. Wound infections are a problem, especially when an emphysematous calf is delivered at surgery (Figure 16-46). These localized infections can often be treated by establishing ventral drainage of the wound and appropriate wound care. Intraabdominal adhesions around the uterus and ovaries may affect future fertility and can be minimized by thoroughly lavaging the uterus and burying suture knots. There are very few studies that have followed a large number of cows after surgery to determine postoperative fertility. A 15% decline in fertility was found in one study in which a population of cattle that had cesarean sections was compared with a similar group that had normal vaginal deliveries. Studies that evaluated cows that have been rebred after cesarean section report a 60% to 80% pregnancy rate with a 5% to 9% loss because of abortion. Cesarean section has been shown to increase the number of services to conception and the days open. If a live calf is delivered at surgery, the cow is in good physical condition, and the procedure goes well, a favorable long-term outcome can be expected. If the cow is in poor physical condition at the time of surgery the results are often less gratifying.

UTERINE TORSION

Uterine torsion is not an uncommon cause of dystocia in cattle. It usually develops at the end of gestation or during the onset of labor and is suspected after prolonged labor. Rarely it can occur in mid-gestation and presents as colic.

The diagnosis of uterine torsion is made by rectal palpation. Dorsally, the broad ligament is stretched tightly across the uterus in the direction of the torsion, and ventrally away from the torsion (i.e., with right-sided torsion—clockwise when viewed from behind—the left side of the broad ligament is stretched dorsally across the uterus and the right side of the broad ligament dives down ventrally). Vaginal examination can also indicate a uterine torsion with folds into the vaginal wall pointing in the direction of the torsion.

Correction of a uterine torsion can be attempted vaginally if the cervix is dilated and the calf's feet can be grasped. The calf is rocked until enough momentum is attained to flip the calf into normal position. If vaginal correction is not possible, the cow should be cast into lateral recumbency on the side of the torsion. A large plank is placed in the cow's flank, and a heavy person balances on the plank to minimize uterine motion. The cow is then rolled over on her back and onto her other side. A rectal examination is performed to evaluate uterine position, and the procedure is repeated as necessary. To summarize, for torsion to the right, the cow is cast on her right side and is rolled to the right as viewed from behind.

For uterine torsion that is unable to be corrected with vaginal manipulation or rolling techniques, a celiotomy should be done. It is recommended to correct the torsion before performing a hysterotomy. However, we have done both (performed the cesarean section before and after the torsion is corrected) and believe either method is equally effective. This is a decision that should be made at the time of surgery and will depend on the condition of the uterus and the difficulty in exteriorizing it. Once the calf is removed, the twist in the uterus is easily corrected.

HYDROPS

When hydrops amnion or allantois is present, it is best to drain the large amount of fluid slowly at surgery to decrease

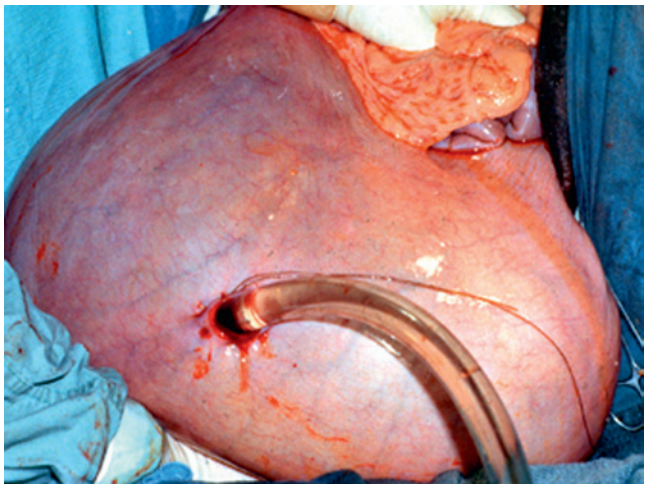


Figure 16-47 Hydrops allantois. The uterine fluid is being emptied slowly with a stomach tube placed through a purse-string suture into the uterus.

the risk of sending the cow into hypovolemic shock. Some surgeons advocate purse stringing a large-bore stomach tube into the uterus to drain the fluid (Figure 16-47). In all cases it is appropriate to administer intravenous fluids.

Cows that survive hydrops allantois are at increased risk of septic metritis and poor future fertility because of pathologic stretching of the myometrium and the likely occurrence of extensive adventitious placentation.

Hydrops amnion is usually the result of abnormal fetal development, and the dam may be a recessive carrier, which should preclude rebreeding.

UTERINE RUPTURE

Uterine rupture/tear can occur after dystocia. Typically, there is a history of extensive manipulations, forced traction, fetotomy, delivery of an emphysematous fetus, or other extensive manipulations.

The tear may be diagnosed on vaginal examination or at the time a cesarean section is performed. If the tear is out of reach during vaginal examination and the calf is delivered without surgery, it may be up to 5 days before signs become apparent.

Clinical signs are those typical of peritonitis, including depression, inappetence, fever, tachycardia, ileus, and abdominal pain. Cattle with large tears and tenesmus run the risk of prolapsing intestine through the uterine rent. Spontaneous uterine rupture secondary to unattended dystocia has resulted in the calf or fetus being extrauterine in the abdomen.

If the diagnosis is suspected, a vaginal examination should be done following appropriate preparation of the vulva. If the cow is less than 48 hours from freshening, it is usually possible to pass one hand through the cervix. Past 48 hours, it may be necessary to perform an exploratory celiotomy. Most tears are dorsal and just cranial to the cervix. Small dorsal tears may heal with conservative therapy that includes antimicrobials, intrauterine medication, and repeated administration of oxytocin. For a valuable animal, direct, aggressive, surgical therapy may be indicated. This includes repair of the laceration through a caudal flank celiotomy, broad-spectrum antibiotics, and ancillary medical therapy such as calcium solutions, nonsteroidal antiinflammatory drugs, and peritoneal lavage.

If the tear is fresh, it may be possible to close it blindly, working through the vagina and cervix. This is difficult, and the cervix closes quickly after parturition. Surgical repair with a caudal laparotomy is the author's first choice. Traction can be placed on the cervix to facilitate exteriorization of the uterus. The tear is identified and a suture is started. The end of the first knot can be left long or a separate suture placed so traction can be applied. A continuous suture line is placed if possible.

It may also be possible to prolapse the uterus after a slow intravenous infusion of 10 mL of 1 : 1000 epinephrine. Theoretically, the tear could be repaired and the uterus replaced. This is difficult to accomplish, and there are cardiovascular consequences of intravenous epinephrine.

The prognosis is guarded and will depend mostly on the degree of peritonitis present and adequacy of the repair.

UTERINE ABSCESSES AND ADHESIONS

Isolated inflamed areas of the uterus can result from compromise of the uterine wall during calving or extension of an endometrial infection. There may be a history of dystocia or an iatrogenic pipetting injury.

Overt clinical signs of a uterine abscess or adhesions are not usually present. Instead, they are found on routine rectal examination. Abscesses can vary greatly in size. They may be accompanied by extensive adhesions. A differential diagnosis includes hematoma, cyst, and tumor. The most common organism isolated is *Trueperella pyogenes*. The diagnosis is made by rectal palpation and ultrasound examination. There may be elevations in plasma protein levels in some chronic cases. Conservative therapy of parenteral antibiotics (penicillin, 20,000 IU/kg sid) for 4 to 6 weeks—possibly in conjunction with 20% sodium iodide (30 g/450 kg IV) followed by daily oral organic iodide (1 oz until signs of iodism are evident)—may be attempted. This is rarely successful, and surgical drainage or resection is recommended. Drainage can be accomplished by performing a celiotomy and placing a 20 French chest trocar into the abscess through a purse-string suture. If the abscess is freely moveable, it may be possible—and preferable—to resect it with a partial hysterectomy.

Adhesions are best treated conservatively. Many will remodel and resolve over time. This may take as long as 4 to 6 months. The same examiner should monitor and follow the cow. If endometritis and a functional corpus luteum are present, the animal may benefit from intermittent injections of prostaglandin ($PGF_{2\alpha}$ or analogs) to encourage uterine involution and evacuation of purulent material. If the adhesions are localized to one side, the cow can sometimes conceive successfully on the contralateral side.

PARTIAL HYSTERECTOMY

Indications for a partial hysterectomy include a localized uterine abscess or tumor and severe chronic endometritis localized to one horn. Reported tumors include lymphosarcoma, adenocarcinoma, and leiomyoma. The uninvolved horn and ovary should be evaluated by rectal palpation, ultrasound, and uterine biopsy. If normal, the prognosis for return to reproductive performance can be favorable.

Surgical Technique

Depending on the extent of the pathology and nature of the cow, surgery may be performed in the standing animal or in lateral recumbency. If lateral recumbency is elected, general anesthesia provides the opportunity for a more controlled

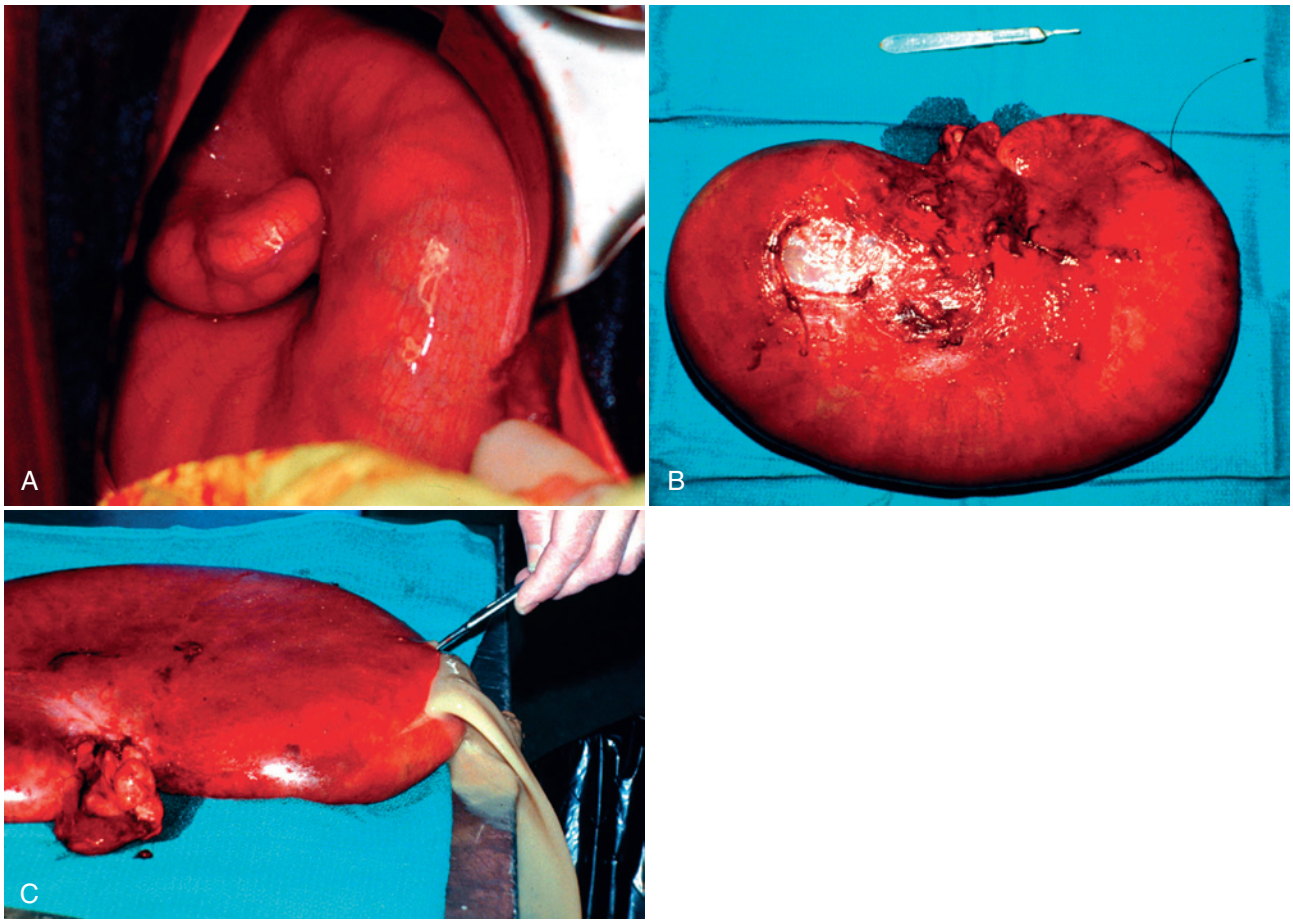


Figure 16-48 *A*, A left uterine horn exteriorized for partial hysterectomy. *B*, The uterine horn has been resected. *C*, The resected horn is incised, revealing purulent contents.

environment. The uterus can be approached through a flank or ventrolateral incision in the recumbent cow. In tractable dairy cattle, the authors have had the best results with a caudal flank approach in the standing cow. In small ruminants, dorsal recumbency and a ventral midline incision is another surgical option.

Withholding food for 24 to 48 hours is necessary for recumbency but also improves visibility and provides more room to maneuver in the standing cow. As mentioned, a caudal flank incision is recommended in the standing cow.

The site is prepared for aseptic surgery and desensitized if the cow is not under general anesthesia. A 20-cm skin incision is made. The muscle layers and peritoneum are sharply incised.

The abnormal horn and ovary are located and gently exteriorized (Figure 16-48*A*). The ovarian pedicle is double ligated with an absorbable suture material. Alternatively, a vessel sealant device[7] may be used. The ovarian pedicle is transected, and the broad ligament is dissected. The vasculature is ligated as necessary. Again, using the Ligasure[7] is another option. The transection site on the uterus is chosen and stay sutures are placed. An intestinal clamp works well as a guide along which to incise. The diseased portion of the uterus is removed and the remaining horn oversewn with a two-layer closure (Figure 16-48*B* and *C*). Another option is to use the TA-90[8] autosuture equipment, which deposits a double row of staggered stainless steel staples across the uterine horn, and perform the transection distal to the staples. Some surgeons advocate oversewing the staple line with an inverted pattern to avoid exposed mucosa. Closure of the abdomen is routine. The administration of perioperative antibiotics is at the surgeon's discretion. The animal should be given 3 weeks before attempting artificial insemination and 6 weeks before natural service.

[7]Ligasure, Covidien Surgical, Mansfield, MA, USA.
[8]Auto Suture, United States Surgical Corporation, Norwalk, CT, USA.

Complete Ovariohysterectomy

Adult Cattle. Complete ovariohysterectomy is done very infrequently but reportedly has been performed in some cows after uterine rupture, uterine torsion, or severe uterine lacerations, or for a heifer with a dead autolyzed fetus. This surgical procedure should be considered for salvage only, and the animal should be culled as soon as it is reasonable.

If possible, the cow is operated on standing. Withholding feed for 24 to 48 hours allows more room for manipulation. At surgery, as much uterus as possible is exteriorized. A loop of umbilical tape or rolled gauze can be placed around the cervix to provide traction. The next step is crude but effective. The entire uterus and its associated vessels are ligated by tightening a 1-m length of $\frac{3}{16}$-inch latex tubing or a similar-sized umbilical tape around the uterine body just in front of the cervix. The tubing or tape is pulled snug, and the first knot thrown is held with a hemostat to prevent slippage while the second throw is placed. The uterus is transected 6 to 9 cm cranial to the ligature. If hemorrhage ensues, additional ligatures can be placed. Sutures are passed through the broad ligament, creating fenestrations that prevent slippage.

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SURGERY OF THE VAGINA

Susan L. Fubini

Injury of the vagina can result in lacerations. These are best treated by debridement and cleansing. Most vaginal lacerations heal well by second intention. At times, perivaginal fat must be transected, but surgical intervention is rarely needed to manage vaginal lacerations. Urovagina and prolapsed vagina are two conditions that require surgical correction.

Urovagina

Management

Urovagina is the accumulation of urine in the cranial vagina. This condition is more common in older, multiparous cows with poor conformation. Abnormal function of the constrictor vestibuli muscle resulting from dystocia can result in urovagina. Poor conformation from repeated pregnancies can be manifested by cranioventral tipping of the pelvis, which causes the external urethral orifice to be higher than the adjacent vaginal floor, so urine collects in the vaginal fornix. The urine weight can exacerbate vaginal cranioventral displacement, thus aggravating the problem further. Hormonal influences may be involved in maintaining vaginal conformation. Indeed, the condition has been recognized in heifer cows used solely as embryo donors that have been superovulated and collected several times. Superovulation—or the hormones used in the process—appears to contribute to pelvic ligament laxity, which can lead to cranioventral displacement of the cranial vagina.

The urine accumulation results in vaginitis and cervicitis. Eventually urine may enter the uterus when the cervix dilates, causing endometritis. These abnormalities combined with the spermicidal nature of urine result in infertility.

Diagnosis

The diagnosis of urovagina can be made by observing urine pooled in the cranial vagina on speculum examination. One study of 14 affected cattle defined a 100-mL accumulation of urine pooled in the vagina as a diagnostic criterion for urovagina. A uterine biopsy may be useful for determining the degree of damage to the uterine wall, although most cows recover well even from severe endometritis once the inciting condition is treated.

Surgical Correction

Surgical descriptions for urovagina in mares and cows can be broadly separated into two categories: vaginoplasty or extension of the urethral tube.

For all procedures, the cow should be restrained in standing stocks and an epidural anesthetic (no more than 5 cm^3 of local anesthetic) administered. The rectum should be evacuated, the vagina rinsed with dilute antiseptic solution, and the tail tied to one side or tied dorsally in preparation for surgery. The perineum is prepared for surgery. The vulvar lips are retracted with stay sutures, towel clamps, or a Balfour self-retaining retractor (Figure 16-49). Incising the vaginal dorsal commissure (while taking care not to invade the rectum) may improve the surgeon's view. A Foley catheter (approximately No. 28) is secured in the urethra. Good lighting of the site provided by a head lamp or a patient, nonsterile assistant who makes constant adjustments to the light is desirable. Taping a flexible light source (such as the endoscope) to the scalpel also provides better visualization. Long-handled instruments facilitate the procedure. Perioperative antibiotics and antiinflammatory agents are indicated until the Foley catheter is removed.

Transverse Fold Techniques

The transverse fold technique used in horses does not allow sufficient urethral extension in cattle. Instead, the urethral extension procedure described here is used. Some authors report additional benefits from creating a thickened transverse urethral fold that acts as a barrier to cranial flow of urine.

To create a more prominent transverse fold that acts like a dam, folds of vaginal mucosa are elevated and held in place by a series of mattress sutures. No long-term report of this technique is available.

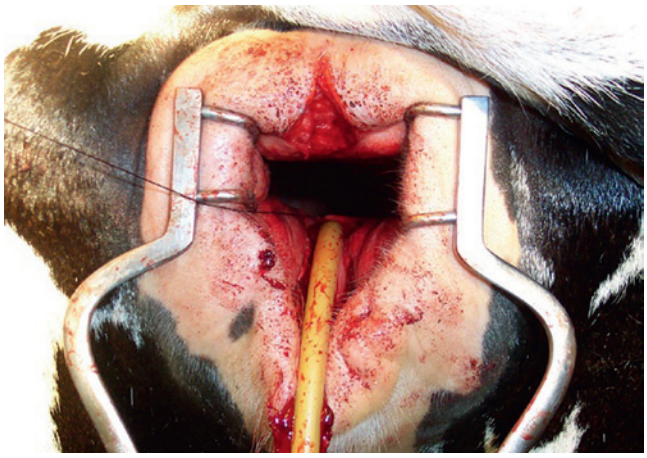


Figure 16-49 Balfour retractors are placed to allow access to the caudal aspect of the vagina. A 28 French Foley catheter has been placed in the urethra. Note the incision of the vaginal dorsal commissure improves the surgeon's view.

A modified purse string (cerclage) placed at the vestibulovaginal junction is simple to apply and effective. Under epidural block, and after placement of a urethral catheter, four large bites are taken of the vestibulovaginal fold (site of the vestigial hymen) using heavy polydioxanone suture. Each bite should occupy about a quarter of the circumference. An attempt is made to introduce each bite at the exit point of the previous bite, allowing the whole suture to be buried. The suture is pulled tight, preventing cranial flow of urine, and allowing only enough space for insertion of an insemination pipette. The cerclage permits establishment of pregnancy, and the suture lacks strength to interfere with parturition by the time it occurs. The surgery should be repeated each lactation if necessary.

Urethral Tube Extension Techniques

Extending the urethral tube has proven reliable in managing urovagina. The cow is prepared as described previously. Balfour retractors or stay sutures are used to retract the vulvar lips. A Foley catheter is placed into the urethra before surgery. To start, the transverse fold is grasped and retracted caudally toward the surgeon (Figure 16-50*A*). A U-shaped incision is made in the vaginal mucosa approximately 1 cm cranial to the urethral orifice, continued caudally from the transverse fold junction with the wall of the vestibule to just cranial to the mucocutaneous junction of the vulva (Figure 16-50*B*). Using sharp dissection, the incisions are carried parallel with the floor along the walls of the vaginal vault at the 3- and 9-o'clock levels until within 2 cm of the vulvar lips. The dissection of each side is continued by using a combination of blunt and sharp dissection so two mucosal flaps (dorsal and ventral) are created on each side (Figure 16-50C and *D*). The ventral flap is first apposed without excessive tension. The incision is closed in the shape of a Y beginning at the junction of the ventral flap of the transverse fold with the ventral flap of the vestibular wall (Figure 16-50*E*). The ventral flaps are sutured with a continuous inverting suture pattern that apposes the raw edges of the mucosal flaps and inverts the free edge into the lumen of the newly created urethral tunnel. The dorsal flaps are then apposed over the ventral flaps. An everting pattern (horizontal or vertical mattress) with 2-0 monofilament absorbable suture is recommended to finish the remainder of the incision. Finally, a Caslick's procedure is done.

The author has had success with the McKinnon technique, which describes closing only the ventral shelf (Figure 16-51). Furthermore, rather than risk leakage at the sites where the arms of the Y join the straight part, the author usually closes the U in a straight suture line that everts the slightly redundant flaps of tissue (see Figure 16-50*G*). To avoid complications, care should be taken to prevent any excessive tension on the repair. This can be done by lifting the vaginal flaps with long forceps and putting them into apposition before suturing (Figure 16-52*A* and *B*).

Another variation that has been described is to use horizontal mattress sutures to pull folds of vaginal mucosa from each side of the urethral orifice over the Foley catheter. After this, the tissue above the mattress sutures is trimmed creating fresh wound edges. These edges are carefully sutured.

After surgery, some advocate leaving a Foley catheter in place for a minimum of 72 hours. Reports of dysuria have followed surgery, presumably because of swelling or a narrow diameter of the new urethral tube. Another report of 14 cows had no cattle that developed postoperative dysuria. The author advocates leaving a Foley catheter in place for 72 hours after having one cow unable to urinate after surgery despite a patent and seemingly large urethral tube.

Fistula formation is the most common reason reported for surgical failure. Inevitably, these are at the most cranial aspect of the new urethral tube. Some fistulas may be repaired surgically by freshening the edges and suturing the defect, but opening the whole urethral tube and resuturing may be necessary in some instances. Some narrowing of the vaginal vault can be expected after surgery, but the procedure is well tolerated, and in most instances the long-term prognosis is favorable.

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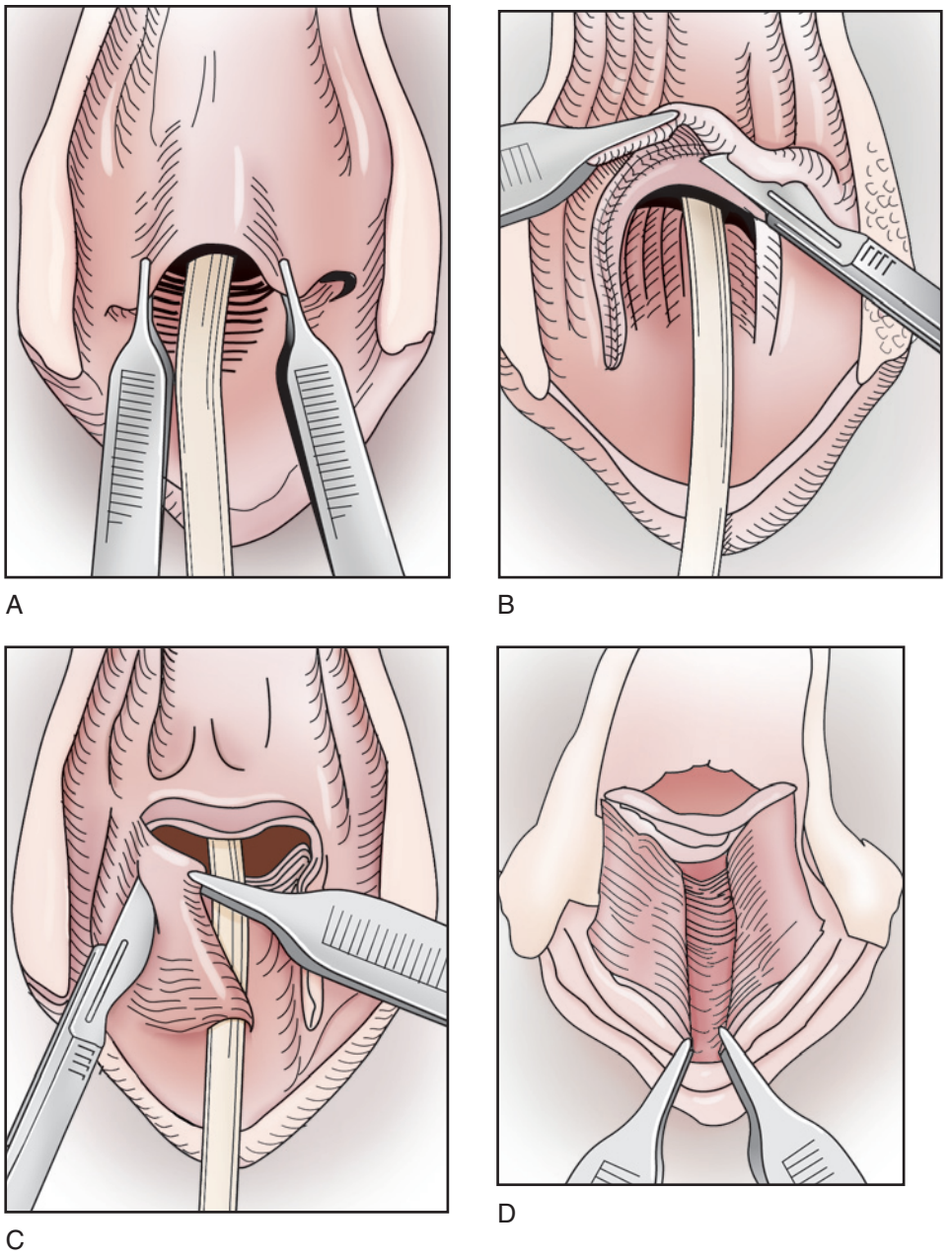


Figure 16-50 *A,* The transverse fold is grasped and retracted caudally. *B,* A U-shaped incision is made in the vaginal mucosa approximately 1 cm cranial to the urethral orifice and continued caudally, thus creating two parallel incisions along the walls of the vaginal vault at the 3 o'clock and 9 o'clock levels. *C,* Using forceps to grasp the incision edge, the surgeon sharply dissects the mucosal flaps from the vagina wall. *D,* Ventral flaps are grasped with forceps and brought into apposition to determine whether dissection is adequate (i.e., no tension on the intended suture line).

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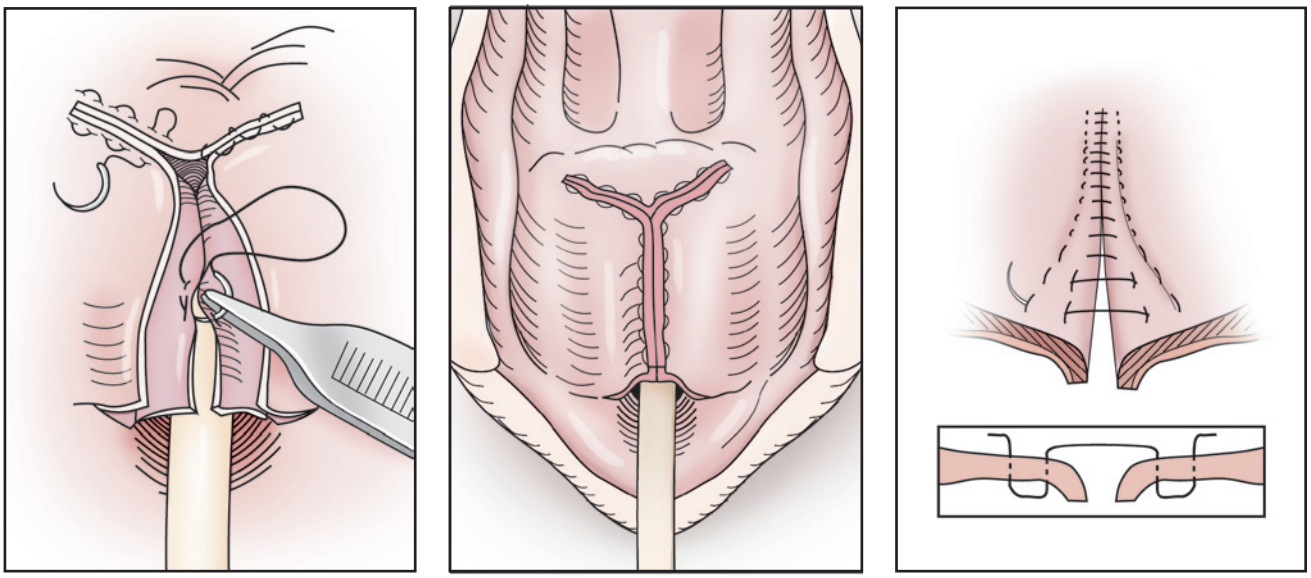


Figure 16-50, cont'd *E,* The vaginal flap incision is closed in a Y configuration, using two layers beginning with the ventral flap. The dorsal flap is sutured next. Continuous suture patterns are shown apposing the raw edges of the mucosal flaps and inverting the free edges into the lumen. *F,* The completed urethal tube extension. *G,* Alternatively, the U-shaped incision can be closed in a straight line without the arms of the Y, as shown here.

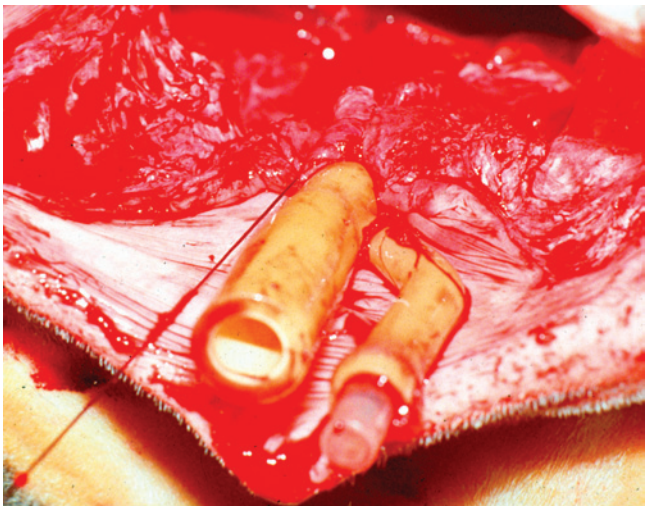


Figure 16-51 Urethral extension in a cow using a one-layer closure. The procedure is almost complete.

IMPERFORATE HYMEN

Robert O. Gilbert

In contrast to the condition in mares in which fluid accumulates behind the hymen (a thin sheet of tissue that may persist) and is easily remedied by incising the hymen, an imperforate hymen in cows is much more complex. In the bovine, imperforate hymen almost always occurs in conjunction with segmental aplasia of other parts of the reproductive tract—the vagina, cervix, or uterine body or horns—as a component of white heifer disease in Shorthorns or other breeds. The vagina ends blindly, and fluid accumulates in portions of the reproductive tract cranial to it. Because of the multiple defects and genetic basis of the condition (believed to be a single, recessive gene linked to the gene for white coat color and sex limited in its expression), the condition is not amenable to surgery, but offspring may be obtained by heroic intervention in some cases.

Vertical strands in the vagina (remnants of the fusion of the two paramesonephric ducts—and not hymenal remnants) may occasionally cause dystocia by entrapping a portion of the fetus. They may be cut with a blade or scissors to relieve the dystocia. Such cases may be encountered in multiparous cows in which calving has previously occurred without complication. Entrapment of a fetal extremity is a matter of chance and occurs relatively uncommonly even when bands of tissue are present.

Cystic Major Vestibular Glands

The major vestibular (formally known as Bartholin's) glands are paired glands in the ventrolateral wall of the vestibulum. They secrete a nearly colorless mucus and are usually quite inconspicuous. Blockage of the duct may result in dramatic cystic enlargement of the gland, which in extreme cases causes it to protrude from the vulvar lips, where it becomes susceptible to contamination, desiccation, and physical damage. The cystic gland may be liberally incised to promote drainage. Suturing is not necessary.

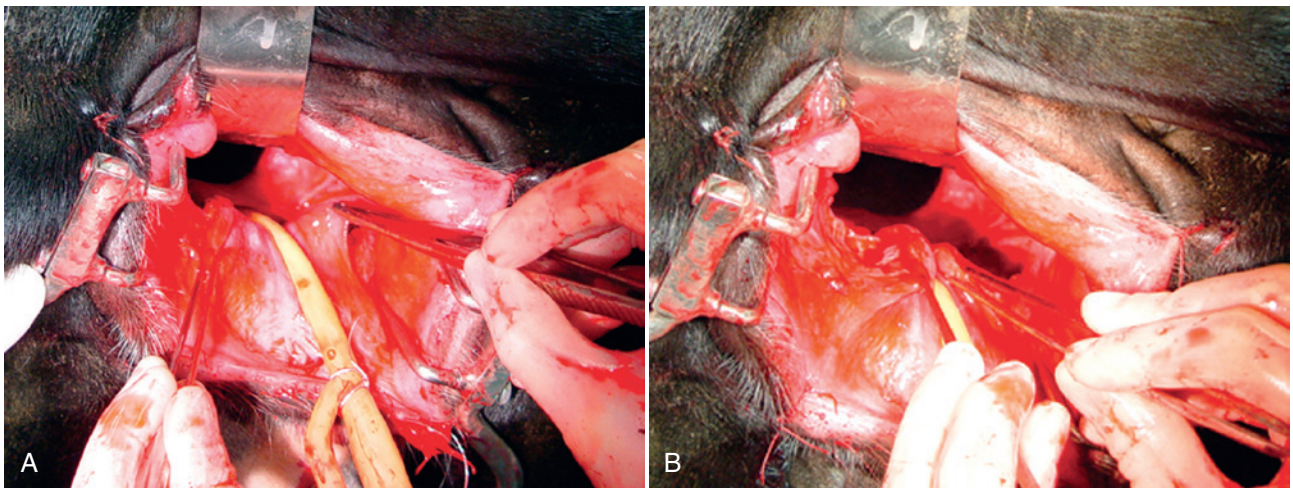


Figure 16-52 A urethral extension in a cow. To determine whether the vaginal flaps can be sutured without excessive tension, they are placed into apposition with long forceps. *A*, Flaps are not adequately dissected. *B*, Flaps are brought into apposition without tension.

DYSTOCIA CAUSED BY STENOSIS OR CONSTRICTION OF THE VULVA AND VESTIBULE

Rarely, dystocia may be solely ascribable to inadequate dilation of the vulva and vestibule. This is usually encountered when parturition is assisted by traction and insufficient time is allowed for normal dilation to occur. In some cases it may accompany an inherited condition such as anovestibular stenosis or rectovaginal constriction (in Jersey cattle). Extensive scarring from previous parturient injury may also account for failure of the vulva to dilate.

In all such cases, it is preferable to attempt to achieve dilation of the caudal genital tract by gentle, moderate traction, with plenty of lubrication over a prolonged (30 to 90 minutes) period of time. The vulva can be dilated by traction of the fetal head or rear limbs or by using the hands and wrists of the operator. Should attempts to achieve dilation fail, or if time is of the essence, episiotomy may be useful.

After application of epidural analgesia, an incision is made through the skin, subcutaneous tissues, and vestibular mucosa, beginning about 2 to 3 cm from the dorsal commissure of the vulva and proceeding dorsolaterally for up to 10 cm. The dorsolateral direction of the incision is important to prevent tissue tearing in a dorsal direction, which risks creation of a rectovaginal laceration. Immediately after delivery of the calf the episiotomy incision is sutured with several layers of deep absorbable sutures. This procedure is rarely required, but in the appropriate circumstances it may be valuable in resolving a stubborn dystocia with minimal injury to fetus or dam.

SURGICAL CONDITIONS OF THE POSTPARTUM PERIOD

Robert O. Gilbert

Hemorrhage into the Uterus or Vagina

Postpartum hemorrhage may result from trauma, laceration, or rupture of the genital organs—most commonly after forced extraction and cases of uterine torsion. Hemorrhage may be profuse if a major vessel is damaged. Minor bleeding usually resolves spontaneously without treatment. More severe bleeding may be controlled by injecting 20 to 50 IU of oxytocin to promote myometrial contraction. If a bleeding vaginal vessel can be identified, it can be clamped and possibly ligated. If this is impossible, the vagina may be packed to provide pressure on the bleeding vessel. Rarely, catastrophic, fatal bleeding into the abdomen from the uterine arteries may occur at the time of parturition; some afflicted cows have been found to suffer from copper deficiency.

Perivaginal Bleeding and Hematoma

Fetus passage may damage the internal pudendal artery, resulting in formation of a large hematoma lateral to the vaginal wall. In rare cases, this condition may be bilateral. In most instances, these hematomata resolve spontaneously; sometimes they become infected and persist as abscesses. The hematoma or abscess may be drained into the vagina by means of a lateral incision, with care taken not to damage the internal pudendal artery in making the incision. This should not be done until 3 days postpartum to allow complete hemostasis.

Hematomata of the vagina may protrude from the vulva. Hematoma of the vulva is usually obvious and may also protrude from the vulva. Both may be readily drained after allowing 3 days for hemostasis. Contusions of the vagina and vulva are favored sites for clostridial growth, and affected cows should be treated with antibiotics and vaccinated (against tetanus) to prevent clostridial myositis or tetanus.

Lacerations of the Vagina and Vulva

Minor lacerations may occur in spontaneous parturition and are usually confined to the area near the vulva. Unless they are severe, these wounds do not require suturing. Lacerations of the vaginal wall may result in prolapse of the urinary bladder or perivaginal fat. Bladder prolapse usually takes place through a tear in the floor of the vagina. The prolapsed bladder fills with urine because the urethra is kinked. It may be necessary to drain the bladder with a fine needle before replacing it to normal position. The rent the bladder passed through should be sutured and the animal placed on parenteral antibiotics. Perivaginal fat may prolapse through a very

small vaginal laceration and may resemble prolapse of the bladder. The prolapsed mass of fat should be traced to the point where it passes through the vaginal wall, where it may be cut off with minimal bleeding. The vaginal defect should be sutured. A more severe laceration results in second- or third-degree perineal laceration.

Vaginal and Cervical Prolapse

Eversion and prolapse of the vagina (Figure 16-53)—with or without prolapse of the cervix—occurs most commonly in cattle and sheep. The condition is usually seen in mature females in the last trimester of pregnancy. Predisposing factors include elevations in intraabdominal pressure associated with increased size of the pregnant uterus, intraabdominal fat, or rumen distention superimposed upon relaxation and softening of the pelvic girdle and associated soft tissue structures in the pelvic canal and perineum. These changes are mediated by elevated circulating concentrations of estrogens and relaxin during late pregnancy. Intraabdominal pressure is increased in the recumbent animal. Added to this, sheep tend to face uphill when lying down, so that gravity assists vaginal eversion and prolapse. In sheep, hilly pasture and multiple pregnancies are predisposing factors.

The prolapse begins as an intussusception-like folding of the ventral vaginal floor just cranial to the vestibule-vaginal junction. In addition to elevated abdominal pressure, discomfort caused by this eversion, coupled with irritation and swelling of the exposed mucosa, results in straining and more extensive prolapse. Eventually the entire vagina may be prolapsed, with the cervix conspicuous at the caudal-most extent of the prolapsus. The urinary bladder or loops of intestine may be contained within the prolapsed vagina, resulting in occlusion of the urethra. The bladder then becomes filled and enlarged, which hinders replacement of the prolapsed vagina unless the bladder is first drained. The bladder may even rupture—with potentially fatal consequences.

Although most common in mature animals in late pregnancy, vaginal prolapse can occur in young, nonpregnant ewes and heifers, especially in fat animals. Predisposing factors include grazing estrogenic plants (especially *Trifolium subterraneum*) or exogenous administration of estrogenic compounds (usually in the form of growth-promoter implants). Estrogenic compounds cause relaxation of the structures of the pelvic girdle, which predisposes to the initial folding of the vaginal floor—the common precursor to complete prolapse. Cervicovaginal prolapse is more common in stabled than pastured animals, suggesting that lack of exercise may be a contributing factor. Vaginal prolapse may also be a problem in cows that are subjected to repeated superovulation for embryo recovery. A genetic component in the pathogenesis of cervicovaginal prolapse is likely because a breed predisposition exists in cattle (Brahman, Brahman crossbreds, Hereford) and in sheep (Kerry Hill, Romney Marsh). In pigs, vaginal prolapse is often associated with estrogenic activity of mycotoxins.



Figure 16-53 Vaginal prolapse in a cow.

Treatment

For replacement of the prolapsed vagina, an epidural anesthetic is first administered. The organ is washed and rinsed, and the bladder is emptied if necessary. This may be achieved by elevating the prolapsus to allow straightening of the urethra; occasionally needle puncture through the vaginal wall may be necessary. The vagina is well lubricated (glycerin provides lubrication and reduces congestion and edema by osmotic action), replaced, and held in position until it feels warm again. Retention is achieved by insertion of a Buhner suture. This is a specific form of deeply buried, circumferential suture placed around the vestibulum to provide support at the vestibule-vaginal junction. This deep suture provides support at the point at which the initial eversion of the vaginal wall occurs, preventing the initiation of the condition. The Buhner suture has largely superseded earlier attempts to prevent prolapse by various patterns of sutures in the vulvar lips (which do not prevent the initial eversion of the vagina into the vestibulum) or methods that relied on placement of a retention device within the vagina (which tend to cause discomfort and further straining). Buhner sutures should be removed before parturition to prevent extensive lacerations unless placed long (at least 6 weeks) before anticipated parturition.

Although the cervical os may be edematous and inflamed, cervicovaginal prolapse seldom interrupts pregnancy and does not specifically predispose to dystocia or postpartum uterine prolapse, which has a different etiology. Vaginal prolapse in sheep may occur simultaneously in many ewes as a herd problem, making surgery impractical. In these cases, use of a commercially available vaginal retention device (a bearing retainer) may be useful. Sheep may lamb without mishap while wearing these devices. Permanent fixation techniques (cervicopexy or vaginopexy) have been described in which the cervix or vaginal wall is anchored to other pelvic structures. They may be useful in individual cases.

Buhner Suture Placement

Epidural analgesia is administered, the tail tied to the side, and the perineum prepared for surgery. Vertical incisions, each about 2 cm in length, passing through skin and subcutaneous fascia are made dorsal and ventral to the vulva. Dorsally, the incision should be midway between the dorsal commissure of the vulva and the anus. The ventral incision is made a similar distance from the ventral commissure. Both incisions need to be deep enough to allow the suture, once placed and tightened, to migrate forward freely. A Görlach needle (a long [approximately 15 cm], sturdy, cutting-edged needle on a handle and with an eye at its forward end) is inserted into the ventral incision and passed up and out of

the dorsal incision (see Figure 3-28*A* and *B*). The needle should be passed as far cranial and lateral as possible, without damaging blood vessels coursing along the sacrosciatic ligament. If the needle is passed too superficially (relative to the vaginal mucosa), there is a risk that the suture will pull through the mucosa eventually. If the needle is not cranial (deep) enough, the suture will not support the vestibule-vaginal region (the region of the pelvic diaphragm) and will not serve its purpose adequately.

The needle is passed though the dorsal incision, sterile umbilical tape is threaded through it, and the needle is withdrawn while one end of the umbilical tape is held. The procedure is repeated on the opposite side. The free end of the umbilical tape that was held dorsally is threaded into the needle before it is withdrawn again. This leaves both free ends in the ventral incision. They are tied together and the suture is tightened until the vestibulum permits passage of two fingers. During tightening, the correctly placed suture should migrate forward so it comes to lie just caudal to the vestibulovaginal junction. Suturing the skin incisions is optional.

If the animal is within 2 months of parturition, the suture ends should be left long, so the suture can be cut and removed to prevent severe laceration at parturition. In any case, the animal should be monitored frequently, and care taken to ensure it is possible for the vestibulum to dilate sufficiently to permit passage of the fetus.

Cervicopexy and Vaginopexy

In some circumstances, pexy of the cranial vagina is used to prevent cervicovaginal prolapse in cows in which the condition recurs frequently. This may be in embryo transfer donors, in which the repeated superovulation, and associated supraphysiological hormone levels, produce softening of the pelvic diaphragm in a way similar to pregnancy. Even in these cases, the condition is usually satisfactorily controlled by correct placement of a Bühner stitch. Rare cases, however, might require fixation of the entire vagina. Before doing this, inherited causes of prolapse (breed predisposition) should be ruled out.

Several methods for vaginopexy have been described. This author's preference is for suturing the cranial vagina to the iliopsoas muscle. This can be done blindly, via the vagina, or by open surgery, with a caudal celiotomy. In the latter case, it is helpful to have an assistant insert a gloved, lubricated hand into the cranial vagina to guide it toward the surgeon. The cranial vagina is secured to the muscle by placement of several sutures through both structures. Another common method involves a through-and-through suture that traverses the gluteal muscles, the sacrosciatic ligament, and the vagina. Usually, the suture is anchored at the skin and in the vagina with a button or similar object to prevent it from pulling through the mucosa or skin. Any pexy should be performed only on one side to avoid causing chronic pneumovagina.

Uterine Prolapse and Eversion

Prolapse of the uterus may occur in any species; however, it is most common in dairy cows (Figure 16-54) and ewes (Figure 16-55) and less frequent in sows. Prolapse invariably occurs immediately after or within several hours of parturition; prolapse more than 24 hours after parturition is extremely rare and is complicated by partial closure of the cervix, thus making uterine replacement difficult or even impossible. Most cases occur in winter and fall, and over half have clinical milk fever. The etiology is unclear and occurrence is sporadic. Most affected cows are hypocalcemic, and uterine atony seems to be the major contributing factor. Prolapse of the uterus usually occurs within a few hours after parturition, when the cervix is open and the uterus lacks tone. The best explanation is that the tip of the postgravid horn becomes invaginated and that the invagination proceeds, either spontaneously or because of abdominal press, until the postgravid horn is completely exteriorized. Prolapse may be precipitated by traction on a fetus or retained placenta. Prolapse of the postgravid uterine horn usually is complete in cows, and the mass of the uterus usually hangs below the hocks. The invagination of the contralateral (formerly nongravid and usually nonprolapsed) horn can be located by careful examination of the surface of the prolapsed organ. In sows one horn may become everted, whereas unborn piglets in the other prevent further prolapse.



Figure 16-54 Uterine prolapse in a cow.



Figure 16-55 Uterine prolapse in a ewe.

Both in its appearance and in its pathogenesis uterine prolapse is quite distinct from cervicovaginal prolapse. Cervicovaginal prolapse usually afflicts pregnant animals, results from relaxation of pelvic structures under hormonal influence, and begins as a rollover of mucosa at the vestibule-vaginal junction. The prolapsed mass is smooth (vaginal mucosa) and the cervix may be visible. In contrast, uterine prolapse occurs immediately postpartum, is predisposed by uterine flaccidity, and starts with invagination of

the tip of the formerly gravid uterine horn. Uterine prolapse is recognizable by the presence of visible caruncles (and sometimes placental remnants) on the surface of the prolapsus.

Treatment

In cows, treatment involves removing the placenta (if still attached), thorough cleaning of the endometrial surface, and repair of any lacerations. Rubbing the surface of the uterus with glycerol helps reduce edema and provides lubrication so that the uterus can be returned to its normal position. First, an epidural anesthetic should be administered. Replacement of the uterus is much easier if the cow is placed in sternal recumbency, with its rear limbs extended caudally (behind it) so that it is in a frog-sitting position. Elevation of the hindquarters is also useful. The cleansed uterus should be elevated to the level of the vulva on a tray or hammock supported by assistants and then replaced by applying steady pressure beginning at the cervical portion and gradually working toward the apex. Another strategy is to locate the opening of the unprolapsed, previously nongravid uterine horn. This appears as an invagination near the base of the prolapsed mass. If it can be identified, pressure can be applied directly to this spot with a clenched fist; this generally permits much easier replacement of the prolapsus than is otherwise possible. Once the uterus is replaced, the operator's hand should be inserted to the tip of both uterine horns to be sure that no remaining invagination could incite abdominal straining and reprolapse. Instillation (and subsequent removal by siphon) of warm, sterile saline solution is useful for ensuring complete replacement of the tip of the uterine horn without trauma. Once the uterus is in its normal position oxytocin (20 IU IV or 40 IU IM) is administered to increase uterine tone. Administration of calcium-containing solutions is indicated in most cases, also as a means of increasing uterine tone, and because most cases are hypocalcemic. Caslick sutures or other forms of vulvar closure are not indicated, because they merely obscure recurrence of the prolapse and do nothing to prevent it. Recurrence is prevented mainly by ensuring complete replacement of the uterus, without invagination of the tip of a horn, and restoration of uterine tone.

In sows, reposition may be achieved by simultaneously manipulating the uterus from outside with one hand and through an abdominal incision with the other. Resection of the uterus is indicated in long-standing cases in which tissue necrosis has occurred.

In sheep, recurrence of the prolapse may be entirely intravaginal, making it difficult to detect unless specifically examined for this possibility. Once cervical closure has proceeded beyond about 1 day, postpartum replacement of the prolapsed uterus becomes impossible.

The prognosis depends on the amount of injury and contamination of the uterus. Prompt replacement of a clean, minimally traumatized uterus allows a favorable prognosis. The crude recovery rate is about 75%. Of recovered cows, about 85% conceive again—taking about 10 days longer to do so than herdmates. No tendency for the condition to recur at subsequent parturitions has been reported. Prognosis is more favorable if the prolapse follows the birth of a live calf and if the cow is primiparous. Complications tend to develop when laceration, necrosis, and/or infection occur or when treatment is delayed. Shock, hemorrhage, and thromboembolism are potential sequelae of a prolonged prolapse. In some instances the urinary bladder and intestines may prolapse in to the everted uterus. These require careful replacement of the viscera before replacement of the uterus. The bladder may be drained with a catheter or needle placed through the uterine wall. Elevating the hindquarters and putting pressure on the uterus aids replacement of the bladder and intestines. It may be necessary to incise the uterus carefully (in a longitudinal direction) to replace these organs. In the cow, amputation of a severely traumatized or necrotic uterus may be the only means of salvaging the animal. Supportive treatment and antibiotic therapy are indicated.

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SURGERY OF THE PERINEUM

Susan L. Fubini

Obstetric trauma is the most common cause of perineal injuries. These injuries can result from an abnormal position and/or size of the calf in relation to the dam or from overzealous attempts by farmers and veterinarians to aid delivery. Although they can be impressive when the injury first occurs, surgery is usually delayed until bruised tissue swelling has subsided, local tissue necrosis has resolved, and the wound edges have healed.

First- and Second-Degree Perineal Lacerations

Lacerations of the perineal body are classified according to location, extent of injury, and tissues involved. A first-degree perineal laceration involves only the skin and mucosa of the vagina or vestibule. Most of these wounds heal without any invasive therapy, but it is best to follow the repair with a Caslick procedure if there is significant disruption of tissue or deep lacerations.

Protrusion of perivaginal fat through the laceration may require its amputation with an emasculator or scalpel. A Caslick procedure is performed in the standing, restrained cow with epidural anesthesia. The injured area is prepared with appropriate aseptic techniques. A strip of tissue at the mucocutaneous junction is excised in an elongated U shape, starting ventrally at the junction of the dorsal two thirds and ventral one third of the vulvar lips and proceeding dorsally to the top of the vulva and down the other side. The freshened edges are sutured in a continuous pattern. Enough room (3 cm) is left for urination at the ventral commissure of the vulva (Figure 16-56).

Second-degree perineal laceration involves disruption of the fibromuscular tissues that separate the rectum and vagina. There are usually considerable swelling and edema of affected tissues. There is no need for emergency surgery. The concern is that loss of functional vulvar and vestibular conformation over time will allow air and fecal contamination of the vaginal vault and eventually lead to infertility through endometritis.

The rectum is evacuated, perineum prepared, and epidural anesthetic administered in preparation to repair these

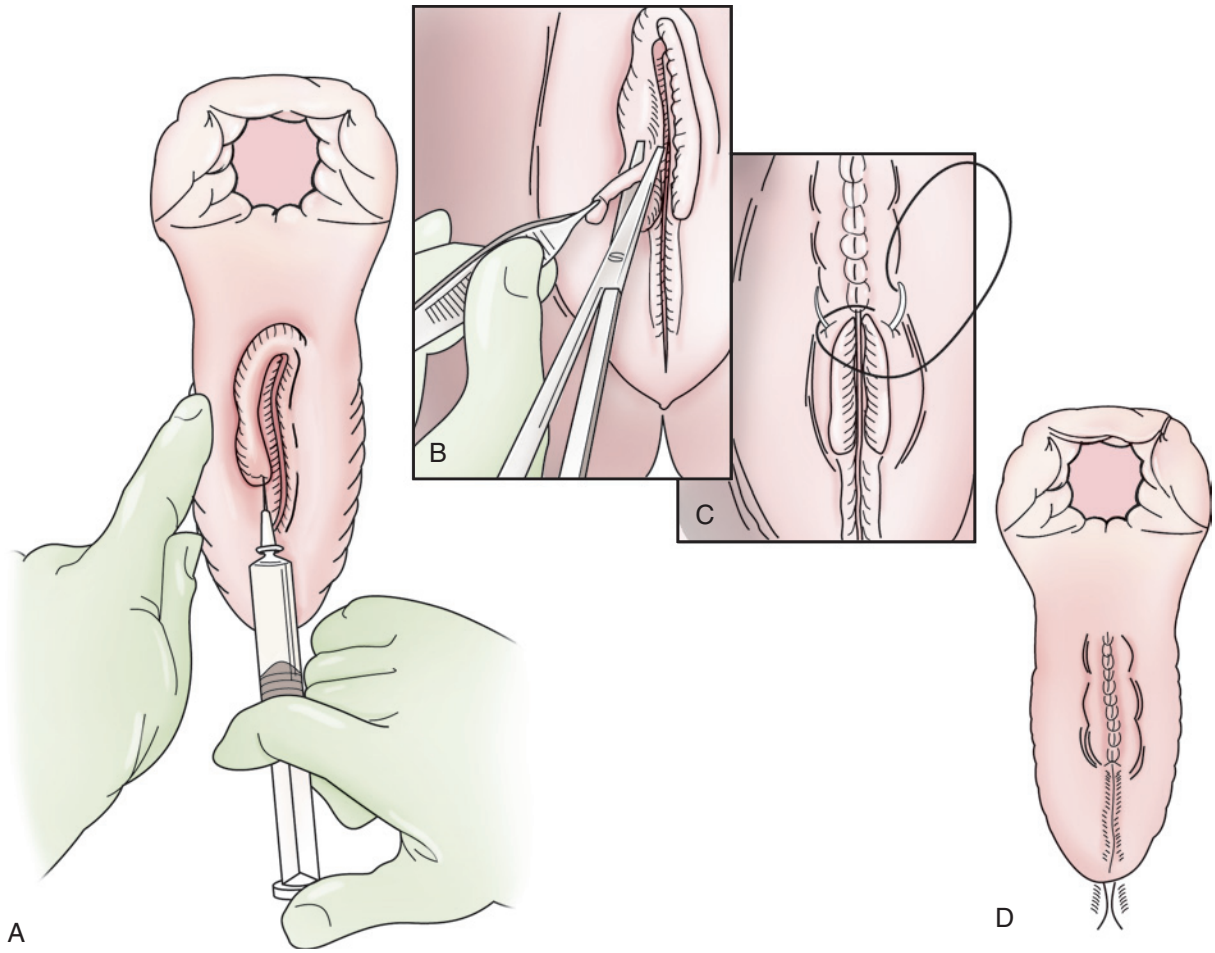


Figure 16-56 Line diagram of a Caslick procedure. *A*, A local anesthetic is injected at the mucocutaneous junction. *B*, A strip of tissue is removed at the mucocutaneous junction. C, The raw edges are apposed, with a continuous suture. *D*, Completed Caslick procedure.

lacerations. A triangular-shaped piece of mucosa and submucosa is removed from each side (Figure 16-57). The base of the triangle should be located at the dorsal aspect of the mucocutaneous junction of the perineal body. One arm of the triangle is along the dorsal commissure of the vagina whereas the other arm parallels the rectum. The mucosa is sharply incised and undermined by carefully using Metzenbaum scissors to lift the mucosa-submucosa flap and leaving a fresh surface on each side. If the tear is asymmetric, this makes it more difficult, and creative modification is needed to design flaps and determine how to appose the tissues. Sutures are first placed deeply, and mucosa and submucosa are apposed in an attempt to create a wide surface like the original perineal body with 2-0 or 3-0 absorbable sutures. Typically a Caslick procedure is done upon completion of the deeper tissue repair.

Third-Degree Perineal Lacerations

Third-degree perineal lacerations result when there is complete disruption of the rectovestibular shelf due to fetal oversize, forced extraction, or some other trauma that leaves a wide opening between the rectum and vagina (Figure 16-58), often with disruption of the anus. This lesion can result in fecal contamination of the vagina and eventually endometritis and infertility. Unlike some other species, the constrictor vestibuli muscle and cervix of the cow help prevent infection, which allows some cattle with complete perineal lacerations to become pregnant.

Initial treatment after injury consists of local wound care. The wound should be cleaned and debrided the same as any other soft tissue injury. Immediate repair of a fresh tear has been reported but is rare because the swelling results in poor suture-holding power. It is also difficult to tell which tissues are viable. Instead, the wound is left alone for 6 to 8 weeks to allow for tissue necrosis and secondary healing.

For surgical repair the cow is restrained in standing stocks, the rectum is evacuated of feces, and the tail is retracted to one side or dorsally. Some surgeons like to construct a rectal tampon from an orthopedic stockinette filled with cotton and secured at the ends with umbilical tape (see Figure 16-58). The authors have not found this to be necessary. After an epidural is administered, the rectum is evacuated and the perineum prepared for aseptic surgery. Perioperative antimicrobials are indicated.

The three steps of the procedure consist of rebuilding the shelf between the rectum and vagina, repairing the perineal body, and performing a Caslick's procedure. The soft consistency of cattle manure eliminates the need for dietary modification.

Retraction is provided by stay sutures, a Balfour self-retaining retractor, or towel clamps. Good lighting is important. The rectovestibular shelf is tented with forceps and

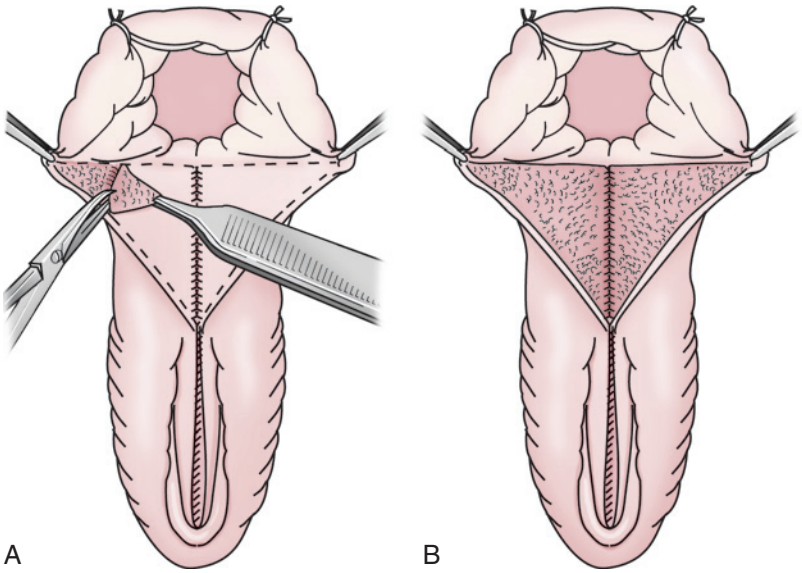


Figure 16-57 Line diagram of repair of second-degree perineal laceration. Triangular flaps of mucosa and submucosa are resected to rebuild the perineal body.

divided in a frontal plane, with care taken to avoid penetration of the rectal mucosa. Ideally, the tissues should be divided so the rectal shelf is two thirds of the thickness and the vaginal shelf is one third. The dissection should be carried forward and along each side at a 2.5- to 3.0-cm depth. It is critical that the flaps created be brought into apposition to determine whether there is sufficient tissue for suturing without any excessive tension. Reconstruction of the shelf is usually performed with a one-stage technique.

One-Stage Repair (Modified Goetz)

Using this technique, a six-bite vertical pattern is used to rebuild the shelf between the rectum and vagina (Figure 16-59). Most older reports describe using a nonabsorbable synthetic suture and leaving the ends long to facilitate suture removal in 14 days. However, there are several easy-to-handle, nonreactive monofilament absorbable sutures (size No. 1 or No. 2) that maintain adequate strength and do not require suture removal. Locating the suture bites through the tissue is described as follows for a right-handed surgeon:

1. Beginning in the vaginal vault, the first bite incorporates 2 to 3 cm of the left vaginal flap directed ventral to dorsal and exiting between the rectal and vestibular flaps.
2. The second bite incorporates the left rectal shelf and exits 2 cm from the edge. Care is taken to ensure penetration of the submucosa—but *not* the rectal mucosa.
3. The next bite is similar to the second bite, which penetrates the right rectal shelf and exits between the rectal and vestibular flaps.
4. The fourth bite is through the right vaginal flap in a dorsal-to-ventral direction that emerges in the vaginal vault.
5. The needle is reversed in the needle holder and backhanded for a shallower (1 cm) bite through the right vestibular fold in a ventral-dorsal direction and exits between the two flaps.
6. The final bite is similar to the one before, penetrating the left vaginal flap in a dorsal-to-ventral direction and exiting in the vaginal vault.

The sutures should be placed 1.0 to 1.5 cm apart. They should be tied under tension, and the closure should be palpated after every bite, feeling for any defect that may have been inadvertently created (Figure 16-60). The author likes to place a simple continuous pattern of 2-0 absorbable sutures (with knots in the rectum) in the rectal mucosa for a better seal and to prevent fecal material from contaminating the shelf sutures.



Figure 16-58 Six-week-old third-degree perineal laceration in a cow. A gauze roll is placed in the rectum to minimize fecal contamination during the repair. Note the complete loss of the rectovaginal shelf. (Courtesy of Dr. Nigel Cook.)

The sutures are continued until the perineal body is reached. If a nonabsorbable suture is used, the ends must be left long to facilitate removal 2 weeks later. The rest of the surgery is performed as described for a perineal body reconstruction (see Figure 16-57). Finally, a Caslick's procedure is performed (see Figure 16-56). Four weeks after surgery, healing can be evaluated. Ideally, 6 to 8 weeks should be allowed before breeding or artificial insemination.

Rectovaginal Fistula Repair

Rectovaginal fistulas are not common in cattle but do occur in adults, secondarily to dystocia. During parturition,

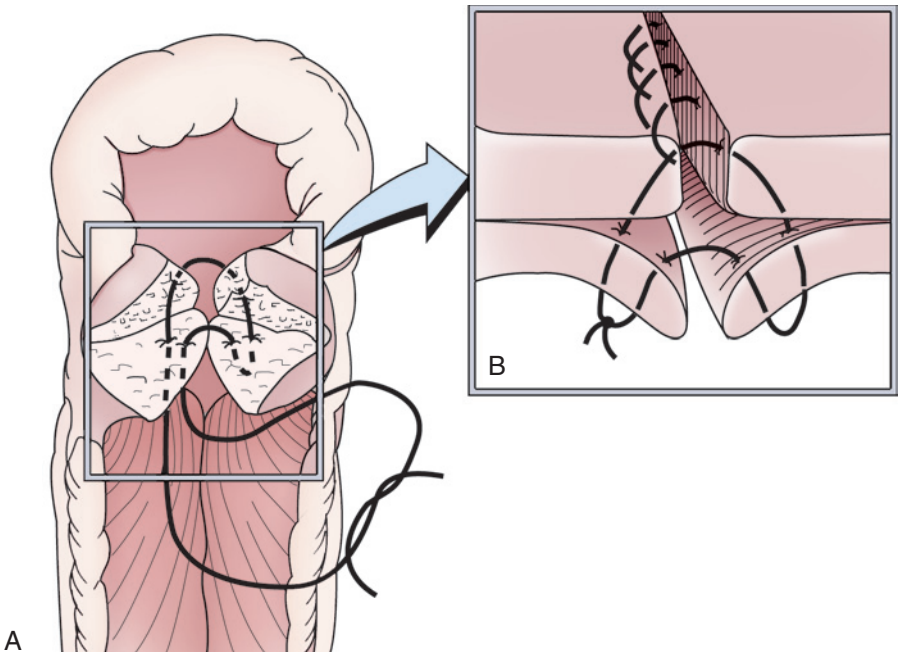


Figure 16-59 Line diagram showing the six-bite technique to repair a third-degree perineal body.

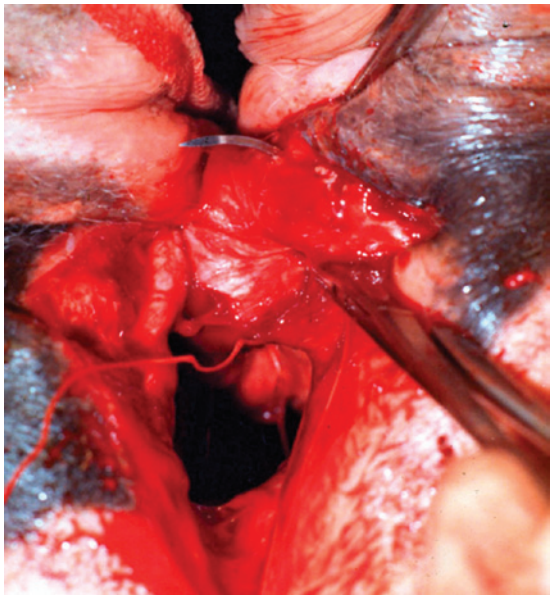


Figure 16-60 Repair of the rectovaginal shelf is being completed. Note slight eversion of rectal mucosa toward the rectum.

the front foot of a calf in an anterior, dorsosacral presentation typically perforates the dorsal aspect of the vestibule and enters the rectum. The foot is withdrawn and leaves a defect between rectum and vagina. Rectovaginal fistulas are also seen in calves with atresia of the anus and cattle with partially failed, third-degree perineal laceration repair.

If the fistula was traumatic, adequate time (4-6 weeks) should be allowed before surgery because the defect size can be reduced markedly as a result of wound contraction. Some smaller defects have been reported to heal completely.

One surgical option (especially with large, deep fistulas) is to convert them to a third-degree perineal laceration before performing the repair. Preparation is the same as for other perineal surgery.

Another option is to repair the fistula primarily. With adequate restraint and preparation, a transverse incision is made between the rectum and vagina. By using a combination of sharp and blunt dissection in a horizontal plane, the fistula is exposed. Ideally, two thirds of the thickness of the shelf should be with the rectum and one third with the vaginal shelf. Most fistulas measure 3 to 5 cm. Dissection is continued 3 to 4 cm rostral to the fistula. The rectal defect is closed transversely by using No. 0 or 1 absorbable sutures in a simple interrupted pattern placed in the submucosa, with care taken not to penetrate the rectal mucosa. The first suture should divide the defect in half; the next two sutures should be placed to bisect the halves, and so on. Alternatively, one can preplace the sutures. In addition, successful repairs have been reported with longitudinal closure of the rectum. Either technique is adequate if there is good tissue apposition with little tension. The vaginal defect is closed next. Many advocate a continuous horizontal mattress pattern in a longitudinal direction so that the two suture rows are at right angles to each other and the vaginal mucosa is everted. The incised perineal body is closed with multiple interrupted sutures of 2-0 suture; the skin is closed routinely. Complications include dehiscence or fistula formation.

In one review article (Dreyfuss et al, 1990) on perineal surgery in cattle, the prognosis was favorable after surgery. Of the cattle that had surgical repair of third-degree perineal lacerations, 71% (10/14) remained fertile, whereas 75% (3/4) of cattle were productive after rectovaginal fistula repair.

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SURGERY OF THE MAMMARY GLAND

Christina Cable and Susan L. Fubini

Relevant Surgical Anatomy

The udder of the dairy cow can vary in size tremendously, but it can get extremely large and weigh as much as 60 kg. The udder comprises four glands, each of which has one principal teat. A prominent median intermammary groove generally marks the division of the udder into right and left halves. The division between fore- and hindquarters of each side is less distinct. The skin covering the udder is thin and freely movable, except in the teats.

The udder is suspended from the body wall by strong fascial medial and lateral laminae that together are termed the suspensory apparatus. The medial lamina is the stronger of the two and is largely made up of elastic tissue. The right and left medial laminae are separated by a small amount of loose connective tissue, which makes it possible to remove one half of the udder fairly easily.

The lateral lamina is composed of dense connective tissue. It arises from the area of the lateral crus of the external inguinal ring and pubic symphysis. It provides protection to the mammary vasculature and superficial inguinal (mammary) lymph nodes. The laminae are thickest dorsally and become progressively thinner at the ventral aspect.

The bulk of the udder is made up of connective tissue mixed with parenchyma. The main arterial supply is the external pudendal artery with a small contribution by the mammary branch of the ventral perineal artery. The external pudendal artery and vein enter the udder after passing through the inguinal canal. The artery first forms a sigmoid flexure before dividing into cranial and caudal mammary branches. The former is large and directed ventrocranially, whereas the caudal branch supplies the back of the udder. Both vessels branch extensively to supply the parenchyma.

A ring of venous drainage is located above the base of the udder. Contributions come from the external pudendal veins, subcutaneous abdominal ("milk") vein, ventral perineal veins, and udder tributaries. Innervation to the udder is from the lumbar spinal nerves (L1, L2, and the genitofemoral nerve) and sacral spinal nerves (mammary branch of the pudendal nerve).

The udder of small ruminants consists of two glands, which vary from conical and deep in the milking goat to small and spherical in sheep. The structure, suspension, vascular, and nervous supply is similar to that of the bovine.

Management of Chronic Mastitis

Hemimastectomy, or radical mastectomy, is occasionally performed in small ruminants and rarely in cattle. Indications include neoplasia (Figure 16-61), chronic or gangrenous mastitis (Figure 16-62), a fibrotic or granulomatous udder, and precocious udder development. In some animals—especially older ones—the suspensory apparatus has weakened, allowing the udder to sag and even ulcerate due to contact with the ground (Figure 16-63). This condition can become inhumane, making amputation necessary. Ideally, surgery should be performed in a nonlactating animal in good physical condition. This is not always possible, especially with gangrenous mastitis cases. If septic shock is present because of gangrenous mastitis, the blood loss associated with surgery and removal of a vascular organ such as the mammary gland can overwhelm the animal's defenses. Instead, teat amputation to allow better drainage should be considered. Chemical destruction of the affected quarter is the medical alternative



Figure 16-61 Goat with mammary lymphosarcoma in dorsal recumbency.



Figure 16-62 A cow with chronic mastitis resulting in failed mammary suspensory apparatus.



Figure 16-63 A goat with chronic mastitis resulting in failed mammary suspensory apparatus.

to chronic mastitis that can be used where the suspensory support of the mammary gland is still intact. Finally, external pudendal artery vein and artery ligation has been used to cause rapid atrophy of the mammary gland, where it would be unwise to perform major surgery on very sick animals.

Chemical Destruction of the Mammary Gland

To perform chemical destruction of the mammary gland, one of several irritating preparations is injected into the affected quarter(s) and not milked out. Significant inflammation (pain swelling and erythema) results, with subsequent atrophy of that part of the gland. If excessive inflammation occurs, it is managed by milking out the preparation 24 to 48 hours after infusion. Chemicals used for this procedure include one of the following: 100 mL of a solution containing 10% formaldehyde diluted in 500 mL of sterile saline, 50 to 100 cm^3 of 3% silver nitrate solution, 20 mL of 5% copper sulfate, 250 mL of a solution containing 1 g of acriflavine in 500 mL of sterile water, or 60 mL of chlorhexidine.



Figure 16-64 The cow in Figure 16-38 placed in dorsal recumbency for surgery.

Mastectomy

Perioperative antimicrobials and nonsteroidal antiinflammatory drugs as well as replacement fluid therapy are indicated, if necessary. Surgery is best performed during fall and winter to avoid fly infestation.

The animal is anesthetized and placed in dorsal recumbency. General anesthesia is recommended because of the risk of aspiration pneumonia and to provide a more controlled environment for vasculature ligation. Should the need arise to administer blood or provide other life support measures, general anesthesia provides better accessibility to the patient. The mammary gland should be cleansed as much as possible and isolated from the rest of the animal with impervious drapes.

An elliptical incision is made around the udder. It is imperative to save as much normal skin as possible so primary closure of the surgical wound can be performed with minimal tension (Figure 16-64). When an udder is very large, the initial incision should come up the side of the udder, and the skin should be reflected down by the base of the udder as the dissection is continued. Once the skin incision is made, subcutaneous tissues are dissected by using a combination of sharp and blunt dissection. Some surgeons suggest that starting the dissection caudally and working in a cranial direction is preferable. Instead, the authors have found starting on the lateral aspect of the udder and establishing a dissection plane before advancing the incision are most useful. After this, the dissection is carried cranially and caudally with a combination of blunt and sharp dissection. The authors prefer to dissect the cranial aspect of the udder first because it is easier to separate the udder from the abdominal wall. This means the vasculature must be isolated to keep from incising it inadvertently as the dissection is carried caudally. Having at least one assistant retract the udder and aid in visualizing the site through suction and sponging of blood is very helpful. The assistant should retract the incised skin edge opposite where the surgeon is working. This allows better exposure of fascial planes and vasculature. Many small blood vessels are encountered, and hemorrhage is controlled with

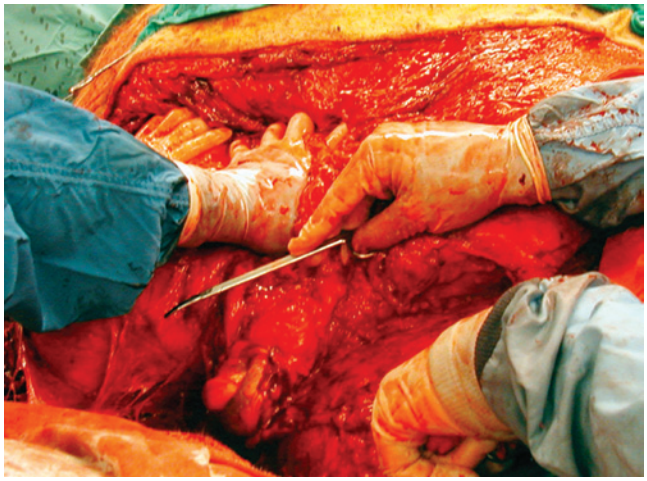


Figure 16-65 The udder is being pushed laterally to allow the surgeon access to the external pudendal vessels.

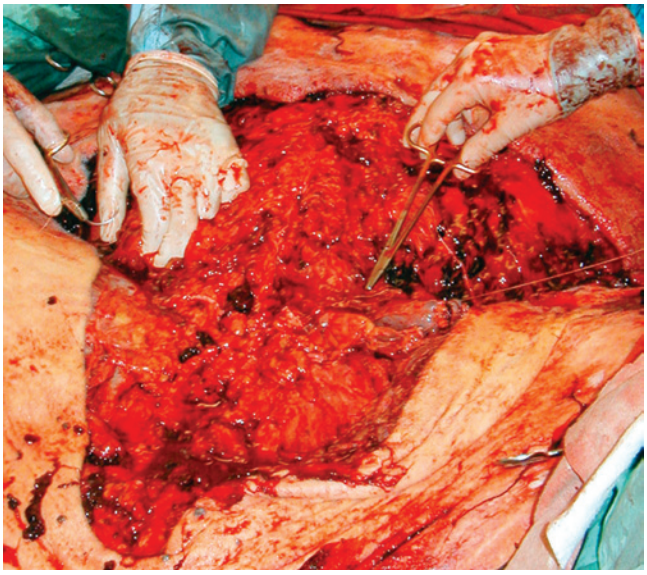


Figure 16-66 The udder has been removed, and the defect will be closed in two or three layers, thus limiting dead space as much as possible.

an electrosurgical unit and ligatures. Some surgeons advocate using a carbon dioxide laser for dissection to prevent excessive bleeding. In the author's experience, laser use is only helpful in the subcutaneous tissues; vessel size precludes effective laser use in deeper tissues. The external pudendal artery and veins, smaller mammary branch of the ventral perineal artery, and caudal superficial epigastric vein are the main vessels that require ligation. A number of additional smaller veins emerge from the cranial aspect of the gland and also require ligation, including branches of the external pudendal vessels adjacent to the suspensory ligament of the udder. The dissection is extended first toward the external pudendal artery and veins with the help of an assistant retracting the udder (Figure 16-65). The artery is double or triple ligated first to minimize vascular loss. Dissection is continued gradually, freeing the entire mammary gland from the body wall (Figure 16-66). If a hemimastectomy is performed, dissection is continued from the lateral side of the incision to the median lamina of the suspensory ligament of the udder. Then, using a combination of blunt and sharp dissection, the surgeon removes the mammary tissue.

After removal of the udder, the incision is closed. If necessary, tension-relieving sutures in the form of a vertical mattress or near-far-far-near sutures can be placed at intervals to appose the deeper tissues. Interrupted sutures can be placed between the tension sutures to bring the remainder of the fascia and subcutaneous tissues into apposition. A Penrose drain may be placed into the defect and exited adjacent to the surgical wound (Figure 16-67). This allows fluids to drain away from the healing incision. Subcutaneous sutures are carefully placed in an effort to occlude dead space. Individual sutures may be necessary as the skin flaps are pulled into apposition. Finally, the skin is apposed. If primary closure is not possible, the wound can be packed with an antiseptic-soaked dressing held in place with a stent, sutures, or bandage. This dressing can be removed 24 to 48 hours later and the area treated like an open wound with daily hydrotherapy and lavage with an antiseptic solution. Fly control is necessary. Antibiotics should be continued for at least 7 to 10 days after surgery. Nonsteroidal antiinflammatory drugs are usually continued for 2 to 3 days. If the wound is left open, diligent wound care is necessary because of possible pockets of fluid and deep recesses that must be flushed. Ideally, exercise is restricted until the wound is at least partially healed.



Figure 16-67 After excising the udder, the incision is closed. A Penrose drain has been placed for drainage.

Ligation of External Pudendal Artery

This procedure is mainly used to treat severe, life-threatening gangrenous mastitis in ruminants, including septic shock cases where the animal's cardiovascular status precludes surgery. Instead, the external pudendal artery and vein are ligated. This decreases toxin absorption into the animal's circulation and leads eventually to atrophy of the affected mammary gland. This procedure is more effective in small ruminants whose major blood supply is from the external pudendal artery. An adult cow's gland also receives blood through the mammary branch of the ventral perineal artery, which may prevent ischemic necrosis and subsequent atrophy of the gland. The procedure is clearly much less invasive than surgery, is not associated with blood loss, and is therefore preferable to udder amputation in a very sick animal. Both the cranial and caudal quarters on the ipsilateral blood

supply will become avascular. If both the left and right mammary glands need to be devascularized, the left and right external pudendal vessels must be ligated.

The animal is placed in lateral recumbency with the affected side uppermost. The upper limb is tied upward to allow access to the inguinal region. Sedation is used if needed at a reduced dose, as the patient is generally in a compromised state. After infiltration of local anesthetic over the inguinal area, a 10- to 15-cm incision is made parallel to the external inguinal ring. Using a curved scissors, the surgeon incises superficial fascia. Blunt dissection is used to locate the external pudendal vessels, which are identified as the only two vascular structures exiting the inguinal canal (Figure 16-68). The external pudendal artery is triple ligated and transected with a double ligation on the cardiac side and a single ligation on the mammary side. The procedure is repeated on the external pudendal vein. The subcutaneous tissues are closed by using three or four purse-string–like sutures. Multiple bites of loose tissue, inguinal fat, and subcutaneous tissue are taken, which reapposes all tissues superficial to the external inguinal ring on either side of the incision. The skin is closed in a routine manner. After ligation and division of the external pudendal vessels, teats from the affected quarters should be amputated at their bases with curved Mayo scissors to allow drainage.

Postoperative care includes continued systemic antibiotics appropriate for the septic process and continued drainage of the udder until it sloughs off, with appropriate wound care as needed.

Udder Biopsy

For research purposes, it is occasionally necessary to obtain a sample of mammary tissue. The portion of the udder to be biopsied should be clipped and prepared for surgery. An area without visible large vessels is identified. A local anesthetic is used to desensitize the site. A 4-cm skin incision is made through the skin and continued through subcutaneous tissues and fascia. It is critical to go deep enough to sample mammary tissue, not fat or fascia. When mammary tissue is reached, the surgeon should quickly and sharply incise the amount of tissue desired. Substantial hemorrhage will result. Rather than trying to grasp individual vessels, large bites of mammary tissue should be pulled together by using No. 1 or 2 absorbable suture in a simple continuous pattern. As soon as a tight seal is obtained, the pressure will stop the hemorrhage. Subcutaneous tissues and skin are closed with 2-0 absorbable suture material, again in a simple continuous pattern. There may be seepage from the site for 24 to 48 hours and mild swelling. There also may be blood in milk from the operated quarter for several days. The author has used this technique in 20 milking dairy cows with no long-term postoperative problems. Electrosurgical units were ineffective for the degree of hemorrhage encountered.

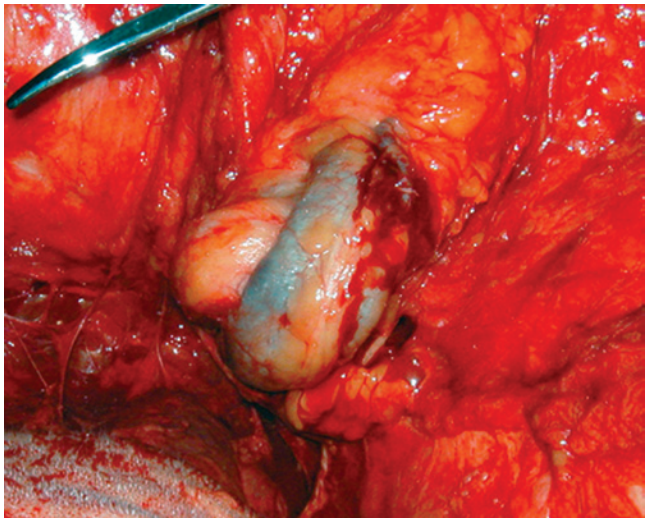


Figure 16-68 External pudendal vessels are easily identified as they exit the inguinal canal. In an adult cow, the vessels are generally 1.5 cm in diameter.

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TEAT SURGERY

Adrian Steiner

Anatomy

The bovine mammary gland usually comprises four quarters with one teat each. The teat consists of the teat wall, apex with the streak canal, and teat sinus (Figure 16-69). Proximally, the teat sinus is continuous with the corresponding gland sinus. The annulus (venous ring of Furstenberg) demarcates the teat sinus from the gland sinus. It contains one or more large veins that encircle the base of the teat. The wall of the teat consists of the following layers: innermost is the teat sinus, which is lined by a two-layered cuboidal epithelium, followed by the submucosa, connective tissue layer, and smooth muscle layer. Externally, the teat is covered by a stratified squamous epithelium. The connective tissue layer contains numerous large blood vessels that become engorged with blood during milking and suckling processes. In this text, the connective tissue and smooth muscle layers will be called the *intermediate layer*. The streak canal (teat canal, papillary duct) is lined with a stratified squamous epithelium and keratin. It varies in length between 5 to 10 mm and is located at the apex of the teat. It connects the teat sinus to the outside, ending at the teat orifice. The rosette of Furstenberg—where the stratified squamous epithelium of the streak canal meets the two-layered cuboidal epithelium of the teat sinus—represents the proximal delineation of the streak canal. The teat sphincter is located beneath the rosette of Furstenberg and consists of circularly oriented bundles of smooth muscle fibers. The teat sphincter

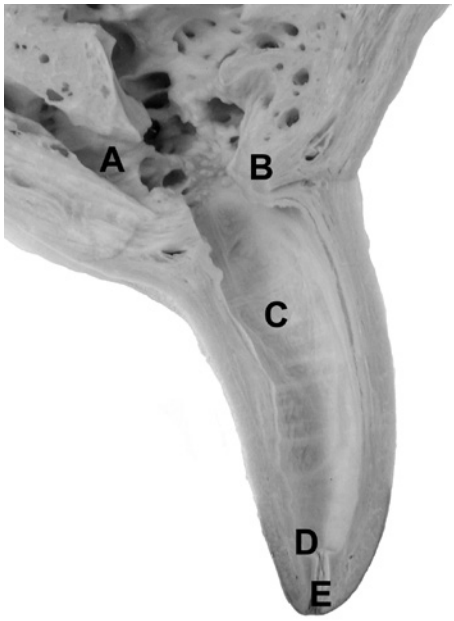


Figure 16-69 A sagittal section through the teat and gland sinus of an adult lactating cow. A, Gland sinus; B, annular ring; C, teat sinus; D, rosette of Furstenberg; E, streak canal.

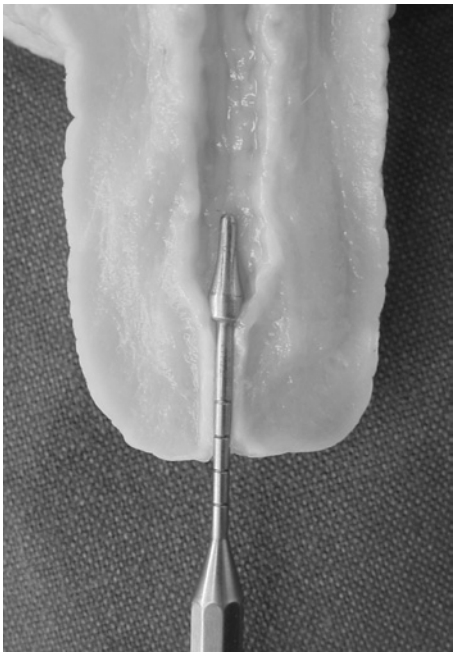


Figure 16-70 A teat probe according to Fritz, introduced into the streak canal and allowing the streak canal length to be measured.

and keratin lining of the streak canal are responsible for milk continence and preventing ascending infections.

Examination

The teat is examined with the following techniques:

1. Visual inspection to describe color, shape, and size of the teat and the type and location of any lacerations present.
2. Careful palpation and rolling of the affected teat between thumb and finger to determine any pain elicited as well as location and size of obstructive tissue present.
3. Hand and machine milking by using either commercial milking equipment or a custom-made quarter milking machine to determine milk flow.
4. California mastitis test or strip test analysis to screen for evidence of mastitis.
5. Microbial culture and/or polymerase chain reaction testing for the presence of specific bacterial DNA and sensitivity testing of a milk sample from a quarter suspected to be affected by mastitis.
6. Probing the streak canal with a teat probe[9] developed by Fritz to compare its length with the healthy contralateral streak canal (Figure 16-70).
7. Probing the teat and gland sinus with a blunt side-opening teat cannula for obstructing tissue in the area.
8. Injecting methylene blue dye into the orifice of a suspected conjoined teat to stain the milk and evaluate for communication with the primary teat.
9. Ultrasonography and endoscopy to visualize size and location of obstructive tissues in the teat and gland sinuses.
10. Measurement of the pressure in the teat cistern at the start and at cessation of leakage of an infused solution in the teat sinus.

Ultrasonography is noninvasive and allows indirect visualization of the teat and gland. It is a valuable technique for diagnosing pathologies, mainly obstructive tissue, in the teat and gland sinuses. Theloscopy—initially proposed as a diagnostic tool to directly visualize intraluminal pathologies in the teat sinus—soon developed into a surgical tool that allows obstructing tissue to be resected with minimal surgical trauma to the teat. Measurement of the intracisternal pressure was proposed to be a valuable tool in evaluating the effectiveness of teat canal surgery in the postoperative period.

Restraint, Anesthesia, and Preparation of the Surgical Field

Adequate restraint and anesthesia are important prerequisites for surgical interventions in the area of the bovine teat. Success depends on aseptic conditions and meticulous surgical technique. For simple procedures such as cutting the teat sphincter, the cow may be restrained in a chute with the tail held in an upward position and 5 mL of lidocaine hydrochloride injected into the streak canal for local analgesia. This type of restraint and anesthesia is not satisfactory for surgical interventions that require suturing. The physical position with the animal standing is very uncomfortable and may be dangerous for the surgeon, and fecal contamination of the wound is likely to occur. Therefore more invasive surgical procedures require the cow to be restrained on a surgery table or in a trough in lateral or dorsal recumbency with the affected teat positioned uppermost. Depending on the cow's temperament, sedation with xylazine hydrochloride (0.2 mg/kg IM or 0.1 mg/kg IV) is indicated. If the procedure is to be performed in lateral recumbency, the cow is attached to the table in a standing position, the tranquilizer administered, and the table tilted 10 minutes later. The procedure is similar in dorsal recumbency; the cow is sedated, casting ropes are applied, and the cow is secured into a trough. The limbs are secured to rings on the adjacent wall with hobbles. Once in position, local anesthesia is performed by circumferential injection of 20 mL of a 2% lidocaine hydrochloride solution at the base of the teat in the area of the annular ring (Figure 16-71). The anesthetic is carefully injected to avoid the circumferential vein and/or the sinus of the teat or gland.

[9]Eisenhut-Vet AG; Switzerland.

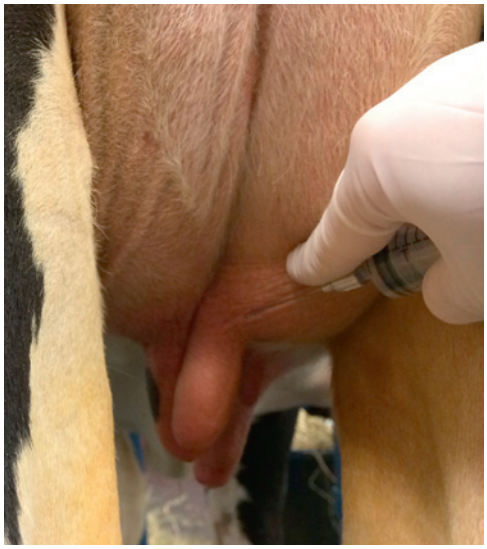


Figure 16-71 Circumferential injection of 20 mL of lidocaine hydrochloride at the base of the teat for local analgesia.

The regional block does not interfere with wound healing, and analgesia is adequate for all teat procedures described in this chapter except for proximal lacerations that involve the gland tissue, where additional local infiltration may be necessary. General anesthesia is not typically necessary for teat surgery. The surgical field is prepared and draped according to aseptic surgery procedures. If the pathology location allows it to be done, a metal tourniquet (teat clamp) is positioned at the base of the teat to reduce intraoperative hemorrhage and prevent milk outflow during the surgical intervention.

Pathologies

Teat pathologies that require surgical intervention include supernumerary and conjoined teats, lesions characterized by reduced milk flow, lacerations, and fistulas. Within the pathologies characterized by reduced milk flow, congenital obstructions, obstructions uncommonly observed before first milking, and pathologies acquired during lactation or dry periods will be discussed.

Supernumerary Teats

Supernumerary teats may be surgically removed for the following reasons: interference with milking, increased risk of mastitis, and cosmetics. Because supernumerary teats carry a heritability factor (h^2) of 0.2 to 0.3, some breeding associations do not allow hidden removal of these teats. The appropriate technique of teat removal depends on the age of the animal. At 3 to 6 months of age, teats are usually large enough for the veterinarian to distinguish primary teats from supernumerary teats. At this age, after local infiltration with lidocaine (2%), supernumerary teats are simply removed with a pair of scissors. The cut is oriented in a craniocaudal direction so the resultant scar blends with the normal folds of the udder. Because of the tendency for increased bleeding at an older age, supernumerary teats in animals older than 6 months are removed with an emasculator. Supernumerary teats removed during the last months of gestation or during lactation require more extensive surgical intervention. The teat is dissected with an elliptical incision performed in the craniocaudal direction at the base, allowing visualization of the mucosa of the accessory gland. Technique of wound closure and type of suture material are similar to those described in the corresponding section of teat amputation.



Figure 16-72 Conjoined teat in a lactating dairy cow.

Any evidence of mastitis should be treated aggressively before surgery.

Conjoined Teats

A conjoined teat (or webbed teat) is defined as a supernumerary teat attached to the side of a primary teat (Figure 16-72). Conjoined teats do have accessory glands of various volumes. Depending on the degree of fusion, the conjoined teat may be identified as a bulge at the proximal aspect of the primary teat or merely as an extra teat orifice at its side. The latter condition has to be differentiated from the teat fistula described in a separate section that represents a connection to the primary teat. Injecting 20 mL of methylene blue dye into the orifice to stain the milk, or ultrasonography, may assist in differentiating a suspected conjoined teat (Figure 16-73). Surgery is indicated because the conjoined teats' interference with milking and increased incidence of mastitis in the accessory gland represent a permanent risk of infection for the primary gland. The accessory gland's incomplete emptying, chronic trauma to the teat orifice during milking, and insufficient development and function of the streak canal and teat sphincter cause the increased incidences of mastitis.

The glandular tissue of the accessory teat usually produces little milk. Therefore surgical intervention mostly consists of resecting the bulging tissue and closing the accessory gland. Elliptical dissection, directed parallel to the long axis of the primary teat, is performed around the contours of the supernumerary teat. The shape of the normal contralateral teat is used as a model. The conjoined teat is carefully dissected to the level of the annular ring to isolate the sinus of the accessory teat. Inadvertent opening of the primary teat sinus should be avoided. A side-opening cannula may be introduced into the accessory teat orifice to aid in the dissection. The accessory tissue is transected at the junction between teat and gland sinus (Figure 16-74). The wound is closed as described for perforating teat lacerations. Prognosis for undisturbed milking of the primary gland is favorable.

The cisterns of the primary and accessory teats may be connected in those rare cases where the accessory gland has significant milk production. The surgical approach is similar to the one described for resecting the conjoined teat. After the cistern of the accessory teat is opened, a 2- to 3-cm-long longitudinal incision is made, with care taken not to sever the circular veins between the accessory and primary cisterns at the level of the annular ring. Wound closure follows the guidelines described for perforating teat lacerations. The

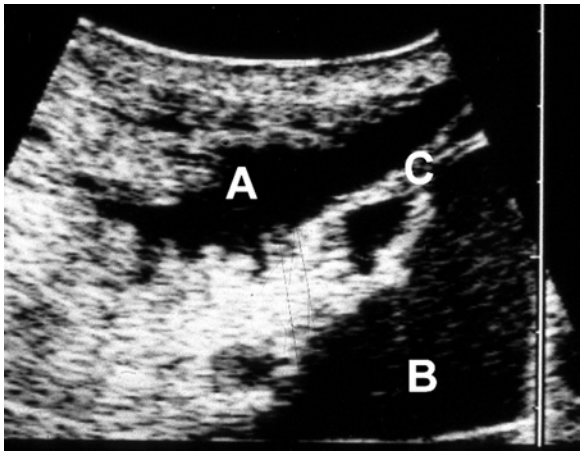


Figure 16-73 Longitudinal ultrasonographic view of a conjoined teat in a cow. Left, proximal; A, sinus of the conjoined gland; B, sinus of the primary gland; C, septum between primary and conjoined teat sinus.

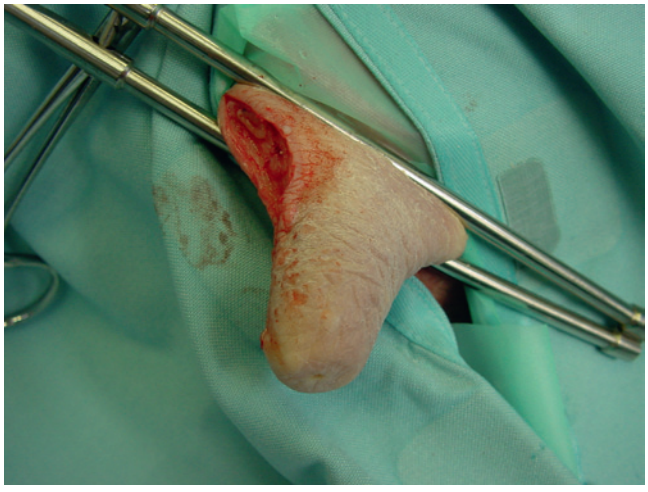


Figure 16-74 Situation after surgical removal of a conjoined teat before wound closure.

respective mucosa wound margins are apposed by using a simple continuous suture pattern. Prognosis for permanent success of this procedure is fair. The main complications include mastitis development, slow milking, blood clots occluding milk flow, and excessive granulation tissue formation occluding the surgically created communication. The heritability of webbed teats is a concern that should be communicated to the owner before surgery.

Pathologies Characterized by Reduced Milk Flow

Reduced or lack of milk flow represents economically important complaints associated with teat problems. Economic losses can be attributed to increased milking time, concurrently increased somatic cell count, treatment costs, discarded milk, clinical and subclinical mastitis, and culling of cows. Reduced milk flow may be caused by various congenital and acquired obstructions, including agenesia, tissue flap, tissue proliferation, varicose vein formation, and milk stones. A thorough clinical and ultrasonographic examination of the affected teat and mammary gland is indicated because any of the pathologies may require considerably different therapeutic procedures and prognoses. Obstructions not recognized before the first milking commonly are considered congenital. However, many of these obstructions are not congenital but result from trauma or infection that occurs before first milking.

(Partial) Agenesis of the Streak Canal

Partial agenesis represents incomplete canalization of the streak canal. Considerable variation of incomplete canalization does exist, with the extremes being an imperforate skin membrane at the end of the streak canal and complete agenesis of the streak canal. A bulge may be observed over the area of the teat orifice when milk is squeezed toward the streak canal in a case with an imperforate skin membrane. The skin membrane is opened by using a No. 11 scalpel blade or a 14-gauge needle. For several days before each milking, the apex of the teat is rolled between thumb and finger. This breaks down fibrinous adhesions and helps open the streak canal. After each milking, a melting teat stent that consists of wax is introduced into the streak canal for 7 consecutive days to keep it patent until healing occurs. The prognosis is usually favorable. Lateral theloscopic examination (see Theloscopy) helps determine the degree of agenesis if incomplete canalization involves more than just the distal end. If the rosette of Furstenberg is not developed, prognosis is poor. If the rosette of Furstenberg and the proximal third of the streak canal are developed, a cutting obturator under visual control is used to perforate the skin and connect the teats outside with the canalized aspect of the teat canal. The obturator is replaced by a permanent teat cannula that is sutured to the teat and left in place for 10 days. During this period, milk is passively drained through the cannula once daily. Complications include mastitis, milk incontinence, and hard milking. Long-term prognosis for undisturbed milk flow after this procedure is fair to good.

Tight Streak Canal

Tight streak canal is usually acquired as a consequence of a self-inflicted injury to the apex of the teat. The cow may crush her teat between its claw and the floor when trying to rise. Chronic trauma as a result of poor function of the milking machine, such as excessive vacuum formation, is considered the second major cause of a tight streak canal. This condition is accompanied by a hyperplasia and roughening of the outer streak canal orifice. Clinical signs include chronic inflammation at the teat apex, pain elicited by the vacuum, and severely decreased milk flow, which leads to increased milking time. This type of lesion is often self-perpetuating. The traditional owner treatment is to use teat dilators to stretch the streak canal and teat sphincter. Unfortunately, this treatment regimen is often unsuccessful and predisposes the animal to complications such as mastitis and trauma to the teat sinus mucosa. Ideally, the crushed teat is allowed to heal without adding further trauma. The affected teat should not be milked for 7 to 10 days after injury, but milk should be passively drained every second day with a blunt side-opening teat catheter. Hand milking and routine machine milking determine whether milk flow is still reduced. The sphincter is cut with a Hug's teat knife if milk flow is still reduced, and ultrasonographic evaluation rules out involvement of a tissue flap in the area of the rosette of Furstenberg. Surgery is best performed before the morning milking to allow proper aftercare during the day. Oxytocin (20 IU) is administered intravenously, the teat is surgically prepared, the streak canal anesthetized with lidocaine hydrochloride, and the Hug's teat knife introduced through the streak canal. The knife is gently pulled out at a 30- to 45-degree angle so only the area of the rosette of Furstenberg (i.e., the teat sphincter and proximal aspect of the streak canal) is cut, but the distal aspect of

the streak canal is not severed (Figure 16-75). Milk flow is assessed by forced hand milking and compared with the contralateral teat. The teat sphincter is cut a second time 180 degrees from the first cut. The procedure may be repeated if necessary at each 90 degrees. Milk flow is evaluated after each cut. A fine stream of milk that passively flows out of the teat for at least 30 seconds after cutting indicates sufficient surgical intervention. Aftercare consists of routine morning milking and forceful hand milking of several streams of milk every 1 to 2 hours until afternoon milking. After each routine machine milking, a melting teat stent of wax is introduced into the streak canal for 5 consecutive days to keep it patent until healing has occurred. Complications include episodes of acute mastitis, milk incontinence, and recurrence of hard milking. Long-term prognosis for undisturbed milk flow after this procedure is good as long as any inflammation is allowed to resolve before cutting and stiff traumatic teat dilators are not used during aftercare.

Obstruction in the Area of the Rosette of Furstenberg

This is among the most common causes of reduced milk flow in dairy cows. Similar to the tight streak canal, obstruction in the area of the rosette of Furstenberg is usually acquired as a consequence of a self-inflicted injury to the teat apex. Although the integrity of the skin is preserved, one or more tissue flaps may originate from the proximal aspect of the streak canal and prolapse into the teat sinus similar to a valve that intermittently interferes with milking. The affected teat should not be milked for 7 to 10 days immediately after the injury, but milk should be passively drained every second day with a blunt side-opening teat catheter. Thereafter, hand milking and routine machine milking determine milk flow. If milk flow is still intermittently reduced, involvement of a tissue flap in the area of the rosette of Furstenberg must be considered. It is diagnosed with the aid of the teat probe and/or ultrasonography (Figure 16-76*A* and *B*). The tissue flap may be removed by blind excision through the streak canal or under visual control during a thelotomy or theloscopy. The latter techniques are described in separate sections. During the postoperative period, milk is drained passively, and the streak canal is kept patent by the daily introduction of a melting teat stent made from wax. Stiff teat dilators should not be used for this purpose because doing so may cause severe trauma to the mucous membrane of the teat sinus, as has been described. If milk flow has not returned to normal by the fourth machine milking after surgical removal of the tissue flap(s), the concurrent presence of a tight streak canal must be considered and treated as described for this condition. Prognosis for return to undisturbed milking is superior if the flap(s) is removed under direct visual control compared with blind excision, which is not recommended. Long-term prognosis for return to undisturbed milking is similar with a thelotomy or theloscopy. However, fewer cows treated by theloscopy require the teat sphincter to be cut postoperatively or suffer from episodes of mastitis, and aftercare is less intensive. Therefore minimally invasive theloscopy to remove tissue flaps in the area of the rosette of Furstenberg is preferred. Nevertheless, obstructions in the area of the rosette of Furstenberg are associated with increased somatic cell count in the lactation of surgery.



Figure 16-75 Halligan's Ultimate Gadget knife introduced into the streak canal at a 30-degree angle.

Milk Stones

These represent floating calculi that are either completely free or attached to the teat mucosa by a pedunculated stalk. Multiple stones may occur and mechanically interfere with milk flow when forced toward the streak canal during milking. Manual palpation or ultrasonography is used to diagnose milk stones, and forced hand milking usually ejects

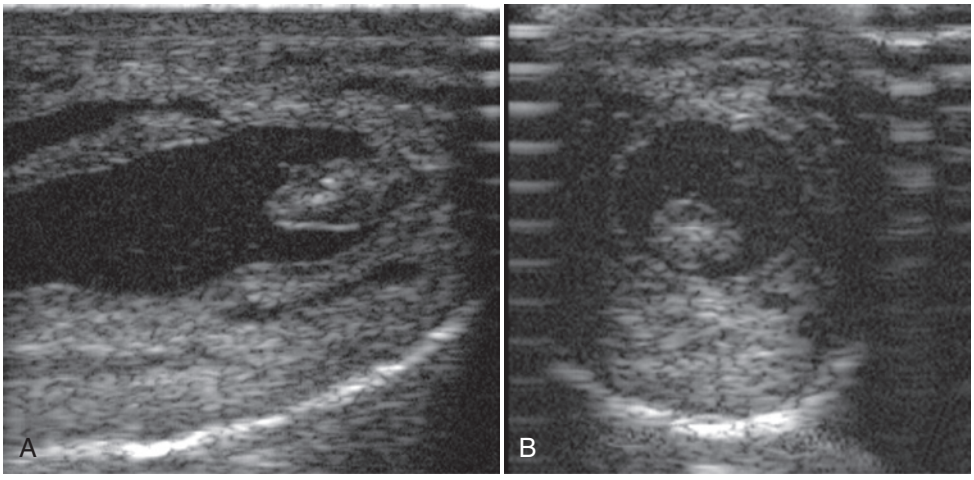


Figure 16-76 Longitudinal (*A*, left, proximal) and horizontal (*B*) ultrasonographic views of an obstruction in the area of the rosette of Furstenberg in a cow.

small stones. A stone that is attached or too large to be milked out is removed or crushed intracisternally with a small alligator forceps introduced through the streak canal. For this procedure, prophylactic intramammary application of an antimicrobial, adequate restraint, local analgesia, and strict aseptic manipulation are recommended. The author has observed recurrence of milk stones.

Obstructions in the Area of the Teat Cistern and/or the Annular Ring

Obstructions in the area of the teat cistern and/or the annular ring are acquired and rarely congenital, although they are not commonly recognized before first milking. Causes of acquired obstructions include acute trauma, chronic trauma from being sucked by herdmates, varicose vein formation, and unnoticed mastitis during the dry period, which may be spread by flies. Congenital obstructions may result in persistent intraluminal membranes or agenesis of the teat sinus. If mammary secretions cannot be obtained from a primiparous heifer, the quarter must be evaluated for dysgenesis. Obstructions of the teat sinus with less than 30% of the mucosal surface affected are classified as Type I lesions (Figure 16-77), and Type II lesions have more than 30% of the mucosal surface affected (Figure 16-78). Obstructions in the area between the teat and mammary gland sinus are considered Type III lesions, and Type IV lesions extend from the teat sinus to the gland sinus. Ultrasonographic examination is used to differentiate the four lesion types (see Figures 16-77 and 16-78). Varicose vein formation may be treated by sclerotherapy (injection of 25% dextrose solution), ligation associated with sclerotherapy, or phlebectomy. Overall prognosis is good (84% at 6 months after surgery); however, recurrence of the obstruction may occur in up to 15% of the cases. Surgical techniques currently used to restore patency of the sinus in case of obstructive tissue formation include tissue removal by introducing a cutting instrument or cryosurgical probe through the streak canal into the teat sinus and thelotomy with the obstructing tissue excised under direct visual control. After removal during thelotomy, the adjacent mucosa is undermined and the margins of the mucosa are carefully apposed using a 4-0 monofilament absorbable suture material. An implant or transplant is considered if insufficient tissue is available to adapt the wound margins. The very loosely attached mucosa and rich tissue blood supply make the teat sinus very prone to granulation tissue formation. Therefore resecting the obstructing tissue through the streak canal is not recommended. New formation of granulation tissue causes the initially good milk flow to decrease and eventually cease within a period of days to a few weeks. A mucosa defect too large to be primarily closed after the obstructing tissue is removed and may be covered by transplanting an autogenous vestibular mucosal graft, implanting a reinforced polytetrafluoroethylene vascular graft, or introducing a Silastic tube. However, the long-term success rate for these techniques is guarded to poor. Complications include recurrence of obstruction, implant migration into the gland sinus, implant collapse, increased milking time, implant infection, and mastitis. Prognosis of Type I and III lesions is good if the defect can be completely covered with mucosal tissue.

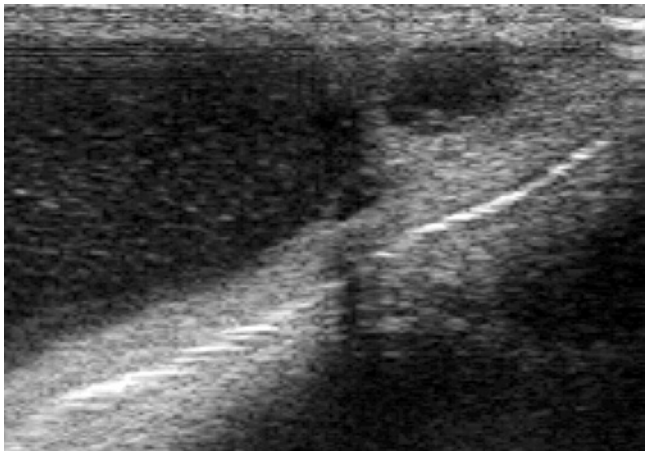


Figure 16-77 Longitudinal ultrasonographic views of a Type I teat lesion in a cow (left, proximal).

Fibrosis of the Gland Sinus

This is characterized by connective tissue replacing normal gland tissue. This can be the result of a congenital disease or it can occur after infection of the gland sinus before first lactation or during the dry period. Fibrosis is suspected if milk flow at first milking is minimal and palpating the affected mammary gland reveals diffuse induration.

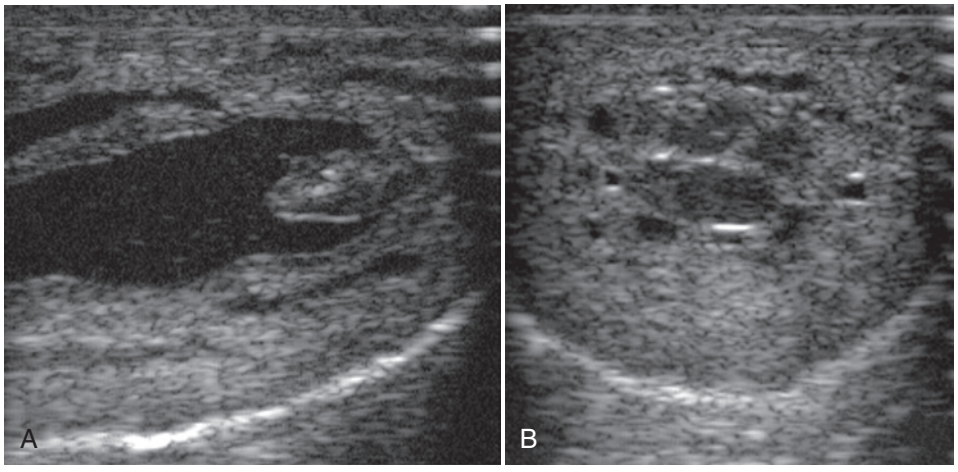


Figure 16-78 Longitudinal (*A*, left, proximal) and horizontal (*B*) ultrasonographic views of a Type II teat lesion in a cow.

Ultrasonographic examination confirms the diagnosis and reveals that fibrous tissue has replaced the secretory tissue, lactiferous ducts, and gland sinus. Currently, no surgical procedure exists to correct this problem. The prognosis for return to milk production is poor. The author has observed complete recovery in the subsequent lactation after the affected quarter was continued to be milked in the current lactation.

Open Teat Lacerations

Teat lacerations can be open lacerations or have skin integrity preserved (covered lacerations causing milk flow disturbance). Open lacerations are classified as partial- or full-thickness lacerations that perforate into the streak canal, teat sinus, or gland sinus. Open teat lacerations should be evaluated carefully to determine the prognosis for return of milk flow and normal somatic cell count and the type of surgical reconstruction to initiate. Prognosis depends on various criteria, such as location, size and direction of the laceration, degree of tissue loss, involvement of the streak canal, presence of mastitis and udder edema, age of laceration, and degree of contamination. Longitudinal lacerations heal better than horizontal lacerations because blood flows from the base toward the apex of the teat. Because perfusion is superior at the base of the teat, proximal lacerations heal better than distal lacerations. Partial-thickness lacerations at the apex of the teat with the base of the tissue flap located distally may have a less favorable prognosis than some full-thickness lacerations perforating into the teat sinus. The presence of edema in the precalving and puerperal period often severely interferes with primary wound healing. Streak canal or gland sinus anatomic repair is difficult, which makes the prognosis worse when they are involved. Because the teat generally has good perfusion, age of the laceration is not of primary concern. In our experience, primary repair may be successful for up to 12 hours after the laceration occurred. In older injuries, delayed primary closure is recommended.

Surgical Correction of Teat Lacerations

If primary repair is initiated, the cow should be restrained in lateral or dorsal recumbency, the teat anesthetized, and reconstruction performed under aseptic conditions. The wound margins are carefully debrided and rinsed with physiologic saline solution. Any necrotic, contaminated, or infected tissue must be removed. Very little extra tissue is available in the teats; therefore preserving as much normal tissue as possible is important. In full-thickness lacerations, a three-layer closure that involves the submucosa, intermediate layer, and skin is appropriate. The submucosa and intermediate layer are apposed separately with a continuous horizontal mattress suture that does not perforate the mucosa using No. 4-0 monofilament synthetic resorbable suture material with a taper point swaged-on needle (Figure 16-79). Polydioxanone is the more appropriate suture material for use in teat surgery compared with poliglecaprone 25 and polyglycolic acid as determined in vitro on the basis of material testing after incubation of suture material in milk or bacteria-contaminated milk. Experience of the author, however, does not seem to support that this difference is clinically relevant. The skin is closed with simple interrupted sutures by using 3-0 or 4-0 monofilament suture material with a reverse cutting swaged-on needle. Partial-thickness lacerations are sutured in a similar fashion, but the innermost suture of the submucosa is omitted. Supernumerary teats as pedicle grafts were used to repair severe teat tip damage in experimental cattle. The teat anatomy was successfully restored. Function of the reconstructed teat in lactating cows, however, remained unknown. As to the author's knowledge, clinical reports of this technique are not available. Postoperative management includes passive milk drainage every second day and administration of intramammary antimicrobials every 4 days for 10 days. Systemic administration of antimicrobials is rarely indicated. The overall prognosis of teat lacerations that involve the teat sinus is favorable. Complications include partial or total wound dehiscence, necrosis of tissue flaps, fistula formation (Figure 16-80), impaired milk flow, increased somatic cell count, and episodes of acute mastitis.



Figure 16-79 A sutured teat laceration.

If the streak canal is affected, the wound is debrided as described; several simple interrupted sutures are placed in the intermediate layer close to the streak canal, a permanent teat catheter is introduced into the streak canal, and the sutures are tightened and knotted. The skin is closed with simple interrupted sutures. The teat catheter is left in place for 10 days to keep the streak canal patent until healing has occurred. In general, the prognosis for cattle with lacerations that involve the streak canal to return to normal milk flow is markedly less favorable compared with lacerations that involve the teat sinus.

If reconstruction of a teat laceration is not possible, the teat may be amputated as a salvage procedure. Delayed primary wound healing should be attempted when primary closure and amputation do not represent viable options for repair. Be aware that teat fistula formation is expected in up to 75% of the cases that use secondary healing of full-thickness lacerations.

Teat Fistula

The teat fistula is an accessory opening on the teat that communicates with the primary teat sinus or streak canal (Figure 16-81). It does not possess a separate streak canal or teat sphincter. It can be congenital but usually results from a full-thickness teat laceration and occurs as a complication of secondary wound healing or dehiscence after primary



Figure 16-80 A healed laceration that resulted in the formation of a teat fistula at the level of the teat sinus.



Figure 16-81 Healed laceration that resulted in the formation of a teat fistula at the level of the streak canal.

healing. Greater parity and higher age of the wound at the time of surgical intervention can be associated with a delay in the wound-healing process, which may result in fistula formation. Methylene blue dye injected through a fistula appears in the milk of the main teat. A teat fistula wound should be allowed to granulate until swelling and infection subside and the fistula is well delineated before surgical repair is initiated. The cow is restrained in lateral recumbency with the teat anesthetized, prepared, and draped for aseptic surgery. A longitudinally oriented elliptical full-thickness specimen of teat wall centered over the fistulous tract is excised to expose unscarred teat wall. The teat wall is closed as described for full-thickness teat lacerations. The prognosis for return to normal milk flow is favorable.

SURGICAL INTERVENTIONS

Restraint, anesthesia, and preparation of the surgical field have been described in a separate section and apply to this chapter, unless specified otherwise. Specific surgical teat interventions routinely used in cattle include teat amputation, thelotomy, and theloscopy.

Teat Amputation

This procedure is performed when teat damage caused by severe trauma is irreversible. Any mastitis present in the corresponding quarter must be treated before surgery. Prophylactic intramammary injections of antimicrobials and milk drainage are performed immediately before amputation. If the laceration does not involve the teat base, a teat clamp is positioned in the area of the annular ring and the teat is routinely amputated. An elliptical skin incision is made around the teat at the junction of the proximal and middle thirds. The teat wall is sharply dissected in a slightly proximal direction and transected, thus creating a fish mouth–like teat stump (Figure 16-82*A* and *B*). Bleeding vessels are ligated separately. With the clamp still in position, the submucosa and intermediate layers are tightly apposed with one nonperforating continuous horizontal mattress suture each and 4-0 monofilament synthetic resorbable suture material with a taper point swaged-on needle. The skin is closed with interrupted sutures accordingly by using 3-0 or 4-0 monofilament suture material with a reverse cutting swaged-on needle. If the laceration does involve the teat base, the amputation is performed just distal to the annular ring. A skin flap attached to the base must be preserved. The wound is curetted and rinsed, margins debrided, and submucosa and intermediate layers routinely sutured. The skin flap is used to cover the defect, which is closed with simple interrupted sutures.

If the corresponding mammary gland did not have mastitis before surgery, the prognosis of teat amputation is favorable. The quarter will secrete milk until pressure atrophy of the alveolar tissue occurs and dries up the quarter. The remaining three quarters will produce considerably more than 75% of the previous milk yield, because blood flow will bypass the dried-up quarter for the secreting quarters.

Thelotomy

After routine local analgesia, aseptic preparation, and draping of the surgical field, a 3- to 4-cm longitudinal incision (depending on the length of the teat) through the skin and intermediate layers is made on the lateral aspect of the teat. A blunt metal probe is introduced through the streak canal into the teat sinus to protect the mucosa of the medial teat wall from inadvertent laceration while the mucosa is being carefully transected with a scalpel blade. The rosette of Furstenberg is exposed and closely inspected (Figure 16-83), and the obstructing tissue is carefully excised with a pair of fine scissors. The submucosa and the intermediate layer are apposed with one continuous horizontal suture pattern with a size 4-0 monofilament synthetic resorbable suture material with a taper point swaged-on needle. The skin is closed with simple interrupted sutures with 3-0 or 4-0 monofilament suture material with a reverse cutting swaged-on needle. Postoperative management is routine. Formation of scar tissue that reduces milk flow—thus necessitating cutting of

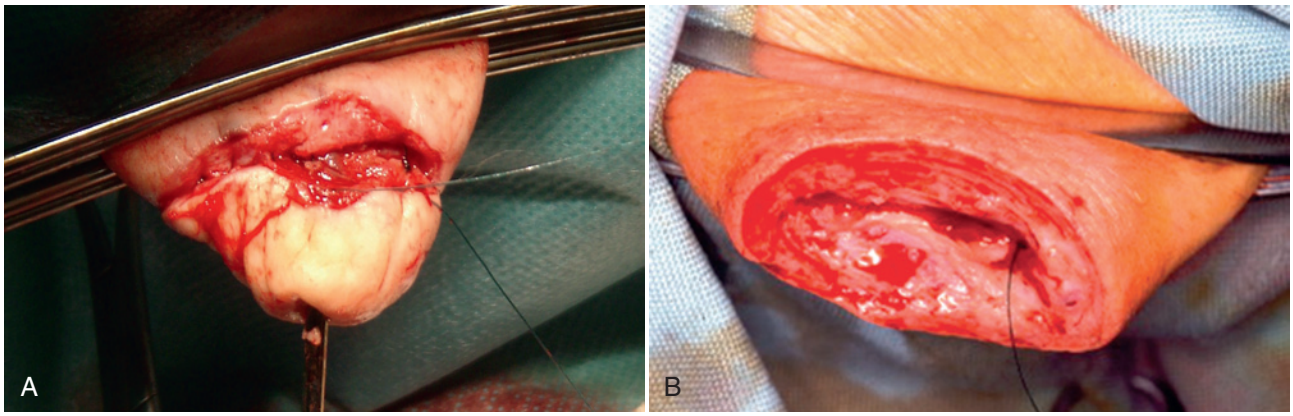


Figure 16-82 *A*, Teat clamped before amputation. *B*, Appearance of base of teat after amputation.

the teat sphincter—is the most common complication. A retrospective analysis found that 73% of cows had the streak canal cut during the first week after obstructive tissue in the area of the rosette of Furstenberg was removed during thelotomy. Milk flow returned to normal when the lactation surgery was performed and remained normal during a second lactation in 68% of the cows.

Theloscopy

Theloscopy is a diagnostic and surgical procedure (Figure 16-84) that has replaced thelotomy for removing obstructive tissue in the area of the rosette of Furstenberg under visual control when equipment is available (Figure 16-85). Theloscopic triangulation or theloresectoscopy with a working endoscope determines the obstruction location. For lateral endoscopy, a blunt side-opening teat catheter is introduced through the streak canal, and air is passed through this catheter to insufflate the teat sinus. A perforating stab incision is made in the lateral wall of the teat 10 mm distal to the teat clamp with a No. 10 scalpel blade. A sleeve and endoscope are introduced through this instrument portal, and the teat sinus is insufflated through the sleeve. The side-opening teat catheter is replaced by a blunt probe. The obstructive tissue in the area of the rosette of Furstenberg is visually examined with the endoscope and manipulated with the probe to determine its size and shape of attachment to healthy tissue. The obstructive tissue is excised and removed using the cautery sling of the working endoscope. If the triangulation technique is used, a pair of endoscopic scissors is introduced into the teat sinus through a separate instrument portal created in the cranial or caudal aspect of the teat approximately 5 mm proximal to the rosette of Furstenberg. Obstructing tissue is excised with the scissors and removed through the instrument portal with a pair of endoscopic tissue forceps. After removal of the instruments, the intermediate layer in the area of the portal(s) is closed with size 4-0 monofilament synthetic resorbable suture material and a taper point swaged-on needle. Skin incisions are closed by using 3-0 or 4-0 monofilament suture material with a reverse cutting swaged-on needle in a horizontal mattress pattern. Main complications include episodes of acute mastitis and formation of scar tissue that reduces milk flow, thus necessitating cutting the teat sphincter. A retrospective study revealed that milk flow returned to normal during the lactation in which surgery was performed in 65% of the animals operated and was judged normal during a second lactation in 76% of the cows treated by theloscopic removal of obstructive tissue in the area of the rosette of Furstenberg. Cutting the streak canal after surgery was performed in only



Figure 16-83 Intraoperative view of obstructive tissue in the area of the rosette of Furstenberg.

15% of the cows. This was significantly less common than after thelotomy. The rate of complications after theloscopic excision was significantly lower and aftercare less expensive compared with thelotomy removal.

IMPLANTATION OF TEAT PROSTHESIS (EDITORS' ADDENDUM)

Norm Ducharme

Teat prostheses have been described for many types of teat obstructions, but they have a high complication rate. They are most successful if used in Type I or II teat sinus obstructions in which normal mucosa proximal and distal to the lesion allows the implant to bridge the mucosal defect. When

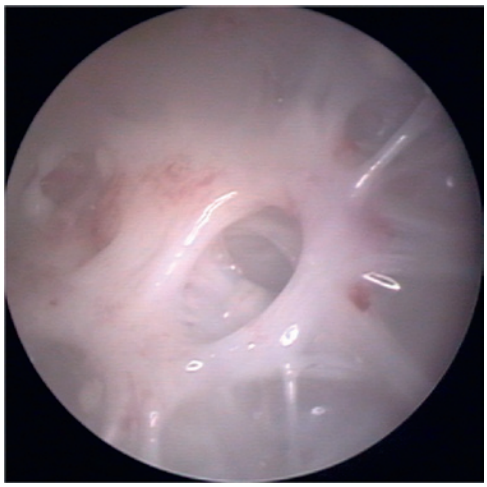


Figure 16-84 Theloscopic view of a Type I lesion situated in the distal third of the teat sinus. The theloscope is introduced through the streak canal into the teat sinus.

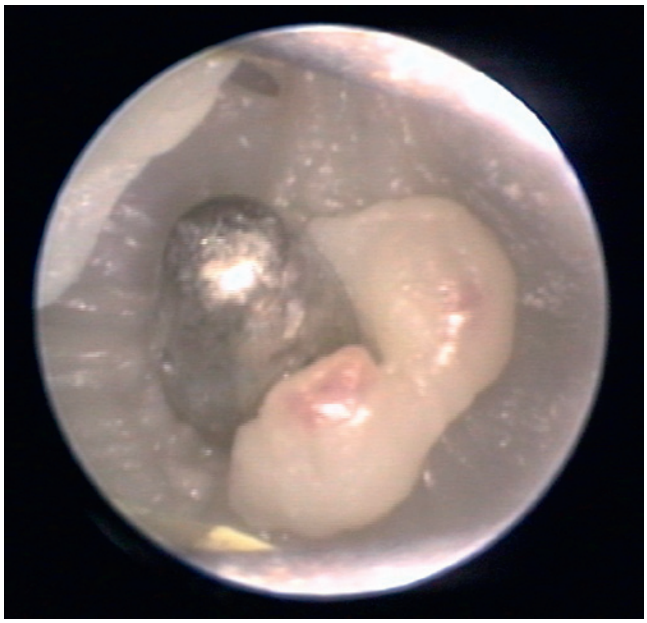


Figure 16-85 Theloscopic view of a tissue flap in the area of the rosette of Furstenberg. The tip of a blunt probe (introduced through the streak canal) is visible. The theloscope is introduced into the teat sinus through a lateral approach.

used in other types of teat obstructions, the procedure offers a guarded to poor long-term prognosis for return to normal milk flow.

A thelotomy, as described previously, is performed opposite the lesion to be resected. After careful excision of the obstructive lesion, one needs to determine whether the adjacent mucosa can be slid over the defect. If the lesion's bed can be covered by mucosa, an implant should not be used. If the mucosal defect cannot be covered and the lesion is limited to the teat sinus with normal mucosa proximal and distal to the lesion, an implant is indicated. The morbidity of the procedure—coupled with the milk production potential of three quarters—dictates careful selection of the patient. The implant consists of sterile Silastic tubing (7-mm



Figure 16-86 Surgery to implant a teat prosthesis. (Courtesy of Dr. Wade Walker.)

inside diameter, 10-mm outside diameter) without any fenestration. A blunt teat cannula is placed through the streak canal, and the implant is placed over the cannula so it rests near the rosette of Furstenberg. The implant is then placed in the teat sinus and the length of the prosthesis selected; the prosthesis must span the teat sinus without entering the gland cistern. The prosthesis is then cut with scissors and replaced in the teat sinus. The implant is secured in place with three vertical equidistant sutures by using nonabsorbable polypropylene 2-0 suture on a cutting needle (Figure 16-86). These three sutures are placed so that the tubing is pulled distally to rest against the rosette of Furstenberg when they are tightened. The specific bites are placed as follows: the first bite of the suture in the center of the thelotomy incision is placed from proximal to distal into the full thickness of the Silastic tubing at the midpoint of the implant. The second bite is placed in the wall of the teat, starting 3 to 4 mm distal to the exit point of the suture in the implant. This suture must be anchored deep in the wall of the teat so the surgeon can feel the needle passing immediately subcutaneously. The suture then exits again a few mm distal to the distal exit point of the suture in the implant. When the suture is tied, the implant is rotated into place. Offsetting the sutures ensures that the implant stays against the proximal aspect of the streak canal (Figure 16-87). A second suture on the cranial wall of the teat sinus and a third at the caudal wall of the teat sinus are placed similarly. The thelotomy is closed as described earlier.

POSTOPERATIVE MANAGEMENT

Excluding prosthesis implantation, routine postoperative management includes passive milk drainage for 10 days, except theloscopy requires only 3 days. Frequency of passive milk drainage depends on daily milk yield of the cow and may vary from once a day to every third day. For this purpose, intermittent introduction of a side-opening metal teat catheter is preferred to temporary implantation of a

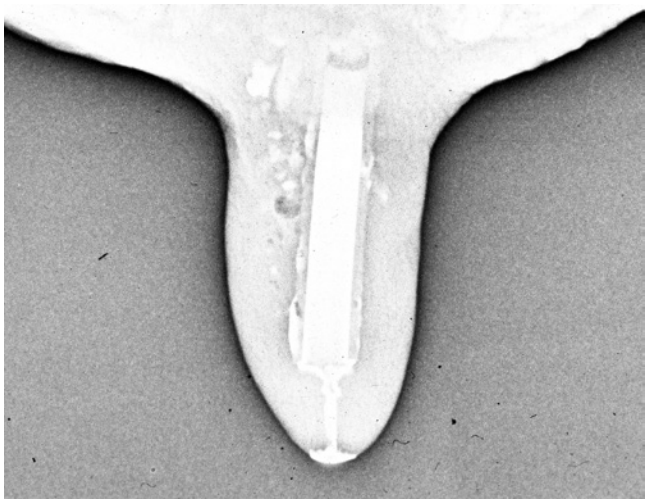


Figure 16-87 Lateral xeroradiograph of a cow's teat after placement of a teat implant. Note that the implant does not extend into the gland sinus and is directly over the streak canal.



Figure 16-88 Dehiscence of a full-thickness teat laceration. The intermediate layer was allowed to granulate, and the wound is now ready for tertiary wound closure.

Silastic catheter except for teat lacerations involving the streak canal. Temporary implantation of stiff teat dilators and catheters for several days caused lacerations to the teat sinus mucosa and submucosa. Daily introduction of a melting teat stent made from wax into the streak canal for 10 days is indicated to keep the streak canal patent and reduce the formation of scar tissue after dissecting obstructing tissue in the area of the rosette of Furstenberg. Intramammary administration of a broad-spectrum antimicrobial drug as a prophylactic measure against mastitis is performed every 4 days until 10 days after surgery. Too-frequent intramammary administration of antimicrobials favors growth of fungi. Systemic administration of antimicrobials is indicated in cases of acute mastitis only. Sutures are removed and machine milking resumed on day 11 after surgery. After theloscopy, routine machine milking is resumed by day 4 after surgery. If milk flow has not returned to normal at the fourth milking session, clinical reevaluation of the teat is performed. Cutting the teat sphincter may be indicated if excessive scar tissue has formed in the area of the streak canal.

After placement of a teat implant, the cow is machine-milked in the postoperative period, starting the first day after surgery. Animals that have implants can only be milked by machine or after a teat cannula is inserted. The latter is not recommended because of the risk of ascending infection and the possibility of implant displacement if forceful placement of the teat cannula is necessary.

COMPLICATIONS

The main complications after teat surgery include occurrence of acute mastitis, increased somatic cell count, reduced milk flow, and wound dehiscence (Figure 16-88). Frequency of episodes of acute mastitis in the postoperative period is markedly reduced if passive milk drainage is performed under aseptic conditions. Somatic cell count depends on the severity of the trauma to the teat and the occurrence of ascending infection in the quarter. Atraumatic surgical technique may help keep somatic cell count low. If reduced milk flow at the fourth session of routine machine milking is evident, thorough examination of the teat is indicated. Slow milking should be avoided because prolonged milking time leads to additional trauma to the teat and decreases milk flow. This development is self-perpetuating. The likelihood of wound dehiscence depends on the degree of wound contamination, age of the teat laceration, degree of interference of blood supply to the wound, and the parity and lactation period of the cow. Presence of excessive udder edema markedly interferes with primary healing of teat wounds and is a very important reason for wound dehiscence and fistula formation. If an implant has been placed, the implant has a tendency to become displaced at 6 to 8 weeks after surgery. This may be of no clinical significance. In some cows, the displaced prosthesis may float into the gland sinus and obstruct milk flow from the gland to the teat sinus. Another complication related to implants is fragmentation of the implant.

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SURGERY OF THE KIDNEY

Susan L. Fubini

ANATOMY

The bovine kidney is large, with distinct renal lobes (Figure 16-89). The lateral border is convex. The vasculature, nerves, and ureters pass through a hilus on its concave medial border. The kidneys are enveloped in a fibrous capsule surrounded by peritoneal fat. They are contained within the abdominal cavity but are retroperitoneal. The right kidney is enough farther forward that it contacts the liver with its cranial pole. It lies just right of midline ventral to the hypaxial musculature, last rib, and first few lumbar vertebrae. The left kidney is further caudad, behind the root of the mesentery. Its position is just right of midline, depending on how much the rumen displaces it. Unlike the right kidney, the left kidney is very mobile and easily palpated per rectum. Both kidneys are accessible from the right paralumbar fossa. The left kidney only is accessible from the left paralumbar fossa. Small ruminant renal lobes are fused, making the kidneys' external surface appear smooth.

Unilateral Nephrectomy

Unilateral nephrectomy is indicated for cattle with unresponsive unilateral pyelonephritis (Figure 16-90*A*), polycystic kidney (Figure 16-90*B*), and hydronephrosis and is occasionally indicated for congenital urinary defects (i.e., ectopic ureter), neoplasia, abscess formation, and renal lithiasis.

If a unilateral nephrectomy is contemplated, a complete evaluation of the integrity of the remaining kidney is essential. Both kidneys' activity is reflected in laboratory values (creatinine and blood urea nitrogen), although serum elevations are usually not abnormal until 75% of the nephrons are diseased. Ultrasonography and renal biopsy may be indicated to thoroughly evaluate the remaining kidney. Ultrasound examination is performed transabdominally for the right kidney, whereas the left is best evaluated by a rectal probe. Ultrasonographic changes from pyelonephritis include dilation of the renal collecting system; an enlarged kidney with acute disease; or a small, irregular kidney with chronic disease (Figure 16-91*A* and *B*). With urolithiasis, echogenic material may be seen within the renal collecting system, and there may be renal enlargement.

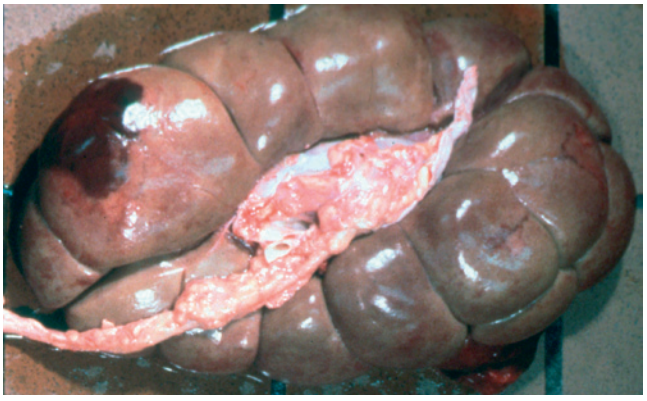


Figure 16-89 A normal bovine kidney. Note the distinct renal lobes. (Courtesy of Dr. John King.)

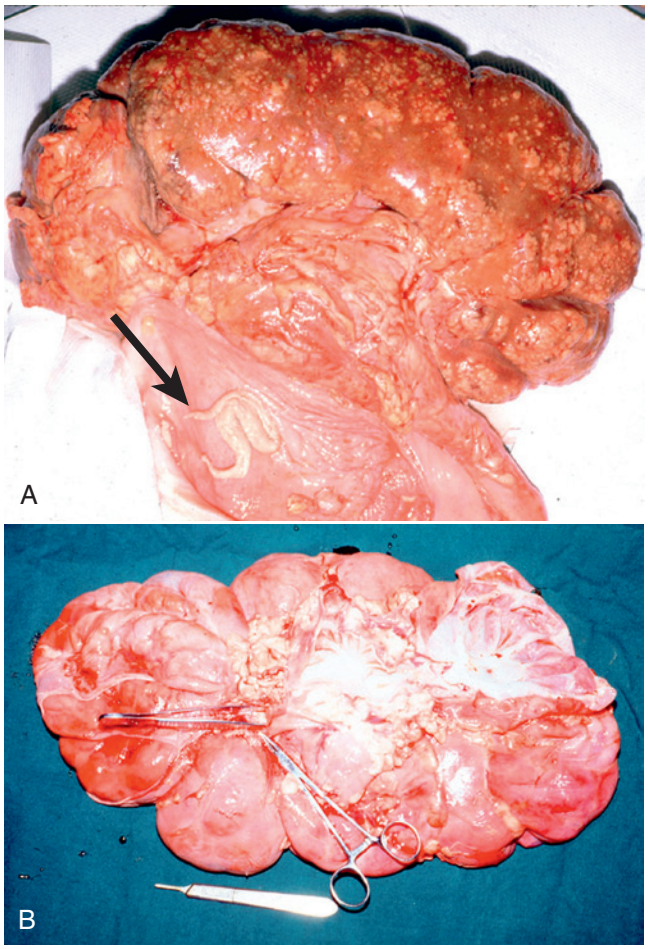


Figure 16-90 *A*, A kidney removed from a cow with pyelonephritis. Note multiple small abscesses in the cortices and pus present in the ureter (*arrow*). *B*, Polycystic kidney. Forceps are outlining the dilated ureter. (Courtesy of Dr. Tom Divers.)

Surgery is usually performed in the standing cow, although general anesthesia may facilitate the procedure. Perioperative antibiotics are indicated. Procaine penicillin is an economical choice, and it reaches good concentrations in the urine. Ideally, the cow is restrained in stocks, a chute, or a head gate. The flank is desensitized with regional or local anesthesia. The author prefers not to sedate cattle for standing surgery because of the likelihood they will lie down. Regardless of whether the left or right kidney is affected, a right-paralumbar fossa approach is used. A 25- to 30-cm incision is made just caudal and parallel to the last rib to remove the right kidney and a midparalumbar fossa incision to remove the left kidney.

The abdominal oblique and transversus muscle layers are incised sharply. Whenever possible, it is preferable to remove the kidney from the retroperitoneal space, which is easier for the right kidney (Figure 16-92). It is not uncommon to have a renal abscess (Figure 16-93) with perirenal adhesions complicate the dissection, resulting in inadvertent entry into the peritoneal cavity. Much of the retroperitoneal fat can be removed with blunt dissection. The renal artery, vein, and ureter are individually identified and ligated if possible (Figure 16-94). Depending on the size of the affected kidney, ligating the renal pedicle may be difficult. Alternatively, the renal vessels and ureter can be identified (Figure 16-95), securely clamped, transected (Figure 16-96*A* and *B*), and ligated after the kidney has been removed. The vessels and ureter should be double ligated with a nonreactive suture material with good knot security because intraabdominal hemorrhage is the most common complication after surgery. If not performed before surgery, a biopsy of the remaining kidney should be performed before closing the abdomen. If there is a perirenal infection, all (or a portion) of the incision may be left open to allow ventral drainage and granulation of the wound. Some clinicians pack the wound with antiseptic-soaked gauze rolls or towels for a few days after surgery. As the wound granulates, a warm water hose may be used to lavage the wound provided there is no communication with the peritoneal cavity. Owners should be warned that these wounds close very slowly and that daily care is required. The prognosis is favorable if the remaining kidney is viable.

In small ruminants, the surgery is performed in lateral recumbency, typically with the animal under general anesthesia. The kidneys are more mobile, thus making the ligations much easier to accomplish.

Renal Biopsy

The left kidney is mobile and easily palpated per rectum, which permits a percutaneous biopsy from either paralumbar fossa. The animal is restrained in a standing stock or chute, and the paralumbar fossa is prepared with appropriate aseptic technique. An epidural anesthetic is useful for a cow that is straining. An assistant palpates the left kidney rectally and positions it against the body wall. The examiner should easily visualize the renal parenchyma with ultrasonography. The biopsy site is chosen and a bleb of local anesthetic is placed to desensitize the skin. A small, 1-cm incision is made to allow insertion of a Vinn-Silverman[10] or Tru-Cut biopsy needle.[11] The biopsy needle is thrust into the parenchyma, avoiding the renal pelvis and vasculature. Once an adequate sample is obtained, it is saved in formalin for histopathology.

The right kidney can usually be visualized well enough ultrasonographically to permit percutaneous biopsy from the cranial right-paralumbar fossa. If not, the biopsy can be performed via laparotomy or laparoscopically.

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[10]J-116V, Vinn-Silverman needle, Jorgensen Laboratories Inc., Loveland, CO, USA. http://www.jorvet.com.

[11]Tru-Cut, Travenol Inc. (a division of Baxter International), Deerfield, IL, USA. http://www.baxter.com.

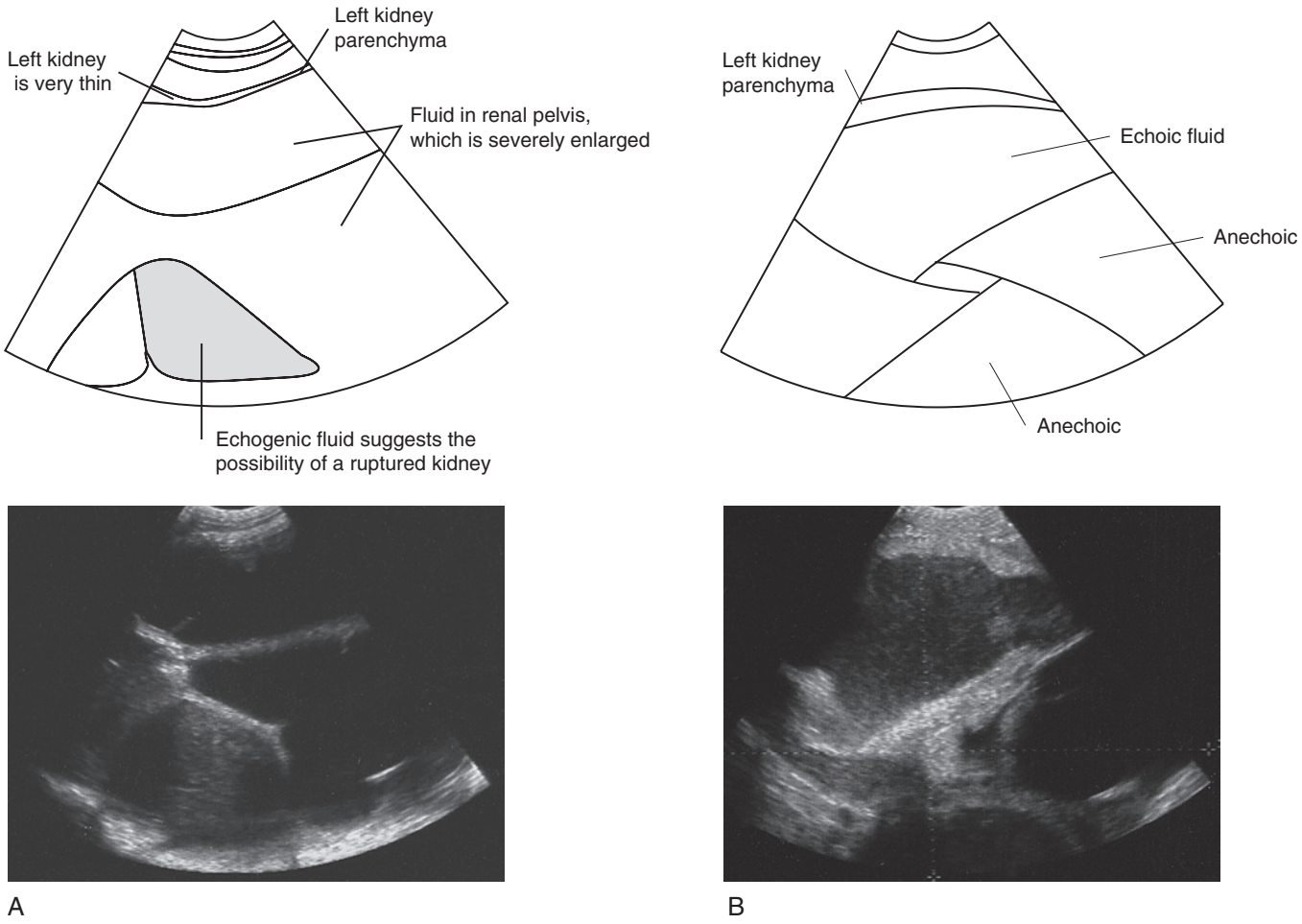


Figure 16-91 Longitudinal sonograms (schema shown earlier) of the left kidney obtained from a 3-year-old Holstein cow with pyohydronephrosis, which was removed surgically. A 2- to 4-MHz convex probe was used. Both sonograms (*A*, *B*) show severe renomegaly (greater than 32 × 21 cm) secondary to hydronephrosis. The severely dilated renal pelvis is surrounded by a 1- to 2-cm rim of thin parenchyma or thick capsule. Some of the fluid compartments comprising the dilated renal pelvis are echoic (*B*). This indicates cellular or high-protein fluid, which represents pus in this case. (Courtesy of Dr. Amy Yeager.)

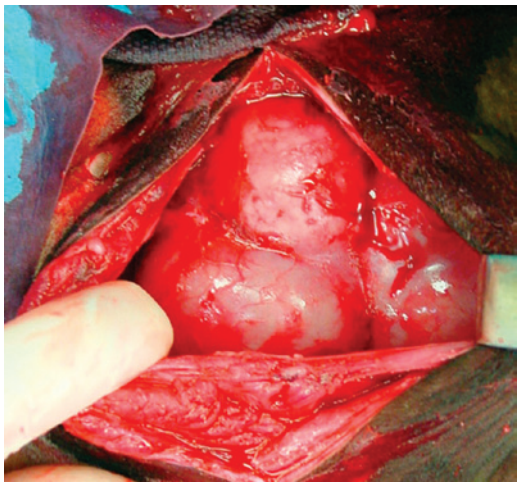


Figure 16-92 Right kidney (with pyelonephritis) being removed through a right-paralumbar fossa incision into the retroperitoneal space in a heifer.

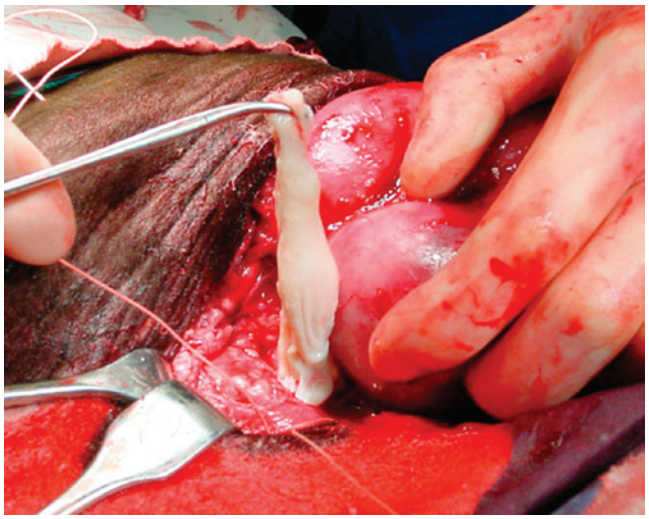


Figure 16-93 The pyelonephritis has resulted in a perirenal abscess. Purulent material is being removed.

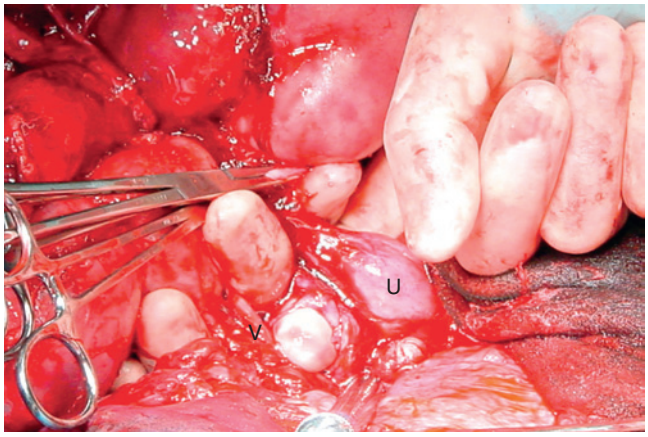


Figure 16-94 Right-flank laparotomy in a cow under general anesthesia. Renal vessels (V) and ureter (U) have been identified.

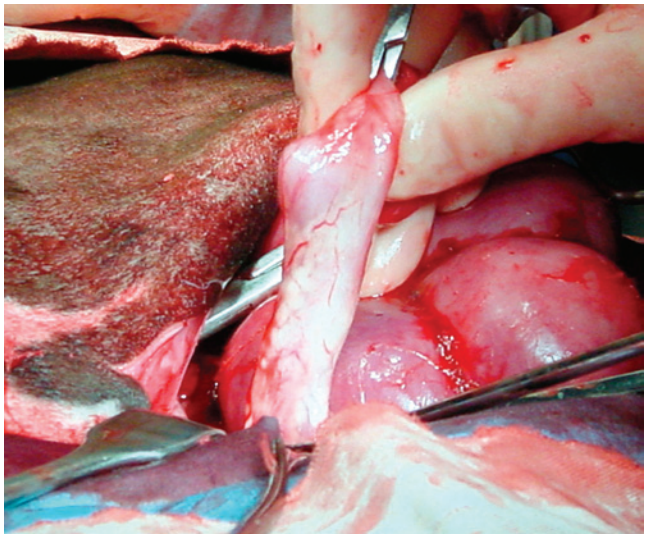


Figure 16-95 A distended ureter is identified in a cow with pyelonephritis.

SURGERY OF THE URINARY BLADDER AND URETERS

Susan L. Fubini

ANATOMY

The urinary bladder is a muscular organ with a blind apex cranially, the body in the middle, and a neck continuous with the urethra caudally. Remnants of the fetal umbilical arteries give rise to the bladder's round ligaments, which are the thickened portion of the lateral ligaments of the bladder. In the fetus, the apex of the bladder is patent and continuous with the urachus, which empties into the allantoic space. The fetal vessels normally contract during the neonatal period.

The cranial aspect of the urinary bladder has a peritoneal covering; the caudal portion is retroperitoneal. The detrusor muscle is made up of three irregular layers that are continuous with the musculature around the neck of the bladder, which forms the urinary sphincter. As in other species, transitional epithelium lines the bladder. The ureters enter the bladder dorsally at the trigone.

Amputating the urinary bladder apex and manipulating the umbilical vessels' remnants are common procedures performed in umbilical surgery and are discussed in Chapter 20. Isolated reports of urinary bladder and ureter surgery are described in the following discussion.

Ruptured Urinary Bladder (Adult Cattle)

The most common source of uroperitoneum in cattle is rupture of the bladder secondary to urethral urolithiasis. Steers in feedlot settings are the most commonly affected group, with bulls of all ages less commonly affected. Clinical signs and treatment related to urethral urolithiasis are discussed in Chapter 25. Isolated reports of bladder rupture in heifers and adult cattle that have recently freshened have been made. In young female animals, the presumed cause of bladder rupture is abdominal trauma. In adult females, it is possible the fetus obstructs the pelvic urethra during prolonged dystocia, which leads to eventual compromise of the urinary bladder. Subsequent manipulation of the fetus could result in bladder rupture. Alternatively, the bladder can be trapped under the uterus in the pelvic cavity and be subjected to trauma during parturition.

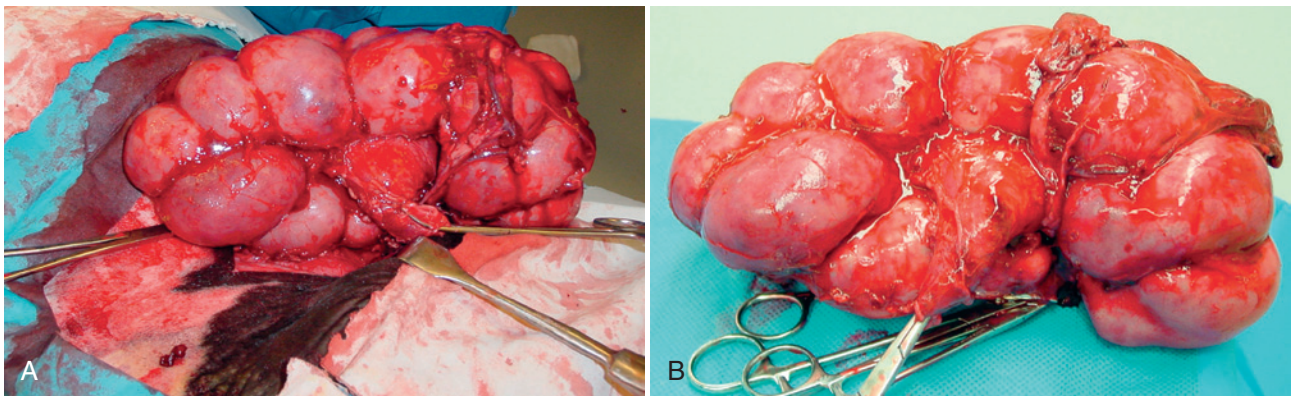


Figure 16-96 *A*, Renal vessels are clamped and transected. *B*, After the kidney is removed, these structures are ligated.

Leakage from other parts of the urinary system—including the kidneys, ureter, or (in the neonate) urachus—is much less common. Leakage after incomplete closure of a cystotomy, placement of a transcutaneous bladder catheter, or cystocentesis can also serve as an occasional source of uroperitoneum.

Uroperitoneum does produce mild chemical peritonitis, but infection is relatively uncommon, and cellular changes in the peritoneal fluid are generally limited to a mild to moderate mature neutrophilia. Infection can occur if the original source of contamination contains bacteria or if organisms are introduced during diagnostic or therapeutic procedures by systemic spread or bacterial translocation. Urokinase, a plasminogen activator in urine, tends to limit the development of peritoneal adhesions but may also promote continued leakage by interfering with the development of a fibrin seal.

Diagnosis in a feedlot setting can typically be made with reasonable accuracy based on the presence of progressive abdominal distention with free fluid, dehydration, anorexia, and depression. Anuria, dysuria, and a palpably flaccid bladder support the diagnosis of uroperitoneum, but a temporary fibrin seal may allow intermittent bladder distention and passage of urine. Evaluation of peritoneal fluid is necessary for diagnosis in less commonly affected groups of cattle and can be beneficial in feedlot cattle with less classic presentations. Peritoneal fluid in cases of uroperitoneum is typically clear to slightly turbid and clear to yellow in color. Heating the peritoneal fluid may enhance the odor of ammonia and support the diagnosis. A peritoneal : serum creatinine ratio of 2 : 1 or greater is considered diagnostic for uroperitoneum in both adult and preruminant cattle.

Changes in blood and peritoneal fluid constituents become apparent as urine is deposited in the peritoneal cavity and allowed to equilibrate with blood. Urea nitrogen is a small molecule and equilibrates too quickly across the peritoneal membrane to reliably indicate peritoneal leakage in functioning ruminants. Furthermore, urea excreted in the saliva can be metabolized by bacteria in the rumen, decreasing the blood urea level. Potassium is also concentrated in urine and equilibrates quickly with serum; however, a peritoneal : serum potassium ratio greater than 2.7 : 1 was a consistent finding in experimental bladder rupture in preruminant calves. Serum potassium levels are subject to a variety of systemic factors that may have a greater impact in the functioning ruminant. These include anorexia, aldosterone-induced salivary secretion, gastrointestinal loss in exchange for sodium, and intracellular shifts in exchange for hydrogen ions. As a result, serum potassium levels in adult cattle with uroperitoneum may be high, normal, or low. A hyponatremic, hypochloremic metabolic alkalosis is common in both adult cattle and preruminant calves with uroperitoneum. If left untreated so the animal becomes dehydrated, a metabolic acidosis might develop.

Phosphorous, which is mainly excreted by the salivary glands, may be elevated because of decreased salivary excretion or secondary to hypocalcemia-associated anorexia.

Replacement fluid therapy that consists of 0.9% NaCl is indicated. If hyperkalemia is present, dextrose solutions may be included (2.5% dextrose with 0.45% NaCl is an option). If the rupture occurs in a recently freshened cow, attention should be paid to recognizing and treating hypocalcemia. Theoretically, peritoneal drainage may be useful; however, the authors have had difficulty maintaining patency of abdominal drains in ruminants because of the greater omentum.

It has been reported that some dorsal tears of the bladder will heal spontaneously if a urethral catheter is placed. This is done with a Foley (approximately 12-20 French) catheter in the adult female cow. After adequate restraint and preparation of the perineum, a gloved hand with sterile lubricant applied is inserted into the vestibule. Just under the transverse fold, the urethral opening is identified. The Foley catheter can be slid into the opening with a finger before filling the balloon with sterile saline. If the decision is made to place an abdominal drain, it is very helpful to localize a pool of fluid by ultrasonography. The intended site of drain placement is prepared for surgery, and the skin is desensitized using a local anesthetic. A 2-cm skin incision is made with a scalpel blade, and a chest trocar is directed into the abdomen with a sharp thrust. In the author's experience, these drains function well for a short period of time but then become sealed by omentum or become infected.

Ventral bladder tears usually require surgery and are approached by using local or general anesthesia via a caudal flank or ventrolateral celiotomy in animals with udder development. In heifers or beef cattle, a ventral midline celiotomy may be used.

During surgery, it may be necessary to infuse the urinary bladder to identify the defect. The tear is debrided if necessary and closed in 2 layers—a simple continuous pattern oversewn by an inverting pattern (Cushing or Lembert). Whether to include the mucosa when closing the bladder is somewhat controversial. The authors incorporate mucosa with synthetic absorbable suture and have not recognized any problem to date.

Complications include failure of the repair and adhesions that involve portions of the reproductive or gastrointestinal tract. In a large cow, exposure can be very limited, thus making the repair difficult.

Eversion and Retroflexion of the Urinary Bladder

Eversion of the urinary bladder is a rare condition in cows because they have a long, narrow urethra. However, this condition has been reported either during or shortly after parturition. One case has been reported in a cow 5 months after calving.

Under excessive abdominal force, the urinary bladder (presumably empty) is forced into the pelvic cavity, where it can enter the vagina either by passing through the urethra (eversion) or by tearing the vaginal wall (retroflexion). External examination reveals a congested and discolored soft mass (sometimes up to 20 cm in diameter) that protrudes downward from the vulva (Figure 16-97). The displaced bladder can become edematous and necrotic if left unattended.

The diagnosis can be made by examining the protruding mass. The mucosa of the bladder is exposed in bladder eversion, and the serosa of the bladder is evident in retroflexion. The retroflexed bladder can contain urine whereas the everted bladder has no urine but can contain a serous exudate, thus making differentiation of the two conditions difficult without a cytologic examination. Vaginal examination further differentiates the two conditions: the neck of the bladder exits the external os of the urethra in bladder eversion, whereas the neck of the bladder exits through a defect in the cranial vaginal wall in bladder retroflexion.

Treatment entails manual reposition or amputation of the apex of the bladder. First, an epidural block is performed to arrest straining. The use of a topical hyperosmotic agent such as 40% dextrose may decrease swelling of the bladder and help facilitate repositioning. If multiple attempts to reposition a bladder eversion are unsuccessful, the dorsal aspect of the urethra can be incised (approximately 8 cm) with curved Metzenbaum scissors. After the bladder eversion has been corrected, the urethral incision is sutured with size 0 nonabsorbable suture material in a simple continuous pattern.



Figure 16-97 Bladder eversion in a cow. Note the congested and discolored soft mass protruding downward from the vulva.

Another option is to perform a complete epidural block with 100 mL of 2% lidocaine hydrochloride and cast the animal. The cow's hind limbs can be extended caudally, which facilitates repositioning the bladder. Amputating the bladder apex should be considered if necrosis is present or all other attempts at repositioning have failed. If a complete epidural block is performed, one should hobble the hind legs in the recovery period to prevent tearing of the adductor muscles. In the days after repositioning, a standard epidural may need to be repeated to prevent reoccurrence of the condition.

Retroflexion of the bladder is easier to reposition after performing an epidural. However, recurrence or evisceration of the intestine is possible unless the cranial vaginal tear is sutured. This is done blindly as the surgeon places one (or more) cruciate sutures with No. 1 or 2 absorbable suture material to close or minimize the vaginal wall defect. Unless treated early, the prognosis for these bladder displacements is guarded because of the difficulty in treating them and the risk of peritonitis.

Surgery of the Ureters

Indications for surgery of the ureters include ureteral calculi and ectopic ureters, both of which are exceedingly rare.

URETERAL CALCULI

Ureteral calculi may result from migration of renal calculi. This is a difficult diagnosis to make, but the calculi occasionally can be palpated per rectum or detected by transrectal ultrasonography. Clinical signs of ureteral urolithiasis are primarily those of acute abdominal pain (Figure 16-98). Other signs similar to those of urethral urolithiasis are also present, such as frequent attempts at micturition, occasionally blood-tinged urine, and urine dribbling. A few reports in the literature describe ruminants treated for ureteral calculi. In several cases, the calculi apparently broke up on their own or with palpation and manipulation. Surgical removal has been mentioned (Fabisch, 1968) but not described in detail.



Figure 16-98 Heifer with unilateral ureteral urolithiasis showing abdominal pain. Note stretching. (Courtesy of Dr. Thomas Divers.)

ECTOPIC URETERS

Isolated reports describe surgery for ectopic ureters. This condition is more commonly recognized in small animals and horses. It has been reported to be both unilateral and bilateral. Females are overrepresented, but this may be because the incontinence is more easily recognized than in males. If the termination of the ectopic ureter is proximal to the external urethral sphincter in males, retrograde filling of the bladder rather than incontinence may result.

Embryologically, an ectopic ureter results from failure of the metanephric and mesonephric ducts to separate properly. In females, an ectopic ureter may terminate in the urethra, vagina, cervix, or caudal to the trigone of the bladder. In males, ectopic ureters have been reported to empty into the urethra, vas deferens, or seminal vesicles.

The most common clinical signs associated with ectopic ureters are urinary incontinence and urine scalding. Urinary tract infection is common, most likely from urine stasis and ascending infection. Hydronephrosis, hydroureter, and polycystic kidney disease have all been reported secondary to ectopic ureters. Ureteral reflux of urine due to the abnormal course of the ureter may cause a functional obstruction.

Clinical examination through speculum-assisted or endoscopic examination of the vagina and vestibule might allow identification of an abnormal ureteral opening. Parenteral injection of dyes that are concentrated in the urine may facilitate visualization of aberrant ureteral openings. Dyes that have been used include sodium fluorescein (11 mg/kg IV), neoprontosil (10 mL IV), and azosulfamide (1.9 mg/kg IM). Ultrasonography is helpful in identifying any dilation or abnormality in the kidney or ureter. An intravenous pyelogram may be useful for identifying an ectopic ureter and associated urinary abnormality in young animals or small ruminants (Figure 16-99).

Either an ipsilateral nephrectomy or vesicoureteral anastomosis can be performed to correct unilateral ectopic ureters. Unilateral nephrectomy is less technically demanding than vesicoureteral anastomosis and has a low morbidity. However, if unilateral nephrectomy is contemplated, the existence and functional status of the contralateral kidney should be determined. Unilateral nephrectomy is discussed in the section Surgery of the Kidney.

Ureterovesicular anastomosis and ureteroneocystostomy are the only surgical options for bilateral ectopic ureters.

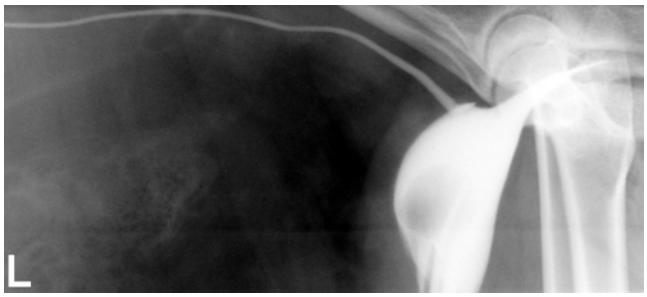


Figure 16-99 **Left-lateral radiograph of the caudal abdomen of a 5-year-old goat with urethritis.** A positive contrast cystogram and partial normograde urethrogram was performed, and retrograde flow into the ureter is seen. Note normal site of entry ureter. (Courtesy of Dr. Anthony Pease.)

These techniques can be technically difficult. Common postsurgical complications include delayed healing caused by tension on the closure and stenosis of the stoma caused by failure to accurately appose urethral mucosa to bladder mucosa.

Ectopic ureters may be intramural or extramural. An ectopic ureter that bypasses the bladder to enter the urinary tract caudal to the trigone is termed *extramural*. At surgery, the ureter is double ligated and transected caudal to the bladder. The urethral artery must be ligated via a ventral cystostomy. A small circle of bladder wall is excised from the dorsal surface. A mosquito hemostat is tunneled through the circular defect created in the wall, and the ureter is grasped and drawn into the bladder lumen. The end is transected, and the ureter is spatulated by making a 1-cm longitudinal incision on one side. The mucosa of the ureter is sutured to the bladder mucosa with 4-0 synthetic absorbable suture material in an interrupted pattern. Efforts must be made to preserve the blood supply and avoid twisting the ureter. The bladder is closed routinely.

An intramural ectopic ureter appears to enter the bladder serosa in the normal position but runs caudally within the bladder wall and enters the genitourinary tract distal to the bladder. Intramural ectopic ureters are corrected from within the bladder. A cystotomy is performed, and an incision is made through the bladder wall and into the lumen of the ureter. The ureter wall and mucosa are sutured to the bladder mucosa. After this, a catheter is passed caudally through the new ureteral opening. The catheter facilitates identifying the portion of the ureter still connected to the ectopic opening distal to the bladder. This portion of the ureter is identified and double ligated as close as possible to the newly created intravesicular opening.

Excretory Urography

The ability to see the kidneys, ureters, and urinary bladder on abdominal survey radiographs is limited by overlying viscera and low subject contrast. Therefore only small animals that weigh less (calves, sheep, and goats) can be imaged at this time. Standard urographic techniques can be used when necessary to examine the urinary system. As for other species, the use of iodinated contrast materials injected intravenously will result in opacification of the urine by virtue of glomerular filtration of an organic iodide compound. After intravenous injection, rapid filtration occurs, and the kidney and ureter should be seen within 3 to 5 minutes. Radiographs should be taken immediately following bolus intravenous dosing. Ideally, ventrodorsal and lateral radiographs are obtained sequentially until anatomic structures are visualized and any abnormalities detected are described. The study may be limited to lateral radiographs because of available equipment and patient cooperation, but some information will be unavailable.

Urographic agents used in veterinary medicine include the ionic compound sodium-methylglucamine diatrizoate (Hypaque,[12] Renografin[13]) and the nonionic compounds iohexol (Omnipaque) and iopamidol (Isovue). The intravenous dose for all products is 800 mg iodine/kg body weight. All are available in various iodine concentrations ranging from 180 to 370 mg iodine/mL solution. A safe guideline for dosing is to start with 2 mL/kg body weight, but twice this dose could be administered under some circumstances. The contrast media should be administered rapidly via an indwelling intravenous catheter, with care taken to avoid extravasation, as the solutions are hypertonic and irritating. Nonionic contrast media are less hypertonic, and fewer local and systemic side effects are reported with these solutions in humans and dogs. The literature has little discussion of dosage or side effects in small ruminants, but the same principles as other species are probably true.

A urographic contrast study for ectopic ureter should ideally combine the positive contrast study of the kidneys and ureters (excretory urography) with pneumocystography. This increases the probability of seeing the location of the ureter at the trigone region. In female sheep or goats, catheterization of the urinary bladder is best performed by direct visualization of the urethral orifice. After removing residual urine, the bladder is insufflated with room air to about 80% volume. This procedure is almost impossible to perform in rams or bucks because of the difficulty in catheterizing the penile urethra (Figure 16-100). After the urinary bladder is filled with air, the intravenous contrast medium is injected, and sequential radiographs are obtained at 3- to 5-minute intervals. Both ventrodorsal and lateral radiographs are useful to follow the ureter(s) to their placement at the trigone. In general, the ureter should course caudally from the kidney and then curve ventrally, cranially, and medially to enter the urinary bladder (see Figure 16-99). The most common congenital malformation is a ureter that bypasses the trigone to enter directly into the urethra. Anesthesia is recommended to allow catheterization, positioning, and radiography without a struggle.

In larger sized animals, intravenous injection of indigo carmine[14] (0.8% ampule use 0.25 mg/kg IV) immediately followed by urethroscopy and cystoscopy can allow identification of an ectopic ureter. Indigo carmine is rapidly excreted through the kidney and gives a blue color to the urine. The ureteral openings are identified by observing the colored urine.

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[12]Hypaque and omnipaque: http://gehealthcare.com/
[13]Renografin and Isovue: http://imaging.bracco.com/
[14]Taylor Pharmaceuticals, Decatur, IL, USA.

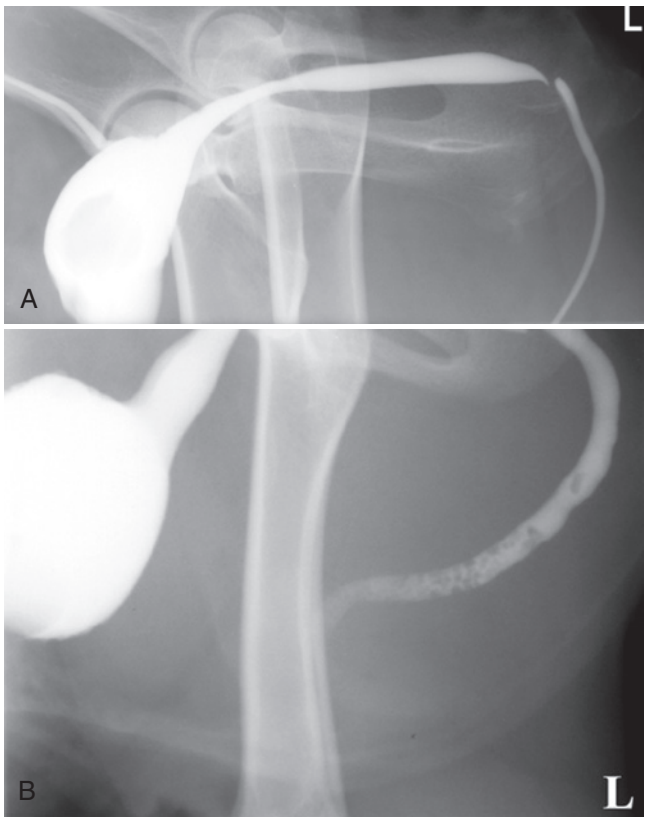


Figure 16-100 *A*, Left-lateral, positive-contrast cystogram and urethrogram. The pelvic portion of the urethra is normally distensible and smooth. The area of the urethral diverticulum is clearly seen at the junction of the pelvic and membranous portion of the urethra. Contrast material flows distally and opacifies the entire portion of the membranous penile urethra. No filling defects or irregularities are recognized. *B*, Left-lateral, positive-contrast cystogram and normograde urethrogram showing multiple, various-sized filling defects in the urethra consistent with urinary calculi. (Courtesy of Dr. Anthony Pease.)

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PART III

CALF

CHAPTER 17

Surgery of the Calf Gastrointestinal System

Ava M. Trent, Norm G. Ducharme, Susan L. Fubini and Adrian Steiner

ABOMASAL DISEASE

Ava M. Trent

A few noteworthy physiologic differences exist between calves and adult cattle (see Chapter 14). The parietal cells in the fundic region responsible for secretion of HCl are essentially inactive in the neonate, and abomasal fluid has a pH near 6.0. The neutral pH, lack of proteolytic enzymes, and diversion of milk through the reticular groove are all essential to allow colostrum to pass rapidly through the abomasum into the duodenum, where immunoglobulins can be absorbed intact. However, parietal cells are active, and the pH of fundic secretions reaches adult pH levels by 36 hours after birth. Suckling also stimulates rennin and pepsin secretion from chief cells in the fundus of the abomasum, which is essential for clot formation in the diverted milk. The volume of milk consumed and the nature of duodenal chyme regulate abomasal emptying in the milk-fed calf. Somatostatin, secretin, and cholecystokinin are hormones that inhibit abomasal emptying in calves. Introduction of hyper- or hypotonic solutions can also depress abomasal motility in milk-fed calves in which normal abomasal contents are essentially isotonic.

In comparison to adults, preruminant calves with abomasal disease have fluid and electrolyte disturbances that are more difficult to predict and more rapidly detrimental. The body fluids of all neonate species represent a higher percentage of their body weight, and fluid loss or sequestration can result in rapid dehydration. Abomasal outflow disturbances can produce the hyponatremic, hypochloremic metabolic alkalosis seen in adult cattle, but mixed metabolic and respiratory disturbances may obscure this change. Outflow disturbances with vascular compromise may also lead more rapidly to ischemic lactic acidosis. Finally, severe abomasal distention can interfere with ventilation, thus adding a component of respiratory acidosis to the clinicopathological picture.

ABOMASAL DISPLACEMENT

The clinical presentation of abomasal disease seen in calves varies. The abomasum can displace without volvulus to the left or right of its normal position by swinging, folding, or stretching the lesser omentum and attached structures. The abomasum and its attachments can stretch to the point at which the abomasum can be exteriorized almost completely through the left-paralumbar fossa. In addition, dilation without apparent displacement is also described in calves. Abomasal volvulus is seen in calves and seems to progress quickly if untreated. Finally, abomasal perforations secondary to abomasal ulcers are prevalent in calves.

Left abomasal displacements are recognized occasionally in beef and dairy calves, most commonly between 3 weeks and 4 months of age, but the dietary predisposing factors are different; high amounts of starch in milk replacer and abomasal ulcers have been reported as factors in the pathogenesis of left abomasal displacements. The prevalence of abomasal ulcers in veal calves has been estimated at 39% of left abomasal displacement cases.

Diagnosis

Clinical signs of left displacement are less well described in calves but are more variable than in adults. They include nonspecific signs such as reduced appetite, poor weight gain, recurrent tympany, and variable fecal consistency. Unlike adult cattle, the distended abomasum typically fills the left flank in affected calves and can cause distinct asymmetry when viewed from behind or above (Figure 17-1). The ping detectable by simultaneous auscultation and percussion may be less high pitched than in adult cattle, making it easily confused with ruminal distention. This may be why the diagnosis is sometimes delayed in calves. The area of percussion can be lower than one would expect, adding to the diagnostic difficulty. Calves may also have concurrent diseases typical of their age group including pneumonia and diarrhea. As noted previously, calves do not consistently demonstrate the hypochloremic metabolic alkalosis shown by adult ruminants with left abomasal displacements, and laboratory evaluation is highly recommended if possible. Ultrasound evaluation can be very useful as well.

Treatment

Some aspects of medical therapy are valuable adjuncts to surgical correction of gastrointestinal disturbances in calves. The potential for rapid dehydration dictates that systemic therapy begin before laboratory results can be obtained, even in calves with mild dehydration. Isotonic saline or lactated

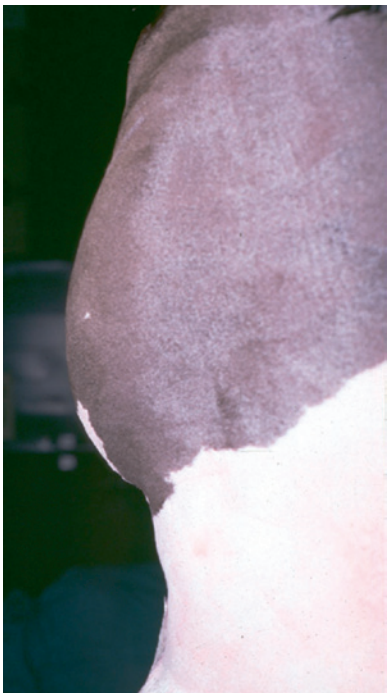


Figure 17-1 Three-month-old calf with large left abomasal displacements viewed from above. Note the prominent left-sided abdominal distention.

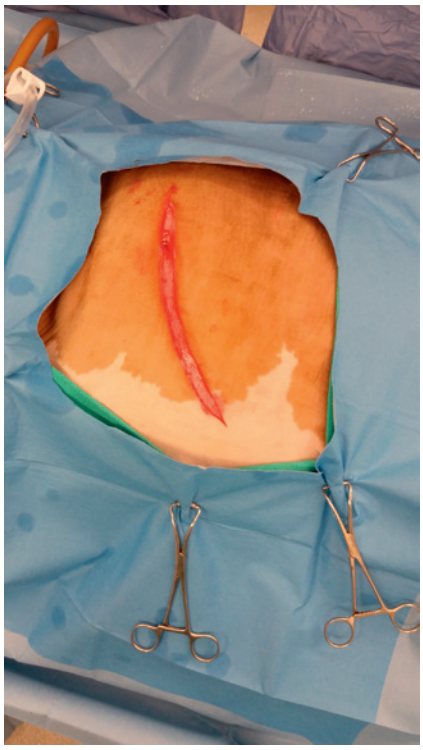


Figure 17-2 Right-paracostal incision with calf in left-lateral recumbency.

Ringer's solution with supplemental dextrose is generally a safe choice until laboratory analysis is available. Oral supplementation should not be used as the primary method of rehydration. Oral and systemic intestinal stimulants have not been well evaluated in calves with abomasal displacement and are not recommended. Initiation of oral or systemic therapy for abomasal ulcers may be appropriate because of the association of displacement with ulcers in calves (see Chapter 4 for more details on fluid therapy). Appropriate medical therapy for other concurrent calf diseases such as pneumonia should be initiated.

Medical Management

Contrary to the relatively poor outcome in adult cattle, rolling may be more effective in managing abomasal dilation as well as right and left displacement in calves. Successful management in 19 out of 21 calves without distinction between left and right displacements was reported in one study after rolling. However, the authors feel that this should be a temporary measure to be used only in sick calves that cannot tolerate immediate surgery.

Surgical Treatment

Standing procedures are not generally recommended in small calves because of their tendency to lie down midprocedure and the difficulty for the surgeon. However, larger calves may tolerate standing surgery. An omentopexy can be performed from a right-flank approach in a calf in left-lateral recumbency or standing; however, the omentum is fragile in calves, and other approaches that directly stabilize the abomasum are preferable. A left-paralumbar fossa abomasopexy is another surgical option. This can also be done in the standing or recumbent animal. If the clinician is unsure whether the left-sided viscus is rumen or abomasum, this is an attractive surgical option.

A right-paramedian abomasopexy can be performed in calves positioned in dorsal recumbency with appropriate reduction in incision length and suture material size. Indications and contraindications are similar to those in adult cattle. Particular attention to the animal's respiratory status is important because pneumonia is a common finding in calves. The lack of access to intestinal structures distal to the abomasum is potentially a greater concern in calves with signs of generalized intestinal distention. The ability to directly stabilize the abomasum is a distinct advantage of this approach.

A modified abomasopexy via a right-paracostal approach with the calf positioned in left-lateral recumbency offers several advantages over the right-paramedian approach (Figure 17-2). The lateral position places less stress on the respiratory system, and the paracostal incision provides better access to evaluate other intestinal structures. Furthermore, if the abomasum needs to be emptied, this can be accomplished better from this lateral approach (Figure 17-3).

ABOMASAL VOLVULUS

Calves with either a right displacement or right volvulus of the abomasum typically present to the herdsman with signs very similar to those described for left displacement (i.e., partial or complete anorexia, abdominal distention, and decreased fecal output with altered consistency [fluid or pasty]). However, in the case of a right volvulus, the progression of signs may be very rapid, and a subset of affected calves will first present with signs of severe depression, anorexia, and dehydration.

The presence of a tympanic area (ping) centered over the 10th to 13th ribs and on a line from elbow to tuber coxae is the primary diagnostic sign of a right displacement or right volvulus (Figure 17-4). This ping must be differentiated from other sources of right-sided pings, which include cecal dilation/torsion, gas accumulation in the duodenum, spiral



Figure 17-3 Distended abomasum exteriorized through right-paracostal celiotomy.



Figure 17-4 Large right-sided ping typical of an abomasal volvulus. The white tape delineates a gas-fluid interface.

colon, ascending colon or small intestine, or right-flank abscess. An abomasal ping generally can be differentiated from pings associated with other structures by combining information about ping location, size, and pitch. The cecum, colon, and small intestines are limited in their mobility by their mesenteric attachments to the dorsal body wall, whereas the abomasum and ascending duodenum are limited by more cranial attachments at the duodenal sigmoid flexure and the reticular connection to the diaphragm. Cecal, colonic, and small-intestinal pings will generally be centered on a point in the paralumbar fossa, more caudal than that for the abomasum or duodenum. The cecum is the only structure that has the potential to dilate to the maximum size possible for the abomasum and is the primary differential for single-pitched pings greater than 10 cm in diameter.



Figure 17-5 Holstein-Friesian calf in left-lateral recumbency. Note the distended paralumbar fossa secondary to cecal distention proximal to a spiral colon obstruction.

In addition, to differentiate the ping's center by location, the outline of the cecum can usually be seen through a right-paralumbar fossa with the calf in lateral recumbency (Figure 17-5). Small-intestinal pings are typically a collection of small-diameter pings of varying pitch. Spiral colon pings also tend to involve multiple areas that vary in pitch. Ultrasound evaluation may be very useful to differentiate the right-sided viscus. The presence of tachycardia (>130/min) and colic has been reported to be more consistent with right volvulus of the abomasum in calves; however, controlled studies are lacking.

A right-paracostal approach can be used to perform an abomasopexy (preferred procedure) in calves positioned in left-lateral recumbency. A rolling procedure with percutaneous decompression (as described for left-abomasal displacements previously) has been reported to be effective in calves with right-sided pings; however, this is risky should the calf have a right volvulus of the abomasum or involvement of another right-sided viscus. The veterinarian should be prepared to move to an open approach within 2 to 3 hours if clinical signs do not improve. A modified right-flank or right-paracostal omentopexy can be used to correct abomasal displacement or volvulus in calves in left-lateral recumbency. However, the limited holding power of the omentum in calves makes this a less desirable approach than the right-paramedian or right-paracostal abomasopexy described earlier.

LUMINAL OBSTRUCTION

Intraluminal obstructions are more common in calves than in adult cattle. Grooming behavior in group-housed calves can result in multiple cases of trichobezoars (hairballs) (Figure 17-6). As for left-abomasal displacements in calves, the specific acid-base and electrolyte changes that result from outflow obstruction are more variable.

Ileus can lead to abomasal dilatation. Excessive milk consumption and changes in nutrition from milk to solid feed have also been suggested as a cause of abomasal distention without displacement in calves. Abomasitis is recognized as an inflammatory condition in young calves presumably as a result of infection with *Clostridium perfringens*, *Sarcina* spp., or *Salmonella typhimurium*. Affected calves present with signs of toxemia, including dehydration, abdominal distention, tachycardia, and a fluid-filled abomasum in normal position on ultrasound examination (Figure 17-7).

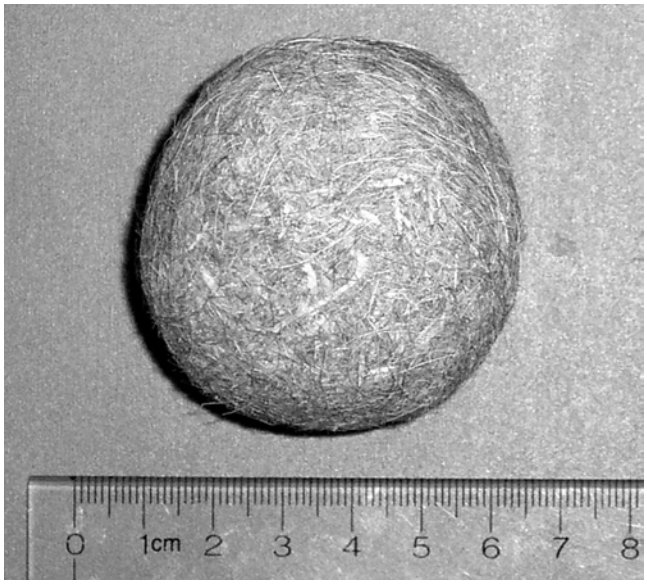


Figure 17-6 Trichobezoar removed from a calf's abomasum. (Courtesy of Dr. Brad L Njaa.)

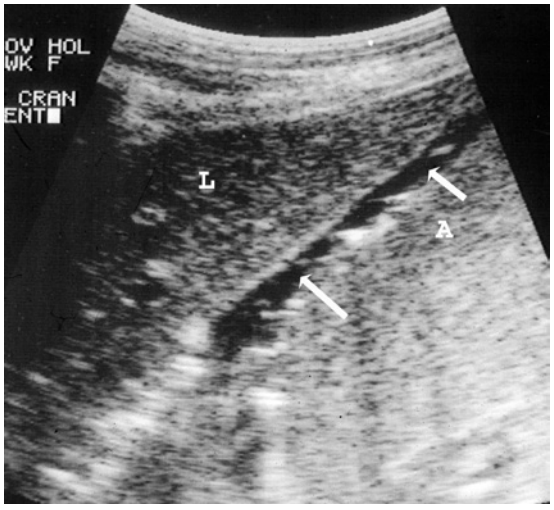


Figure 17-7 An ultrasound image of a calf with abomasitis presumed to be caused by *Clostridium perfringens*. The liver is imaged (L); the abomasum (A) is distended with fluid, and the abomasal wall is thickened and edematous (*arrows*).

Surgical access to the pyloric area in calves can be achieved from a right-flank, right-paracostal, or right-paramedian approach with the calf positioned in left-lateral recumbency (flank or paracostal) or dorsal recumbency (paracostal or paramedian). This allows an incision over or near the site of obstruction and extraction of the obstructing material with minimal contamination.

ABOMASAL ULCERATION

In one study of calves with clinically apparent abomasal ulceration, 17 of 118 animals had bleeding ulcers. Perforating ulcers (Types III and IV) appeared to be most common in veal calves, beef calves, and yearling feedlot cattle (Figure 17-8). The incidence in beef and veal calves was highest at 4 to 8 weeks of age, with most cases occurring by 12 weeks

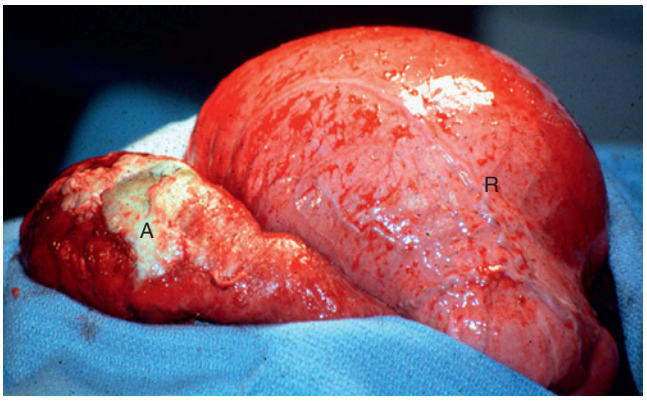


Figure 17-8 Type III abomasal ulceration in a calf. Note distended rumen covered by greater omentum (R). Note fibrin surrounding abomasum (A).

of age. Of clinically apparent ulcers in a 3-year study of calves, 81 of 118 were perforating. The occurrence of perforating ulcers in beef calves is highest in the spring, reflecting the age of greatest risk. The incidence of fatal ulcers (Types II, III, and IV combined) was highest in the winter in yearling feedlot cattle but occurred throughout the year. Ninety-three percent of 209 fatal ulcers in beef calves were perforating.

A variety of factors have been proposed as causative, including nutritional deficiencies, bacterial and fungal agents, abrasive agents, and stress. Copper deficiency has been the primary mineral incriminated, although a large study of western Canadian beef herds found a higher fatal ulcer incidence in calves in herds with adequate mineral supplementation. The incidence of ulcers in general increases 20% to 30% when calves are allowed access to roughage. Transition to solid feed and/or transition in abomasal function have been attributed with predisposing and protective effects in beef calves. C. *perfringens* type A has been the pathogen most commonly incriminated in calves, although fatal ulceration may remain as a problem in herds that use consistent vaccination programs. Hairballs in extremely cold weather conditions and poor-quality roughage are the most commonly suggested abrasive agents. However, hairballs were as common in calves of the same age dying of other causes as they were in calves dying of perforating ulcers. Although nonspecific stress is commonly associated with development of diffuse nonpenetrating ulcers (Type I), the association with focal perforating ulcers is less clear.

Diagnosis

Type I Ulcers

Type I ulcers often lack any detectable clinical signs. However, the presence of Type I erosions/ulcers may be suspected in those groups of calves known to be at risk and showing signs of poor appetite and decreased weight gain.

Type II Ulcers

Calves are identified by loss of appetite, weakness, depression, occasional mild colic, and black, tarry, foul-smelling feces. Pale mucous membranes are common. Aspirated ruminal fluid may be visibly contaminated with blood or may be occult blood positive.

Type III and IV Ulcers

Clinical signs of perforating ulcers appear to be more severe and rapidly progressive in calves than in adult cattle. In a

controlled study of veal calves, many calves showed normal development until the day before perforation. Herdsmen report progression from a normal nursing calf to recumbency within 12 hours. Seventy-five percent of surveyed herdsman indicated that most calves affected by fatal abomasal perforation were found dead without preceding clinical signs. The rapid progression of clinical signs in calves compared with adult cattle may reflect the tendency for perforating ulcers in calves to occur in the pyloric antrum and fundus of the abomasum that is not covered by omentum, thus resulting in generalized peritonitis. In addition, calves are more susceptible to dehydration and infection. Clinical signs when present include depression, colic, anorexia, hypothermia, tachycardia, pale mucous membranes, dehydration, a tense abdominal wall with pain on deep palpation, and an expiratory grunt consistent with abdominal pain. Mild to moderate abdominal distention may be present in some cases, with detectable free fluid on ballottement and auscultation in approximately half of affected animals.

Feces were positive for occult blood in 20% of calves with perforating ulcers. Abdominocentesis may be useful in confirming diffuse or localized peritonitis in some cases, but false negatives are common. In one study of 50 veal calves, abdominocentesis was diagnostic for peritonitis in 30% of calves with perforating ulcers and nondiagnostic in 70%. A strong acid or putrid odor, low pH, or high chloride content in the peritoneal fluid suggests abomasal perforation. Ruminal fluid pH may be decreased below 6.0, and rumen chloride levels may be increased above 60 mmol/L. If left untreated, death occurs from diffuse fibrinopurulent peritonitis, toxemia, and systemic shock within 48 hours.

Management

Treatment of individual animals with Type I or multiple Type II ulcers with systemic agents such as clenbuterol and H2 receptor antagonists such as cimetidine have been tested as prophylactic and therapeutic agents in calves with little beneficial effect.

The small size of the abdomen, limited development of the omentum, ease of visceral manipulation, and relatively rapid rate of systemic deterioration make surgical intervention a viable proposition for calves with perforating ulcers. The preferred approaches in calves are low right-paracostal incisions with the animal positioned in left-lateral recumbency as described earlier. The goal of surgery is surgical exploration with identification of the ulcer. The ulcer may require resection and closure, or it may be possible to simply oversew the affected portion of the abomasal wall. Aggressive abdominal lavage and systemic fluid and antibiotic therapy are appropriate ancillary therapy.

Calves should be positioned in left-lateral recumbency for a 20-cm right-paramedian or right-paracostal approach. The right-paracostal approach provides adequate access to the entire abomasum in most calves of this age and is generally preferred. The abomasum should be exteriorized and stay sutures placed cranial and caudal to the ulcer site. Using laparotomy sponges to pack off the abdominal cavity, the surgeon should resect the ulcer site, if necessary, and the contents of the abomasum, including any hairballs, should be drained away from the incision. The abomasal surface should be vigorously lavaged and the resection site closed with a simple continuous pattern and an inverting oversew using an absorbable suture material. If contamination from the ulcer appears to be restricted to the right body wall, then lavage should be restricted to this area by exposing contaminated tissue for lavage. If this is not possible or if signs of inflammation extend beyond this area, it is possible to effectively lavage the entire abdominal cavity in calves. Care should be taken to use a sterile pH-balanced isotonic solution for lavage and to remove as much fluid as possible from the abdominal cavity after lavage. If the ulcer is small and focal, it may be possible to simply invert it into the lumen of the abomasum and oversew it with an inverting pattern.

If a localized abscess is adjacent to the abomasum or within the omental bursa, it may be marsupialized for drainage as described for adult cattle (see Chapter 14).

PROGNOSIS

Information on the prognosis for surgical management of calves with perforating ulcers is limited. In one study of 10 4- to 6-week-old calves with perforating fundic and greater curvature ulcers, 4 were successfully treated with surgical intervention and aggressive supportive care.

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RUMINAL DISTENTION IN CALVES

Norm G. Ducharme and Susan L. Fubini

Diet inadequate in roughage can prevent normal growth of ruminal flora and is the most common cause of indigestion in calves. Undigested roughage accumulates and ruminal distention develops. It has been suggested that exclusively milk (or milk replacer) diets can cause hyperkeratosis of the rumen and recurrent ruminal distention. A similar syndrome is called *ruminal drinkers*, where a calf's esophageal groove partially or completely fails to close, so ingested milk is diverted to the rumen instead of the abomasum. This leads to fermentation and ruminal distention. Why this syndrome



Figure 17-9 "Papple-shaped" abdomen in a calf with chronic bronchopneumonia and presumed vagal nerve damage.

develops is unclear, but the following factors must be present for the esophageal groove to close normally. The fluid drunk by a calf must contact the pharyngeal receptors, be consumed voluntarily, and have no unpleasant taste or odor, and the general status of the calf should not be disturbed. Altering the method of intake or weaning the calf can be curative.

Another source of ruminal distention in calves is vagus nerve impairment due to pharyngeal disorders or chronic severe bronchopneumonia. The vagus nerve can apparently become inflamed or compressed by enlarged lymph nodes or severe pulmonary parenchymal damage. Because this nerve provides innervation to the forestomach compartments, an abomasum outflow obstruction develops with distention of the dorsal and ventral sacs of the rumen (Figure 17-9).

CLINICAL FINDINGS

Pharyngeal trauma can be diagnosed by physical examination findings that include swelling, dysphagia, and excessive salivation. Thoracic lesions can be identified based on physical examination and imaging studies. For example, signs of bronchopneumonia, such as coughing, tachypnea, abnormal auscultation (wheezes, squeaks, crackles, or decreased lung sounds), and dullness on thoracic percussion, help identify a primary respiratory problem requiring treatment. Imaging of the head or thoracic cavity by ultrasonography or radiography could confirm a diagnosis of trauma or bronchopneumonia.

RUMEN FISTULA

Rumen fistulas are indicated to relieve free-gas bloat in calves. The procedure is most effective in calves free from other disease that respond to a stomach tube passed to relieve gaseous accumulation. Fistulas are also placed to allow alimentation for calves unable to eat because of another disease process (i.e., tetanus, pharyngeal trauma).

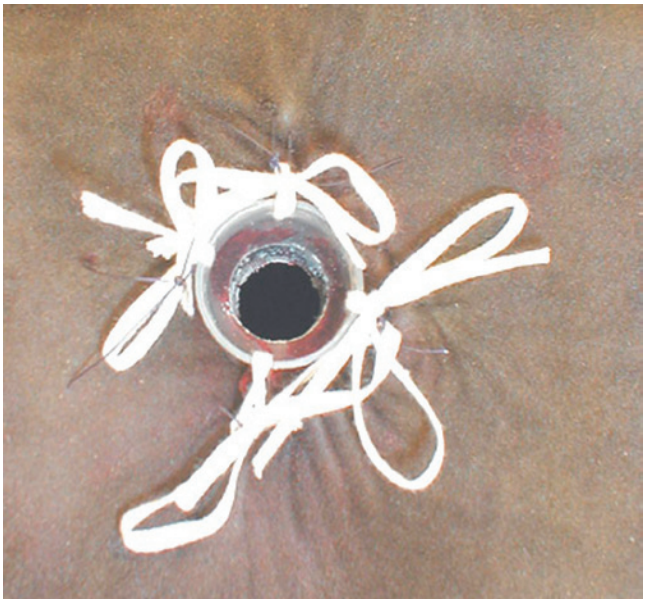


Figure 17-10 Completed rumen fistula in a calf.

Calves that have had severe bronchopneumonia and subsequently develop free-gas bloat, presumably from vagal nerve damage, may benefit from a rumen fistula that gives gas an escape route until the thoracic inflammation subsides.

Commercial trocars can be used in free-gas bloat or in an emergency situation. For longer-term use, surgically placing a fistula is recommended.

SURGICAL TECHNIQUE

The purpose of surgery is to allow decompression of the rumen, giving the primary condition an opportunity to resolve. The fistula should not be too ventral or ingesta will tend to occlude the fistula, allowing ruminal distention to recur. However, the fistula should not be too dorsal if the rumen is empty (i.e., an animal with tetanus), or it will cause excessive tension on the suture line. The appropriate area on the left flank is identified, desensitized with a local block, and prepared for surgery. A 6-cm vertical skin incision is made. The external abdominal oblique and transversus muscles are incised sharply. The peritoneum is tented and incised.

Several surgical options are available, including the three-layer technique the authors use. We recommend the transversus abdominis (which is mostly fascia) and peritoneum be sutured to the dermis on each side of the incision for the first layer. This protects the muscle layers and is usually done with a size 0 absorbable suture on a cutting needle. For the second layer, the rumen wall is sutured circumferentially to the dermis to provide a "seal" between the rumen and the skin. For this layer, a cutting needle is required, and the suture line is broken several times to avoid a purse-string effect. For the third layer, the rumen is incised and the wall is sutured to the skin in a simple continuous pattern (also broken dorsally and ventrally) with size 0 nonabsorbable sutures. The ends are left long to facilitate removal. To keep the fistula patent, an appropriate-sized syringe case (with four holes in its collar) is fitted into the incision site. The syringe case is secured to the skin with umbilical tape placed through the preplaced holes in the collar to four separate loops of sutures, placed in the skin at four corners approximately 5 cm from the fistula (Figure 17-10).

The syringe case is capped when the primary cause of the ruminal distention appears to have resolved. If the ruminal distention does not recur after a few weeks, the syringe case is removed. In some calves, the fistula will close over in the ensuing weeks. In other calves, the fistula will need to be resected en bloc and the rumen and body wall closed separately.

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SMALL-INTESTINAL SURGERY IN CALVES

Susan L Fubini

Small-intestinal surgery in calves is much the same as in adult cattle, although intestinal accidents due to congenital abnormalities are more common in calves. In addition, intestinal accidents caused by urachal remnants or related to adhesions and umbilical infections are prevalent in the calf age group. Intussusceptions occur in the calf small intestine (Figures 17-11 and 17-12) as they do in adults, but calves also suffer from intussusceptions throughout the intestinal tract. This may be because calves have less substantial mesenteric fat.

Signs of small-intestinal obstruction are similar to those in an adult and include abdominal pain, abdominal distention, scant manure, succussible fluid on the right side of the abdomen, and small variable areas of tympanic resonance on the right. It can be very difficult to distinguish between an ileus secondary to enteritis and a small-intestinal obstruction. A digital rectal examination is rarely beneficial. Ultrasound examination can confirm the bowel distention and sometimes image the actual obstruction (Figure 17-13). Subjectively, we think abdominal pain in young calves is more often seen with obstructive bowel disease than with enteritis.



Figure 17-11 Small-intestinal intussusception in a 1-month-old calf. Note distended small intestine proximal to the lesion and the intussusception in the surgeon's hand. (Courtesy of Dr. Ryland B. Edwards III.)



Figure 17-12 Postmortem specimen of intussusception in the distal small intestine of a calf. Note bowel distended proximal to the obstruction and empty distally. (Courtesy of Dr. Donald Smith.)

Surgical preparation is as described for adult cattle. Local anesthesia and sedation is an option, but general anesthesia is preferable. A right-flank celiotomy is the approach of choice. Upon entry into the abdomen, one should be aware of the more common causes of small-intestinal obstruction: intussusception, volvulus, and intestinal entrapment in adhesions or umbilical remnants. The bowel in small ruminants is thin walled and easily traumatized, thus making gentle tissue handling essential. A 1% carboxymethylcellulose[1] application is recommended before beginning surgical manipulation to avoid serosal trauma or drying. Once the lesion is identified, it should be corrected if possible, and the viability of the bowel should be assessed.

If an area requires resection, it should be kept exteriorized while the remainder of the bowel is replaced into the abdomen. The bowel to be resected should be packed off from the rest of the abdomen with sterile bath towels or laparotomy pads. Penrose drains can be used to occlude the lumen of the bowel proximal and distal to the site of resection. The drains should be carefully placed to minimize the defect created in the mesentery. The vasculature is easier to see in calves because the mesentery is not as fat filled as in adults. Vessels should be ligated close to the bowel. The authors recommend using small (3-0) absorbable suture material for anastomosis or enterotomy closure to avoid leakage through the needle tracts. For an end-to-end anastomosis,

[1]Solution of high–molecular weight carboxymethylcellulose (700 to 1000 kd) is prepared as follows. The carboxymethylcellulose (grade 7HFPH, Aqualon, Delaware) is added to isoosmolar phosphate-buffered saline solution of pH adjusted to 7.1 and pressure-filtered first through a 410-µm filter mesh, then through a 10-µm filter mesh to remove gel bodies. The solution is then placed in a 1-L bottle and sterilized by autoclaving at 115° C for 25 minutes by using a liquid slow-release cycle.

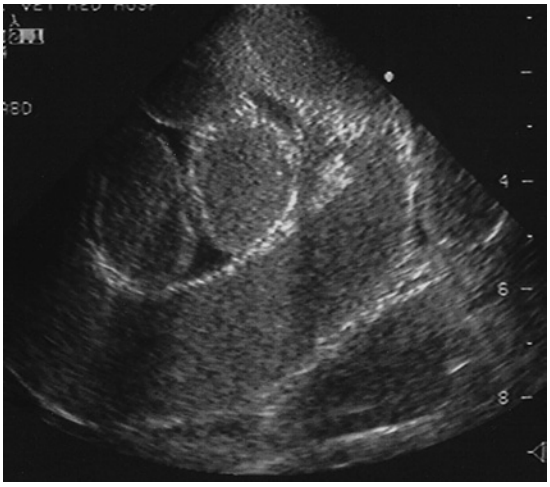


Figure 17-13 Ultrasound showing distended small intestine in a calf with intussusception.

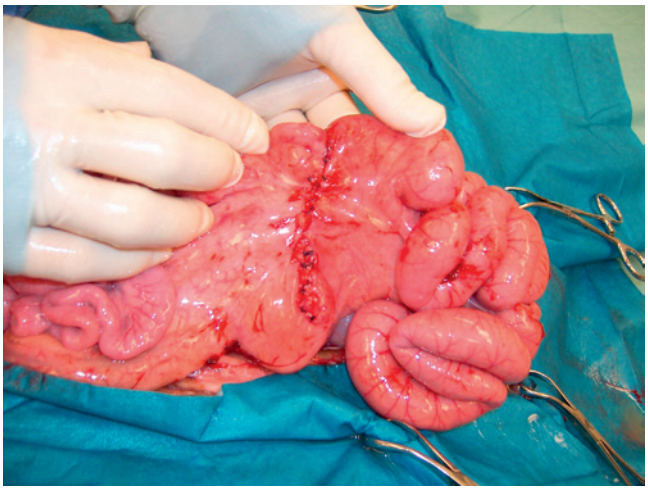


Figure 17-14 End-to-end anastomosis in calf small intestine.

the mesenteric and antimesenteric sutures are placed first and tagged. The anastomosis is completed with a simple interrupted or continuous pattern. After anastomosis, the mesenteric defect is closed (Figure 17-14). To minimize peritoneal adhesions, liberal lavage with sterile isotonic fluids or 1% carboxymethylcellulose during surgery is indicated. Gloves and instruments are changed, and closure is routine.

After surgery, strict attention must be paid to keeping the calf warm and adequately hydrated. Antimicrobials are indicated for 5 to 7 days if a resection and anastomosis were performed.

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CECAL INTUSSUSCEPTIONS

Adrian Steiner

OCCURRENCE

One suggestion as to why adult cattle have a low occurrence of intussusception in the cecal region is that they have a fat-filled mesentery that maintains the relationship of the various segments of the intestine. Calves' mesenteric fat is usually minimal, which allows increased mobility of the slings of the intestine. This may partially explain why intussusception in general, and specifically intussusception of the cecum, is significantly more common in calves less than 2 months of age than in older cattle. Four different types of intussusceptions involving the cecum have been described. They include cecocecal (Figure 17-15), cecocolic (Figure 17-16), ileocecocolic (Figure 17-17), and ileocecal (Figure 17-18). In a retrospective study of 48 cases of intussusception diagnosed over a 9-year period that involved the cecum, the breakdown of cases was found to be 46% cecocolic and 25% cecocecal intussusception. Seventy-eight percent of the cases occurred within the first 4 weeks of life, and 80% had a history of severe diarrhea with a mean duration of 1 week. Intussusception that involves the cecum rarely occurred spontaneously without concurrent disease.

SYMPTOMS AND DIAGNOSIS

Symptoms include moderate to severe depression, partial to complete anorexia, abdominal distention accentuated in the right flank, and mild signs of abdominal pain. Scant amounts of dark-red feces and mucous strands may be present. Tachycardia and dehydration may be evident. Auscultation performed simultaneously with percussion identifies variable small pings and superficial splashing sounds of fluid-filled bowel in the right flank when performed simultaneously

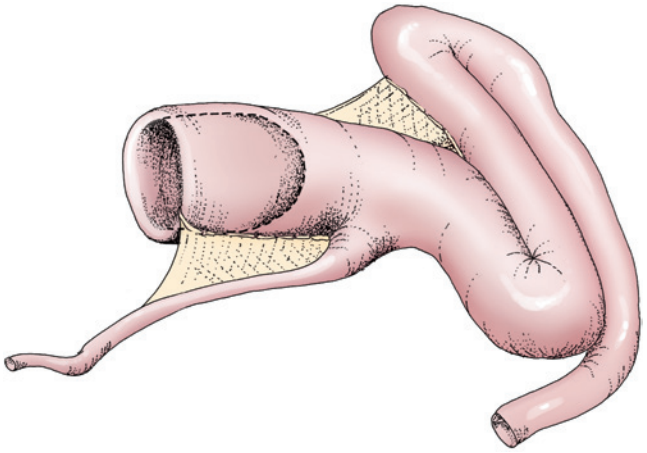


Figure 17-15 Schematic representation of cecocecal intussusception.

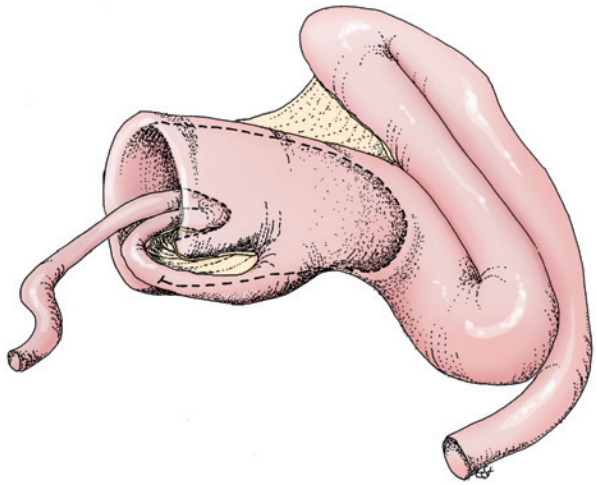


Figure 17-16 Schematic representation of cecocolic intussusception.

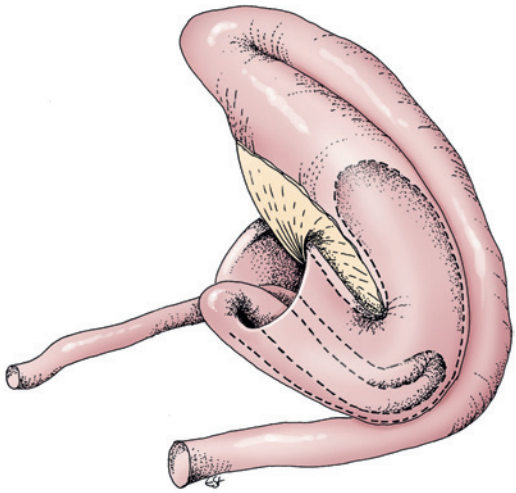


Figure 17-17 Schematic representation of ileocecocolic intussusception.

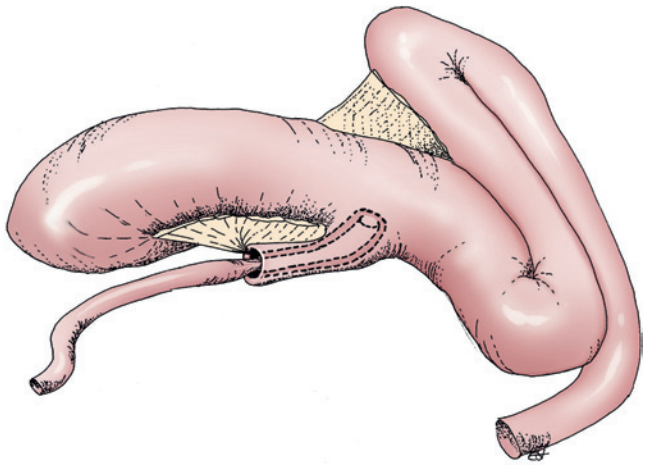


Figure 17-18 Schematic representation of ileocecal intussusception.



Figure 17-19 En bloc resection of cecocolic intussusception in a calf. (Courtesy of Dr. Donald Smith.)

with succussion. Radiography and ultrasonography may be used as diagnostic aids to identify distended bowel in young calves where a rectal examination cannot be performed. The definitive diagnosis is usually made during exploratory celiotomy.

THERAPY AND PROGNOSIS

Dehydration and acid/base imbalances should be corrected before surgery. Perioperative antimicrobials should also be administered. The calf is restrained in left-lateral recumbency and an exploratory celiotomy performed in the right flank under local or general anesthesia. The affected bowel is exteriorized, and the intussusception manually reduced if possible. Depending on the type of intussusception, cecal amputation (see Chapter 14 for details on cecal amputation) and resection of the ileum and proximal loop of the ascending colon may be indicated (Figure 17-19). The high recurrence rate of intussusception necessitates cecum amputation, even if the compromised bowel is viable. The ileocecal junction is left intact if it is not compromised by the intussusception. Postoperative measures include correcting electrolytes, acid/base, and energy imbalances/losses and aggressively treating the primary disease (for example, diarrhea).

The prognosis is guarded after treating cecal intussusception because affected calves are frequently in poor general condition before surgery. Rate of survival is mainly influenced by the prognosis for the concurrent diarrhea.

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SURGERY OF THE COLON

Adrian Steiner

INTUSSUSCEPTION OF THE SPIRAL COLON

Intussusception of the spiral colon is rare. The history of affected animals may include diarrhea, which presumably leads to irregular motility patterns and the intestinal accident. Affected calves present with distention of the abdomen, which is especially evident on the right side of the abdomen as the cecum and colon proximal to the obstruction distend with fluid and gas. Other presenting signs are vague but include a decreased appetite, mild abdominal pain, and progressive dehydration. There may be an area of tympanic resonance in the right-paralumbar fossa and succussible fluid. Ultrasound examination confirms the cecal and colonic distention.

Treatment consists of reduction with or without resection of the intussusceptum (Figure 17-20); resection in situ is required if the intussusception cannot be manually reduced. Manual reduction of intussusception without subsequent resection may only be performed successfully if the bowel is not compromised and the presence of any predisposing causes, such as intraluminal or intramural masses, is excluded. Because intussusceptions are typically relatively short, resection of a short segment may be all that is needed to revitalize the bowel, and only minimal mesenteric dissection may be necessary. When a resection is performed, it behooves the surgeon to stay close to the bowel, thereby avoiding any major disruption of the mesentery. This also prevents disturbance of the vascular supply to the colon. If manual reduction of the intussusception is possible and only both ends of the intussusceptum remain pale, oversewing of the areas with compromised vitality without resection, using a continuous Lembert pattern, may be opted for.

LUMINAL OBSTRUCTION OF SPIRAL COLON

Calves with severe diarrhea may slough their intestinal mucosa. This may result in a fibrinous cast that can obstruct the spiral colon. An affected animal shows signs of abdominal distention, progressive depression, and decreased appetite. Exploratory celiotomy through a right-paralumbar fossa approach reveals distention orad to the obstruction. The obstruction is felt as a firm object within the lumen of the spiral colon. After isolating the spiral colon with sterile towels, an enterotomy is made along the longitudinal axis of the affected segment of spiral colon (Figure 17-21). The intraluminal obstruction is removed, and the longitudinal enterotomy is closed transversely to prevent stricture, using a one-layer simple interrupted suture pattern with 3-0 polyglactin or similar absorbable suture material.

ATRESIA COLI

Occurrence and Etiology

Intestinal atresia is the complete absence of a portion of the intestinal lumen. The ascending colon is one of the most commonly affected segments in the calf. Atresia of the colon is most frequently located in the mid–spiral loop of the ascending colon (Figure 17-22). The cause of atresia coli in calves is not well understood and represents a matter of scientific controversy. In a retrospective study, Holstein-Friesian calves were identified significantly more often with atresia coli than would have been expected from the hospital population. The odds ratio toward other dairy cattle breeds was 4.5 and toward other cattle breeds was 7.1. Supporting this finding, in a Holstein-Friesian herd, atresia coli was found to be inherited autosomally recessive with a single locus displaying two alleles being responsible for the disease. On the other hand, atresia coli was found in one of a pair of identical twin calves—but not the other. In addition, purposely mating five affected cows and two affected bulls produced 23 calves but failed to create a single offspring with atresia coli. The heritability of atresia coli was estimated to be 0.0875, which implies other, nongenetic etiologies, such as early manual pregnancy testing. Rectal palpation of the amniotic vesicle at 42 days of age or earlier was associated with increased incidence of colonic and jejunal atresia. In one study, early pregnancy diagnosis via rectal palpation increased the risk of intestinal atresia 119.7 times compared with the control population palpated after day 42. At this time, we consider this a nongenetic disease because of the above observations and the low heritability factor.



Figure 17-20 Intussusception in the proximal spiral colon of a 3-week-old calf. Note the distended bowel proximal to the obstruction and the empty bowel distally. (Courtesy of Dr. Brett Woodie.)



Figure 17-21 Intraoperative view of a fibrinous cast obstructing the midspiral loop of the ascending colon. The cast is being removed through an enterotomy.



Figure 17-22 Intraoperative view of a 3-day-old calf with atresia coli in the midspiral loop of the ascending colon.



Figure 17-23 Ultrasonographic view from the ventral aspect of the right flank showing distended small-intestinal loops in a calf with atresia coli.



Figure 17-24 Ultrasonographic view from the dorsal aspect of the right flank showing distended large-intestinal loops of the same calf as Figure 17-23.

CLINICAL SIGNS AND DIAGNOSIS

Affected calves are usually born without incident and have a normal appetite until 12 to 48 hours later when they develop inappetence, abdominal distention, signs of abdominal pain, and progressive depression and weakness. The hallmark of the disorder is that no manure is passed. At clinical examination, tachycardia, hyperpnea, and normal to reduced rectal temperature are evident. Calves have a normal-appearing anus and rectum. On digital palpation per rectum, a clear to yellow mucus, sometimes blood tinged, is identified. A well-lubricated flexible catheter may be passed through the descending colon without resistance. However, this is not recommended because of the risk of trauma to the bowel. The abdomen becomes severely distended, and percussion (ping) and succussion auscultation in both flanks are positive (for gas and fluid accumulation). The contours of distended large-intestinal loops may be detected by visual examination or palpation in the right-paralumbar fossa. A presumptive diagnosis can be made with an accurate history and physical examination. Imaging studies can confirm the distended viscera. Lateral radiographic examination of the standing animal reveals gas distention of the small and large intestines. Distended small- (Figure 17-23) and large- (Figure 17-24) intestinal loops are routinely observed on ultrasonographic examination of the ventral and dorsal aspects of the right flank, respectively. Dehydration with normal to low plasma protein concentration and neutrophilia with left shift are typically observed at hematological analysis. The diagnosis is confirmed by a right-paralumbar fossa exploratory celiotomy.

Surgical Management

Because immediate surgical intervention is rarely considered necessary, supportive medical treatment—including rehydration with warm crystalloids, correction of acid-base imbalances, hypoglycemia, if present, and antimicrobial treatment—is initiated before subjecting the calf to additional stress. Plasma may be necessary because failure of passive transfer of colostral immunoglobulins can be present in these calves either because of intake failure or poor absorption. Nonsteroidal antiinflammatory drugs should be used judiciously preoperatively after the calf has been rehydrated. Clipping of the surgical site and the initial surgical scrub can be performed while the calf is being stabilized prior to anesthesia induction. Surgery is performed under local or general anesthesia through the right-paralumbar fossa with the calf in left-lateral recumbency. Local anesthesia can be used to reduce inhalation anesthetic dose, but care should be used during lidocaine infiltration because of stretching of the body wall from visceral distention. Supplemental warming via warm fluid bags or a Bair GasHugger system placed between the rear legs and over the calf's back can help prevent hypothermia during the procedure. Gas is evacuated from the distended cecum and spiral colon. Digesta are removed from the intestine proximal to the site of atresia through an enterotomy at the apex of the cecum or through the dissected proximal blind end of the colon (Figure 17-25). If the enterotomy site is in the cecum, it is



Figure 17-25 Intraoperative view of a calf with atresia coli. A typhlotomy is being performed to removal ingesta and meconium.

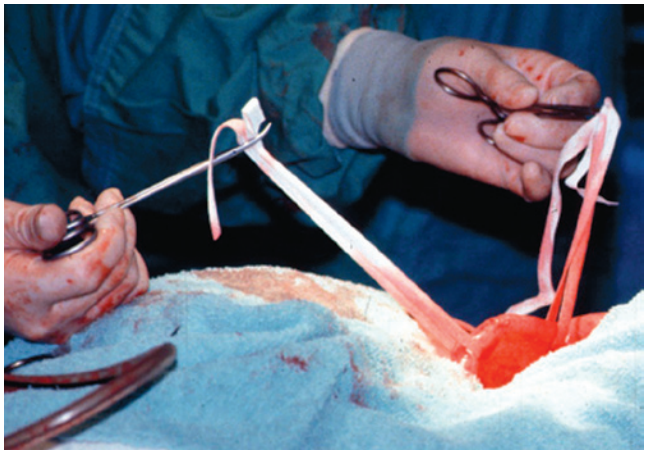


Figure 17-26 Intraoperative view of a calf with atresia coli. The descending colon is identified by passing a stallion catheter gently per rectum and isolated with two umbilical tape loops placed carefully through the mesocolon.

closed with two layers by using at least one inverting pattern. The compromised segment of the dilated blind end is resected, and continuity is established to the descending colon by either an end-to-side or side-to-side anastomosis. It is usually recommended to perform an end-to-side anastomosis because two calves that had side-to-side anastomoses developed a volvulus of the blind end, which grew in length; this is presumably because of the growth potential of the bowel in the neonate. However, retrospective studies have not found a significant difference in survival rate between end-to-side and side-to-side anastomosis. The descending colon is best identified by passing a flexible catheter into the rectum and then isolated with two umbilical tape loops placed carefully through the mesocolon (Figure 17-26). The surgeon must be careful not to puncture the friable descending colon when passing the umbilical tape and that the blind end is oriented in a manner that will not partially kink at the anastomosis when the colon is returned to the abdomen. Anastomosis is achieved by either a single layer of apposing

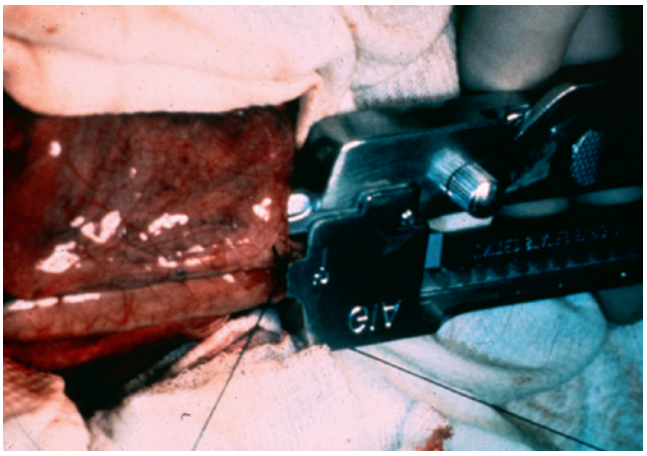


Figure 17-27 Intraoperative view of a calf with atresia coli. The ascending colon is being anastomosed to the descending colon using a GIA 55-mm stapling instrument.

simple interrupted or continuous sutures (broken at 180 degrees) or a GIA 55-mm stapling instrument (Figure 17-27). Abdominal lavage with warm isotonic fluids with or without 1% carboxymethylcellulose (4-6 mL/kg) may be used to decrease the chance of adhesion formation following surgery.

Postoperative management is extremely important to surgical success and includes maintenance of appropriate electrolyte and fluid therapy, antimicrobial treatment for 5 to 7 days, judicious use of nonsteroidal antiinflammatory drugs, and gradual resumption of oral feeding within 6-12 hours after surgery. Typically small, frequent feedings (every 3-4 hours) of electrolyte solution are offered the first 48-72 hours, followed by increasing volumes and decreasing frequency of milk replacer as the calf begins to pass manure of more normal consistency. Short walks can also be used to stimulate intestinal motility postoperatively. In most cases loose manure will be passed in the first 24 hours post surgery. Delay in manure passage or change from a slab-sided appearance in the flank may indicate the need for surgical reexploration.

As alternative procedures to intestinal anastomosis, cecostomy or colostomy in the right flank may be performed. Cecostomy allows bypass of the colon and fattening of the calf to a final body weight of 130 to 140 kg. For colostomy of the blind end either a right-flank or median approach is performed. In both techniques, digesta are evacuated through an incision at the cecal apex before creating the stoma.

Right-Flank Approach

To lessen fecal incontinence, a grid approach to the abdomen (blunt dissection of the internal abdominal oblique and transverse muscles in the direction of their fibers) is chosen. The blind end of the colon is then sutured to the abdominal wall at the mid-aspect of the right-flank incision.

Median Approach

With the calf in dorsal recumbency, a median or paraprepucial skin incision of 18-20 cm in length is performed caudal to the umbilicus. The stoma is placed paramedian to the right, about 5 cm caudal to the umbilicus and 4 cm lateral to the laparotomy site. A modified colostomy technique may be used to lessen fecal incontinence: a constricted colonic segment is created by placing two circumferential sutures in the seromuscular layer of the colon about 1.5 cm apart from

each other, ending up with an hourglass shape of the colon at the site of the stoma.

Prognosis

Prognosis depends mainly on acid-base and electrolyte status at admission, with an anion gap exceeding 24 mEq/L predicting death. Calves that do well are bright, alert, and hungry by 12 to 24 hours after surgery. Feces are passed by this time and are initially loose but firm up over the next few days. If problems are going to develop, they usually are evident in the immediate postoperative period. The most commonly reported complications after surgery include peritonitis, failure of anastomosis, diarrhea, impact at the anastomosis site, incisional infection, chronic cecal dilation, functional obstruction of the spiral colon, and adhesive bowel obstruction. An astute observer will note abdominal distention and decreased fecal output, followed by inappetence and loss of appetite in calves developing complications related to the gastrointestinal tract. Some of the complications related to the anastomosis can be resolved with additional surgery, although it becomes an expensive undertaking. The overall long-term survival rate, defined as reaching reproductive age, varies from 12% to 37% in the literature, but our personal experience suggests that closer to half of the calves go on to become productive members of their herds. Long-term survivors are likely to have loose feces and not to grow as well as otherwise expected. The survival rate after colostomy ranges from 42% (8/19) at reaching the slaughter weight of 120 kg to 71% (10/14) at 6 months after surgery. Both the growth rate and the health status of these calves are usually suboptimal.

The current knowledge is that atresia coli is not a heritable disease in Holstein-Friesian calves, but a genetic contribution has not been ruled out completely. Caution should still be used in breeding affected animals. The author judges surgical treatment of an affected calf as questionable because of economic and ethical reasons. Adjustments in herd health management practices through the use of ultrasound or delay of pregnancy diagnosis via rectal palpation beyond day 42 are reducing the number of calves presented for correction of atresia coli.

ATRESIA ANI (ET RECTI)

Occurrence and Etiology

Atresia ani is found less often in dairy than beef cattle breeds. Lack of tail, fistula formation between the rectum and the reproductive tract, and abnormalities of the urinary tract may accompany atresia ani. In females, the rectum may communicate with the vagina, in males with the urethra or the urinary bladder. Inheritance is reported in swine and lambs and is possible in calves—but not documented. Surgical treatment of animals with breeding potential, presence of a fistula, and/or other abnormalities is ethically and economically questionable.

Clinical Signs and Diagnosis

Affected calves show signs within the first day of life because they are unable to pass feces. An exception to this is the affected female with a rectovaginal fistula that passes some feces through the fistula. Other congenital defects—including cleft palate, polydactyly polydactylia, and abnormalities of the urogenital tract—can be seen (Figure 17-28). They exhibit progressive abdominal distention, straining, signs of abdominal pain, depression, and weakness. If only the anus is involved, the rectum usually bulges subcutaneously in the normal region of the anus during straining and when the abdomen is manually compressed. If no bulge is observed, atresia of the caudal rectum is suspected (Figure 17-29). The degree of involvement of the rectum may be determined radiographically. In newborn infants, ultrasonography was found to be an adequate noninvasive method to determine the distance between rectal pouch and perineal skin.



Figure 17-28 Polydactyly in a newborn calf with multiple congenital defects including atresia ani.



Figure 17-29 Atresia ani et recti in a 1-day-old calf.

Surgical Management and Prognosis

For surgical correction, 1 mL of 1% lidocaine solution is injected epidurally, and the hind part of the calf is directed toward the edge of the surgery table in sternal recumbency with the hind feet pulled slightly craniad (Figure 17-30). After routine aseptic preparation of the surgical field, a



Figure 17-30 Atresia of the anus in a calf in sternal recumbency being prepared for surgery.

1.5-cm-diameter circular incision is made through the skin and subcutaneous tissue at the site where the anus would normally be located. Careful blunt dissection in a cranial direction is used to identify the rectal pouch, which is gently pulled caudad with a pair of tissue forceps (rectal pull-through procedure). If this does not allow the rectum to be identified, it may be grasped during left-flank exploratory celiotomy and moved in a caudal direction by simultaneous traction through the pelvic canal and manipulation in the abdomen. The rectum is sutured to the subcutaneous tissue with four to six interrupted sutures, the rectal pouch is incised, and the rectal mucosa is sutured to the skin using a broken simple continuous or interrupted suture pattern. Intraoperatively, the presence of anal sphincter muscles is rarely evident. Fecal incontinence is therefore a frequent complication of surgical correction of atresia ani (et recti). A single stab incision through the perineum into the rectum is not successful, as stricture and obstruction are likely to occur. If there is a sizable portion of rectum (and descending colon) missing, surgery is exceedingly difficult because the short mesocolon does not readily stretch. In these cases, surgery should be discouraged.

Before suturing the rectum to the perineal skin, any rectovaginal or urethral fistula needs to be located and transected in the female. This is usually done most easily by exploring the vaginal opening and fistula with a blunt instrument.

If no other congenital abnormalities besides atresia ani are present, calves with anal reconstruction usually recover well, weight gain is normal, and prognosis is favorable.

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CHAPTER 18

Surgery of the Calf Musculoskeletal System

Norm G. Ducharme, André Desrochers and David Freeman

Numerous musculoskeletal system diseases in farm animals exist—ranging from the rarer congenital abnormality (malformation, angular or flexural deformity) to acquired diseases such as septic arthritis and fractures. This section will describe diseases seen mainly in calves, such as angular and flexural deformity as well as other congenital abnormalities. The readers are directed to Chapter 15 for the principles of diagnosing and managing fractures.

POLYDACTYLY

Norm G. Ducharme

Polydactyly is a duplication of one or more digits that has been reported in many breeds of cattle. The etiology of this disease has been reported in Simmental cattle to a mixed dominant (one locus) and recessive gene (another locus). In the Alpine cattle it has been suggested that a mutation in the *EVC* or *EVC2* gene may explain the presence of polydactyly as well as ectodermal and heart defects. Sonic hedgehog (Shh) regulates the digit number and the digit identity. Errors in its expression may explain the mechanism by which polydactyly occurs. This congenital malformation is rare in farm animals, and treating it should be seen only as a salvage procedure for food production. Indeed, the possibility of inheritable diseases in all breeds argues against adding these animals to the genetic pool.

The clinical diagnosis is straightforward. The front limbs are generally affected. Radiographic examination helps determine the extent of the abnormalities (Figure 18-1). Surgical removal is done with the animal under general anesthesia with the abnormal digit uppermost. Consideration of placement of surgical incisions should allow sufficient skin for closure. In addition to the skeleton being removed (Figure 18-2*A* and *B*), the flexor tendons associated with a deformity must also be removed. One should carefully dissect the flexor tendons to ensure that the remaining flexor tendons are left as a functional unit.

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SURGERY OF FLEXURAL AND HYPEREXTENSION DEFORMITIES

Norm G. Ducharme

Calves present with flexural deformity (i.e., contracted tendons) or hypertension either as a congenital or acquired problem. Congenital deformities are seen within 1 or 2 weeks of birth. Flexural deformity ranges in severity from mild knuckling at the fetlock to being unable to walk, stand, and nurse. Likewise, the degree of hyperextension varies from weak flexors to walking on the ventral surface of the fetlock joint. The etiology of these congenital deformities in cattle is generally unknown, but cattle seen with additional congenital abnormalities may have a heritable condition and should be removed from the breeding pool. Other congenital abnormalities sometimes seen simultaneously with flexural deformity are cleft palate, dwarfism, and arthrogryposis. Lupine ingestion by the dam between 30 and 70 days of gestation may result in arthrogryposis. In addition to congenital flexural deformity, acquired flexural deformity is seen secondary to reduced weight bearing associated with a primary painful orthopedic disease.

CLINICAL PRESENTATION AND MANAGEMENT OF HYPEREXTENSION DEFORMITIES

Hypertension deformity is usually seen in newborn calves predominantly affecting the fetlock or the carpus and tends to be bilateral unless a congenital malformation of a joint is involved (Figure 18-3*A*). However, hypertension deformity is also seen associated with excessive long-term weight bearing and is often then unilateral. Mild and moderate hyperextension is generally best managed by increased (yet still limited) exercise that increases the tonus in the muscles. If this is not successful at improving the condition within 1 week, or if the condition is severe, corrective shoeing is used. Many forms of heel extension can be used (usually glue-on wood, equine shoes, or aluminum extensions) and are most often successful. If an equine glue-on shoe is used, both the cuffs of the shoe must be cut (usually dorsally) to prevent compression of the claws (Figure 18-3*B*). Fast-acting glues are preferable to methyl methacrylate because they are far less exothermic. If methyl methacrylate is used, a thin layer of material is used with cold water applied during the process to prevent damage to the calf's claws. More severe deformity and deformity proximal to the fetlocks should be treated with splints and bandaging to correct alignment yet allows weight bearing.

The prognosis is usually favorable for all congenital hyperextension deformities without malformation to the bone structures. Acquired, long-lasting flexural deformities carry a less favorable prognosis. They must be treated with longer-term application of splints, bandage casts, orthotics with more severe cases are treated by arthrodesis (see Chapter 15).



Figure 18-1 Lateral radiograph of a 10-day-old Holstein-Friesian heifer calf with polydactylia and flexural deformity. Supranumerary carpal, metacarpal, sesamoids, and phalangeal bones are present. Note the two additional carpal bones (*arrow*). (Courtesy of Dr. Markus Wilke.)

CLINICAL PRESENTATION AND MANAGEMENT OF FLEXURAL DEFORMITIES

Most commonly, calves present with mild metacarpophalangeal (MP) or carpal flexural deformity. The condition is mild and usually bilateral. In a more severe presentation, the calves have constant knuckling of the fetlocks (Figure 18-4); the carpus sometimes is also involved. Rarely, the metatarsophalangeal joints are affected. Owners typically report that calves are born with this condition or develop it within a few days to a week of birth. The deformity may be so severe that calves are unable to stand. In those cases failure of passive immunity transfer may be a complicating factor. Abnormal hoof wear is present as a result of irregular weight bearing. Depending on the housing situation and disease chronicity, affected calves that must compete for feed may have poor body condition.

Acquired flexural deformity seen in older calves is generally unilateral and secondary to a severe orthopedic injury where the animal cannot bear any or only minimal weight on the affected limb (Figure 18-5). A dropped fetlock and varus deformity at the carpus of the contralateral limb is evidence of excessive weight bearing.

A chronic deformity may have associated skin ulcerations on the dorsum of the fetlock, with the wound extending into the joint, resulting in septic arthritis.

DIAGNOSIS

The diagnosis can be easily made when the abnormally flexed position of the limb with the deformity centered on the affected joint is observed (see Figure 18-4). One should use palpation in an attempt to identify a cause for the deformity,

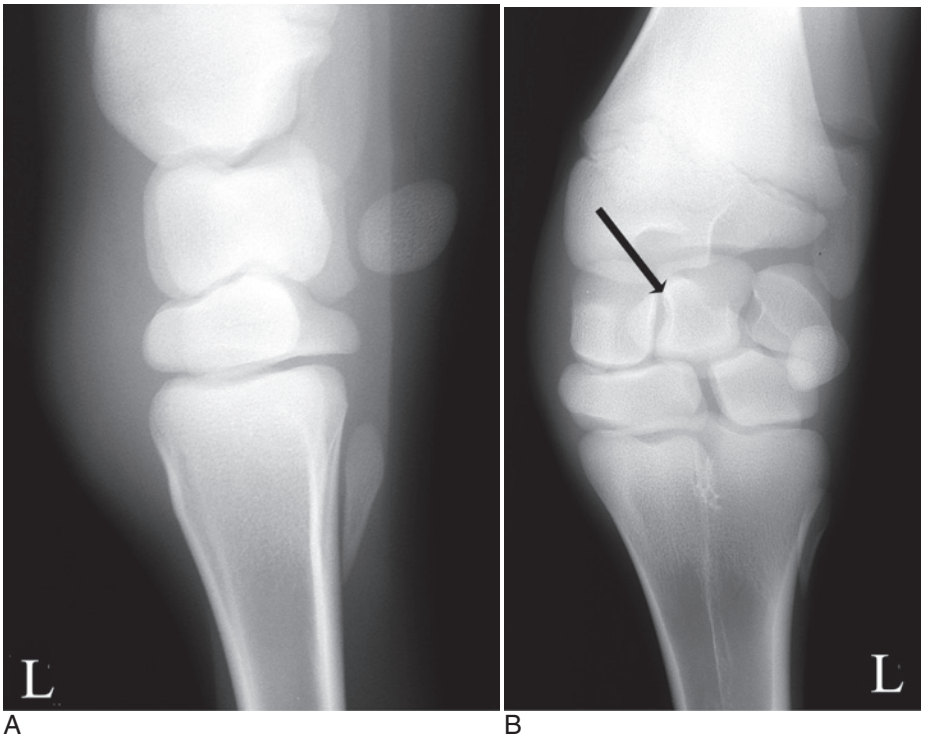


Figure 18-2 Postoperative radiographs of the calf in Figure 18-1 after removal of the supranumerary phalangeal, sesamoids, metacarpal, and distal carpal bones. *A*, Lateral view. *B*, Dorsopalmar view; note the remaining supranumerary proximal carpal bone (*arrow*).





Figure 18-3 *A*, A calf with a unilateral hyperextension of the right forelimb associated with a congenital malformation of the carpal joint. *B*, A glue-on shoe with a heel extension has improved the distal limb hyperextension but does not improve the carpal component.



Figure 18-4 A newborn calf with bilateral carpal and metacarpophalangeal deformities.



Figure 18-5 A heifer calf with unilateral carpal flexural deformity secondary to a primary carpal orthopedic disease. Note enlarged carpus.

such as a swollen joint, ruptured extensor tendon, or other orthopedic lesions (see Figure 18-5). This is especially true in acquired flexural deformities of calves. One should flex and extend the affected limb to identify a painful process that may be contributing to the deformity. The veterinarian should also evaluate how much of the deformity can be corrected by manually extending the limb. Although radiographs illustrate the deformity of the axial skeleton well, they rarely add to the diagnosis. Radiographs only help identify the extremely rare orthopedic malformations (i.e., deformed joints that cause a deformity).

MANAGEMENT

Mild cases of flexural deformity respond well when patients are placed in housing with good footing. In addition, rather than spending extended periods standing, daily walking exercise is preferable. Treatment for more affected calves depends on whether the leg can be straightened manually so that the calf can walk. Medical treatment is indicated when no predisposing orthopedic anomaly is present and the limb can be manually extended so the toe's ventral aspect can touch the ground. A splint should be placed on the palmar aspect of the limb, starting at the heel (leaving the claws out) and extending to the proximal metacarpal (or metatarsal) III bone (for metacarpophalangeal flexural deformity) or proximal radius (for carpal flexural deformity). The splint is changed every 2 to 3 days. Alternatively, a cast may be placed and removed/changed 2 to 3 weeks later (Figure 18-6). Although intravenous (IV) oxytetracycline (3 g in 250 mL of physiologic saline) can be given to relax the muscles for more rapid correction of the limb, it should be avoided whenever possible in calves. Tetracycline is very nephrotoxic in



Figure 18-6 A calf with full leg cast used in management of carpal flexural deformity.

calves, so a single treatment may result in significant renal damage.

The splint is placed as follows: three to four cotton sheets (or roll) are placed around the limb for sufficient padding to minimize skin ulceration at the pressure points of the splint. Alternatively, reusable quilt material can be used. The splint should be light so as to cause as little interference as possible with movement. Satisfactory splint materials include a piece of wood or polyvinyl chloride piping (10 cm in diameter cut into quarters or halves). The splint is placed at the palmar aspect of the limb, starting at the heel and extending to either the proximal cannon bone or radius, depending on the location of the deformity. A splint terminating at the proximal end of the cannon bone should be placed to allow maximum flexion of the carpus. If palmar skin sores develop, the splint should be placed on the dorsal aspect of the limb. Young calves with bilateral splinting may require assistance to stand at first. Surgical treatment should be considered if an animal does not respond within a few weeks of treatment.

SURGICAL CORRECTION

Surgical correction is indicated for calves not responding to splinting or with insufficient correction of the deformity to allow weight bearing. Metacarpophalangeal flexural deformity is treated by sequentially transecting the superficial flexor tendon, deep digital flexor, and suspensory ligament until the deformity is released. The number of tendons transected is decided during surgery. The tendons of the flexor carpi ulnaris and ulnaris lateralis muscles are transected to treat carpal flexural deformity.

Anatomic Considerations

The relevant anatomy of the flexor tendons and suspensory ligaments is important in relation to surgical transection. The level of the incision is influenced by the number of structures that need to be transected to release the flexural deformity.

The superficial digital flexor muscle arises from the medial epicondyle of the humerus and divides in two parts, forming two distinct tendons: a deep tendon that passes through the carpal canal and a superficial tendon that passes outside the carpal canal. Both tendons fuse in the midcannon bone but divide at the fetlock into the medial and lateral digit, forming a sleeve that encircles the deep flexor tendon. Each divided superficial flexor tendon inserts on the proximal palmar aspect of their respective middle phalanx.

The deep digital flexor tendon passes into the carpal canal and lays dorsal (deep) to the superficial flexor tendon until near the fetlock, where it divides to insert on the palmar aspect of the distal phalanges of the medial or lateral digit, respectively.

The suspensory ligament (i.e., interosseus muscle in young animals and ligamentous in adults) on the palmar aspect of the metacarpal bone lies deep in both flexor tendons. It originates from the proximal aspect of the metacarpal bone and divides at the midmetacarpal region, sending a band that joins the superficial flexor tendon. A few centimeters distally, the suspensory ligament divides into three branches: two abaxial and one in the middle. The two abaxial branches further divide distally into two branches that each attach to the corresponding medial and lateral sesamoid bone before continuing to their insertion on the palmar aspect of each proximal phalanx. In addition, each suspensory ligament abaxial branch continues into an extensor branch that joins the abaxial aspect of the extensor tendons on the dorsal aspect of each digit. The middle branch passes through the intertrochlear notch and divides into two branches that each join the axial aspect of the extensor tendons of each digit.

The ulnaris lateralis and flexor carpi ulnaris both insert on the accessory carpal bone. The ulnaris lateralis originates from the lateral epicondyle of the humerus, and the flexor carpi ulnaris originates from the medial epicondyle of the humerus and ulna.

Surgical Alternatives

The surgical procedure is performed under sedation (xylazine hydrochloride 0.1 mg/kg intramuscularly) and infiltration of local anesthesia at the intended surgery site or under general anesthesia. The calf is placed in lateral recumbency with the affected limb uppermost. This is critical for tenotomies of the flexor carpi radialis and ulnaris lateralis, but the digital flexor tendons can be transected from either a medial or lateral approach. Anatomically, two superficial digital flexor tendons each receive a branch from the suspensory ligament, two deep digital flexor tendons, and two abaxial suspensory ligaments, each with two branches. When a structure is transected, the specified flexor tendons and/or suspensory ligaments for both medial and lateral digits must be transected. Antibiotic prophylaxis is optional, but the animal should receive nonsteroidal antiinflammatory drugs (NSAIDs) preoperatively and for 2 to 3 days after surgery (i.e., meloxicam 1 mg/kg sid orally, flunixin meglumine 1 mg/kg sid IV, or aspirin 100 mg/kg bid orally, although note that local regulatory restrictions supersede these dosages).

To correct a metacarpophalangeal flexural deformity, a 7.5-cm incision is made over the lateral (or medial) aspect of the deep digital flexor tendon at the level of the midcannon bone. The fascia surrounding the flexor tendon is incised in the same plane, with care taken not to injure the lateral (or medial) palmar (or plantar) digital artery, vein, or nerve. The superficial digital flexor tendons and the connecting branches from the suspensory ligament are identified and elevated with curved hemostats. The superficial digital flexor tendons should be carefully elevated and isolated to prevent injury to the contralateral vessels. The superficial digital flexor tendons and the connecting branches from the

suspensory ligament are transected after they are isolated. The surgeon then extends the fetlock to evaluate the degree of correction achieved. The goal is to obtain sufficient correction so that the hoof contacts the ground without the fetlock knuckling. Exercise and the calf's body weight will place the joint in a normal position when the calf is walking if the knuckling is corrected. If the deformity is not sufficiently corrected after the superficial digital flexor muscle is transected, the tendons of the deep digital flexor muscle are isolated and transected as described previously. If the deformity is still not sufficiently corrected, the suspensory ligament is identified immediately caudal to metacarpal (or metatarsal) III, isolated with a curved hemostat, and transected. The peritendinous fascia and subcutaneous tissues are closed separately with nonabsorbable sutures in a simple continuous pattern. The skin is closed with an acceptable pattern.

The limb is bandaged, and a decision is made as to whether a splint is needed. When the superficial digital flexor tendons and their connecting branches from the suspensory ligament are transected, a splint is not needed postoperatively unless tension from the splint is needed to force additional extension for optimum correction. In rare cases, a splint is needed after surgery if the animal appears pained. If the deep digital flexor tendons are also transected, the limb(s) may need splint support up to 30 days. In addition, if the deep and superficial flexor tendons (tenotomies) plus the suspensory ligament are transected, destabilization of the palmar aspect of the carpus occurs. Therefore a splint that extends to the radius to give palmar support to the carpus needs to be placed on the back of the limb.

For carpal flexural deformity, a 10-cm incision starting at the accessory carpal bone and extending proximally is made on the lateral aspect of the carpus over the tendon of the ulnaris lateralis. The incision is extended bluntly until the tendons of the ulnaris lateralis and flexor carpi ulnaris tendon are identified, isolated with a curved hemostat, and transected. The subcutaneous tissues are closed separately with nonabsorbable sutures in a simple continuous pattern. The skin is closed with an acceptable pattern. A splint is placed postoperatively on the palmar aspect of the knee unless full correction is obtained. The care of splints is described under Medical Management.

In calves with flexural deformity secondary to an orthopedic injury, one must first address the primary problem. Splints, as described previously, are used to combat secondary flexural deformities.

PROGNOSIS

The prognosis for calves with flexural deformity is usually good. Secondary healing after transection of flexor tendons and even the suspensory ligament usually results in a functional gait. The low athletic demand on farm animals explains the fairly good success in treating primary flexural deformity.

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SURGERY OF ANGULAR AND ROTATIONAL LIMB DEFORMITIES

Norm G. Ducharme

Limb deformity can be classified as rotational, angular, or both. Rotational deformity is when the long bones composing the axial skeleton are aligned but the hoof is pointing externally or internally. Angular deformity is defined as a deviation of the lower limb in the lateral or medial direction from the normal axis. It is generally classified in relation to the joint at which the deviation originates (i.e., fetlock, hock, and carpus etc.). The angular deformity is further characterized (in veterinary medicine) as *valgus* when the distal limb is deviated laterally and *varus* when it is deviated medially. These deformities are often seen in association because it is common to observe a calf with a valgus deformity and an external rotation. Similarly a varus deformity is often associated with internal rotation. Therefore the claws usually rotate outward with a valgus and inward with a varus deformity except in cases of multiple angulations in a limb. The reverse is not true insofar as it is common to have an internal or an external rotational deformity without associated angular deformity.

ETIOLOGY

Congenital angular deformity is very rare in cattle and reportedly is in the middiaphysis of the affected long bone when it occurs. The exact etiology is unknown but has been attributed to in utero bending stresses early in gestation. These deformities can originate from many sources: growth plate abnormality, diaphyseal malformation and malunion, fracture, and ligament rupture.

Congenital abnormalities most commonly involve multiple joints sometimes with flexural deformities. Growth plate differential growth, commonly seen in horses, is rarely seen in farm animals unless associated with excessive weight bearing where varus deformity is seen (see Figure 15-4). Angular deformity is a common event in cattle in that most calves have a mild carpal valgus deformity of approximately 7 degrees (Figure 18-7), which is within the normal range for most farm animals and does not require treatment. Orthopedic injuries such as fracture and its healing process, collateral ligament tear, physeal infection (Figure 18-8), or physeal fracture commonly cause secondary angular deformity.

Wolff's Law (1872) states that gradual or repetitive load changes due to trauma or change in activity cause functional remodeling so that trabeculae are reoriented to align with new stress axes. This plays a role in misaligned fracture healing (i.e., malunion) and an animal's ability to remodel the area to correct or improve the deformity. The effect of pressure and shear force on longitudinal growth varies and depends on the degree of pressure and whether it is intermittent or constant. Intermittent pressure allows the growth plate to respond to the line of stress. Partially through

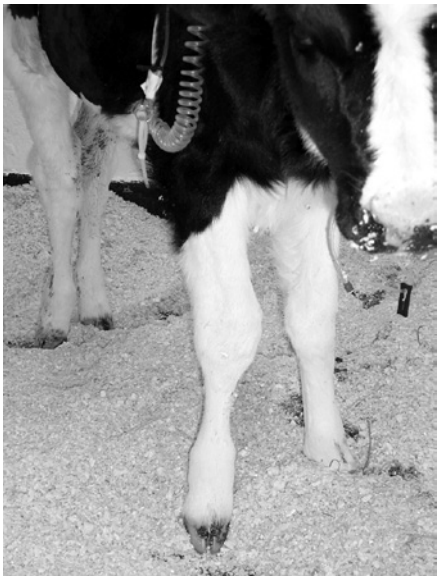


Figure 18-7 The right forelimb of a 1-week-old calf is examined. The observer is aligned with the center of the front claws to determine whether the pastern area, third metacarpal bone, and radius are in line. Note the slight normal divergence of the line between the metacarpal bone and the radius that is within normal limits for cattle. Contrast with Figure 18-9.



Figure 18-8 Septic physitis in a ewe with angular deformity. Note the lytic area at the physis (*arrows*). (Courtesy of Dr. Anthony Pease.)

reduced blood flow, constant pressure reduces longitudinal growth from the affected physis plate. The uncompressed side of the physis maintains normal growth, which results in an angular deformity (usually varus). This is often seen at the hock or carpus on the contralateral limb (i.e., limb not affected with a painful orthopedic problem).



Figure 18-9 The right forelimb of a 3-week-old calf is examined. The observer is aligned with the center of the front claws to determine whether the pastern area, third metacarpal bone, and radius are in line. Note the marked normal divergence of the line between the metacarpal bone and the radius. Contrast with Figure 18-7.

CLINICAL PRESENTATION

Animals presented for evaluation of angular deformities are easy to recognize. For an accurate diagnosis, one should align himself or herself with the claws and evaluate whether all the long bones are in line (see Figure 18-7). This perspective is important to differentiate an angular deformity from a rotational deformity, which is difficult when one is observing the animal from the front or back. Standing directly in the center front of the claws eliminates the rotational deformity as a confounding factor, and the clinician is able to then verify that the claws, pastern bones, metacarpal, and radius (or tibia) are all in line (with allowances made for the anatomically normal mild carpus valgus of cattle; see Figure 18-7 and compare with Figure 18-9).

Further examination should focus on the area where the limb loses linearity. Physical examination can assess pain or other signs of an orthopedic injury, including the following: increased laxity, swelling and its characteristics, degree of lameness, and presence of muscle atrophy. Although mild valgus deformity is relatively common, varus deformity is abnormal (Figure 18-10). If varus deformity is found unilaterally, the contralateral limb should be examined for a significant orthopedic injury as a cause for excessive weight bearing in the deformed limb/joint. Obtaining radiographic evaluation is important in investigation of orthopedic injuries, which are often important causal factors in angular deformity in farm animals.

DIAGNOSIS

The diagnosis is made based on the clinical signs, but the exact etiology may not be determined unless radiographic

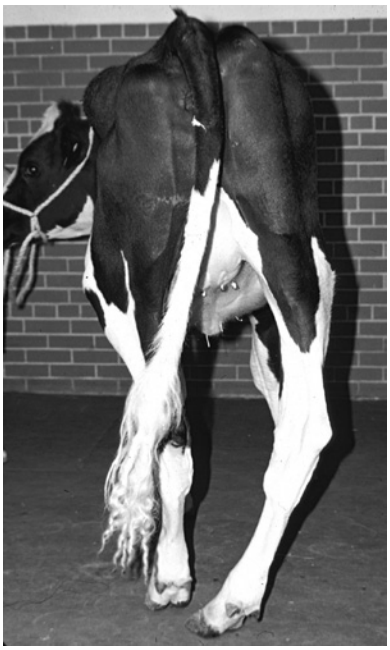


Figure 18-10 A calf with varus deformity of the right hock secondary to excessive weight bearing.

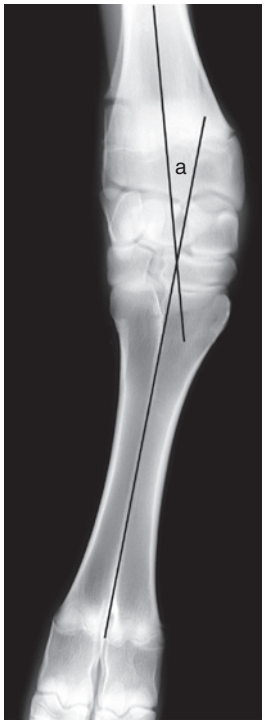


Figure 18-11 A dorsopalmar view of a radiograph of a calf forelimb. Lines overlying the center of the longitudinal axis have been drawn. The pivot angle (a) marks the degree of angular deformity. (Courtesy of Dr. Anthony Pease.)

examination is done. A dorsopalmar view is needed for examination of the anatomic location of the deformity and its measurement (Figure 18-11). Like the visual examination, the dorsopalmar view must be taken with the radiographic beam in line with the claws. To estimate the degree of angular deformity, a long cassette is needed so that more accurate lines overlying the center of the longitudinal axis can be drawn. The area of divergence (pivot point) of these lines confirms the angular deformity site, and the radiographic abnormality helps identify the causes (see Figure 18-11). Further radiographic views may be needed, depending on the nature of the injury or problem.



Figure 18-12 An animal with valgus deformity of the right hind limb. Note that the inside claw is shorter than the outside claw, contributing to the lateral deviation and external rotation. (Courtesy of Steve Kraus.)

MANAGEMENT

Medical Management

Trimming the claws of a young calf creates growth plate response to stress applied opposite the deformity so self-correction occurs. The trimming and other hoof manipulation is based on the principle that the hoof will turn in the direction of the longer claw or toward the side of the wider wall (Figure 18-12). To correct a valgus deformity, the lateral claw is trimmed so that it is shorter than the medial claw. To correct a varus deformity, the medial claw is trimmed so that it is shorter than the lateral claw. Acrylic can also be applied. Acrylic is applied over the lateral aspect of the lateral claw of a varus deformity to make the claw wider with more lateral contact with the ground (Figure 18-13). The lateral claw must not extend more than 1 cm; otherwise the stress on the lamina may cause inflammation and pain. The procedure is reversed for a valgus deformity (extend the medial wall of the medial claw). Finally, a shoe may be glued onto the claw to extend the lateral or medial claw (see Figure 15-147*A*).

Primary treatment is directed at the orthopedic injury if a varus deformity is present secondary to a contralateral limb orthopedic injury. Preventing a secondary varus abnormality is far more effective than treating it. Resolving excessive weight bearing, trimming the medial claw, and sometimes applying acrylic over the lateral aspect of the lateral claw may help correct a varus deformity.

Surgical Management

When significant marked angular deformity is associated with growth plate disturbance, growth retardation can help correct the deformity. It is important to note that no



Figure 18-13 A calf in lateral recumbency. Acrylic has been applied on the lateral aspect of the lateral claw to add support and guide the claw to a more external position while walking.

significant studies have documented the results of periosteal stripping in calves. This technique was extrapolated from its use in horses, which is itself controversial. At the time of this writing, periosteal stripping is no longer recommended to correct growth deformity; instead transphyseal screws are placed across the growth plate to retard growth on the convexed site of the deformity. It is worth noting that no known data exists regarding when the various growth plates of cattle functionally close. The general belief is that cattle growth plates close a few months later than their equine counterparts.

The procedure is performed under general anesthesia. This procedure can be performed on either the medial or lateral aspect of a given growth plate. Although no studies have documented its use in calves, this procedure is effective if sufficient growth is left in the affected growth plate. The procedure (best done under radiographic control) is performed on the convex side of the limb: the lateral aspect for a varus deformity and the medial aspect for a valgus deformity. In a unilateral case, the calf is placed in lateral recumbency with the physis targeted for growth retardation uppermost. In a bilateral case, the calf is placed in dorsal recumbency. If medial physis is targeted, the affected limb is tied in an extended position. The targeted growth plate is aseptically prepared, and a 1-cm stab incision is made midway 2 to 3 cm above the growth plate (except for the hock, where a stab incision is made at the most distal and extraarticular area of the appropriate malleolus). A pilot hole is drilled with a 2.5- or 3.2-mm drill bit, and one self-tapping screw, 3.5- or 4.5-mm, respectively (usually 32-36 mm in length) to be placed across the ipsilateral third of the growth plate. The stab incisions are then closed in an acceptable manner.

The area is bandaged postoperatively. The bandage is removed 3 days later, and the skin sutures are removed 10 to 14 days postoperatively. The calf is allowed normal exercise after the sutures are removed. The implant must be removed as soon as the leg is acceptably straightened, or overcorrection will occur. If the procedure was done bilaterally, the implants must be removed from each leg as soon as it straightens. Under general anesthesia, a needle is used to palpate and locate a screw head; imaging may be required to identify the screw head. A stab incision is made when the screw head is located and the screw is removed.



Figure 18-14 Radiographs of a a metaphyseal deformity with measurement and drawing to illustrate the preoperative measurement for a closed wedge osteotomy. The pivot angle (a) was previously calculated as indicated in Figure 18-11 (albeit for the carpus), which determines the height of the wedge (*white bracket*). The *black lines* illustrate the intended line of the two osteotomies.

A closing wedge osteotomy, step osteotomy, or cylindrical osteotomy can be performed (if financially justifiable) when an angular deformity is related to a malunion, malformation of the diaphysis, or premature closure of the physis that prevents further growth. To prepare the location and site of the osteotomies, preoperative radiographs should be measured. These measurements are used to determine the pivot point and angle of angulation by measuring the angle between the intersecting lines.

Preoperative Measurements

These measurements and radiographic markings serve only as guides because adjustments for magnification error must be made intraoperatively.

Closing Wedge Osteotomy

Sufficient bone should be left when the closing wedge osteotomy is designed for appropriate purchase of the screws through the plate being used to immobilize the osteotomy site. A line is drawn parallel to the joint at the level of the pivot point. The height of the second osteotomy site is calculated by using the angle of deviation at the pivot point.

Step-wise Osteotomy

A horizontal osteotomy line is drawn parallel to the joint, starting again at the pivot line but extending only through half the diameter of the affected bone in the dorsopalmar (plantar) plane (Figure 18-14). A line is drawn from the axial end of the horizontal osteotomy line and extends 5 cm proximally along the long axis of the bone. A second vertical line the same length is drawn from the same starting point but angled to represent the previously measured pivot angle; the width of that wedge is measured. The last osteotomy line is

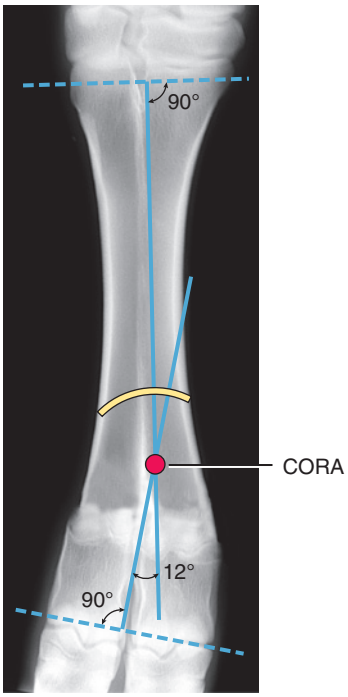


Figure 18-15 The same radiograph as in Figure 18-14 to illustrate the intended preoperative measurement for a dome osteotomy. The center of rotation of angulation (CORA; *red dot*) is determined from the intersection of the axial line of the distal and proximal components of the deformity. The inclination or deviation angle is determined from the angle of these intersection lines. The arc (*yellow line*) of the osteotomy is centered on the CORA.

drawn horizontally from the proximal aspect of these two vertical lines and extending perpendicular to the long axis of the proximal bone.

Cylindrical (i.e., Dome) Osteotomy

First the pivot point is identified from the anatomic axis of the bone proximal and distal to the deformity (Figure 18-15). This pivot point is referred to as the center of rotation of angulation (CORA). Second, the angle of the deformity is determined from the intersection of the drawn line (see Figure 18-15). A dome or curve osteotomy is performed centered on the CORA. This allows two curved bone ends to angulate and translate on each other to correct the deformity with maximal bone contact. In addition the limb length is maintained because no bone is removed.

Surgical Techniques

A skin incision is made over the dorso or dorsolateral aspect of the affected long bone. An inverted-V-shaped tenotomy of the common (or long) digital flexor tendon is done exposing the diaphysis. The incision is extended to the affected bone, and subperiosteal dissection exposes the bone before the osteotomies. A 2-mm Kirschner wire is then placed 2 cm proximal to the joint below and 2 cm distal to the joint above at 90 degrees to the long axis of the bone to be osteomized. These will facilitate realignment of the bone ends after the osteotomy(ies).

Closing wedge osteotomy is performed as follows. Using a reciprocating saw, the surgeon transects the affected bone parallel to the joint surface immediately distal to the level of the pivot point, carefully protecting all surrounding soft tissue. The height of the second osteotomy is measured from the radiographs. Starting on the convex side, the second osteotomy is extended to the opposite side of the bone until it meets the first osteotomy site. The bone fragments are fixed after the wedge removal is performed (see Internal Fixation in Chapter 15).

To perform a step-wedge osteotomy, a 3.2-mm hole is drilled from dorsal to palmar (plantar) in the center of the bone at the intended start of the longitudinal osteotomy lines. A second hole is drilled 5 cm proximal. These two holes prevent inadvertent longitudinal fissures associated with the creation of the longitudinal (i.e., vertical) osteotomies. Using an oscillating saw or Gigli wire, the surgeon joins two holes by a longitudinal osteotomy. Using the width measurement of the wedge needed, another hole is placed proximally, and the surgeon performs the second longitudinal osteotomy. The horizontal osteotomies are made by cutting the bone parallel to the joint without extending any further than the distal aspect of the longitudinal osteotomies. The proximal osteotomy site is done perpendicular to the long axis of the proximal fragment. The distal osteotomy is made parallel to the distal joint. Reduction to correct a rotational deformity can be enhanced by removing an additional bone wedge at the dorsal or palmar (plantar) aspect of the vertical bone segment created. During the repair, lag screws are applied across the vertical component created as part of the internal fixation repair. Appropriate surgical closure is done. Depending on the weight of the animal, a cast may be needed for further support.

The cylindrical or dome osteotomy is performed by an arc osteotomy using a biradial saw with the calculated arc of a circle centered on CORA. This allows translation of the bone so that the largest contact area is maintained without loss of limb length. In the clinical report of this procedure two locking plates were used to reduce and fix the proximal and distal fragment.

Prognosis

The prognosis is reasonable for angular deformities associated with growth plate imbalance, such as most valgus deformities. There should be an expectation of mild to moderate fibrous tissue, and enlargement of the surgery site is evident for up to 2 months after surgery. The fibrous tissue remodels after 2 months, which makes the surgical site cosmetically acceptable in most cases. Wedge osteotomies carry a fair prognosis for functionality, although a cosmetic defect due to enlargement at the surgery site is expected.

The prognosis for angular deformity secondary to contralateral orthopedic injury (such as most varus deformities) is generally poor because it is usually centered over a joint (carpus or tarso crural joint) and is also dependent on the prognosis of the primary orthopedic injury.

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SURGERY OF SEPTIC JOINTS

André Desrochers

Systemic or remote infection has to be considered when a calf is diagnosed with septic arthritis, especially if more than one joint is affected and no wound can be seen. The umbilicus is a very common route of infection. Inadequate hygiene, not disinfecting the umbilicus after birth, and passive immunity transfer failure are the most important factors that contribute to umbilical infection. Calves with omphalophlebitis are at high risk of septicemia and consequently septic arthritis. Pneumonia, diarrhea, septicemia, and passive immunity transfer failure must also be considered when physical or ultrasound examination reveals a normal umbilicus. Systemic origin rather than local trauma increases the probability of more than one joint being infected. Calves with septic arthritis must have a thorough physical examination to find a remote infection site until proven otherwise. Other causes include direct trauma to the carpi seen when calves are kept on inadequate flooring, have flexural deformities, or are unable to stand adequately.

Frequency of septic arthritis in a herd is generally low. *Mycoplasma* and *Histophilus somnus* should be considered as possible causes when the incidence of septic joints increases in a herd without umbilical involvement. Incidences of septic arthritis increase in the presence of *Mycoplasma* pneumonia and mastitis in a herd.

DIAGNOSIS

Onset of clinical signs in calves is acute and severe. The differential diagnosis of swollen joints in calves should include septic arthritis, ligament injury, osteochondrosis, articular fracture, and idiopathic arthritis. Septic arthritis should remain high on the list of possible diagnoses for swollen joints in calves. Lameness will vary, depending on the duration and severity of the infection and number of joints affected. During the physical examination, investigating the origin of septic arthritis should be emphasized—with a very special focus on the umbilicus. All of the joints should be palpated, and particular attention should be paid to the most commonly involved joints in septic arthritis (carpus, tarsus, stifle, and fetlock). A low serum total protein (less than 55 g/L) or immunoglobulin level indicates that passive immunity transfer has failed, which helps determine the calf's immune status. If passive immunity transfer failure is diagnosed, plasma or whole blood can be administered to the animal.

A blood culture improves the chance of finding bacteria in a febrile calf. *Mycoplasma* should be considered if the calf's umbilicus is within normal limits at the physical examination, especially if multiple animals are affected. Among all *Mycoplasma* species, *Mycoplasma bovis* is reported to be frequently isolated in septic joints. Clinical cases of *M. bovis* tend to be sporadic and are typically considered as a sequel to respiratory disease or mastitis within a herd or animal. However, outbreaks of *M. bovis* arthritis as the primary and/or predominant clinical manifestation have been reported in calves and dairy cows. Intrauterine transmission of *M. bovis* is suspected in neonates. If *Mycoplasma* is suspected it must be specified on the laboratory request.

Arthrocentesis can be performed to confirm diagnosis. Macroscopic examination of the synovial fluids is usually diagnostic. If doubt exists, the specimen is submitted for cytologic examination. Culture of the synovial fluids helps the clinician confirm or modify the choice of antibiotic. Cytologic examination and bacterial culture of the synovial fluid can be repeated if the animal does not respond well to initial treatment.

Radiographs of the infected joint confirm the diagnosis and prognosis. Radiographic lesions in calves have a tendency to be more lytic, with less new bone formation occurring in comparison to older animals (Figure 18-16*A* and *B*).

Joint ultrasonography can be achieved on a calf with a 7.5-MHz rectal probe. Joint space, bone lysis, and fibrin content can be viewed. It might influence treatment protocol and prognosis. A joint that contains fibrin has to be drained surgically instead of just lavaged with a needle (Figure 18-17).

TREATMENT

Septic arthritis is a very painful condition that necessitates immediate intervention. Antibiotics, antiinflammatory drugs, joint lavage or drainage, and physical therapy are the principal components of septic arthritis treatment (Figures 18-18 and 18-19). The treatment will vary based on the severity and duration of the disease, location and number of joints infected, microorganism isolated from the septic joint, comorbidities (umbilical infection, pneumonia), and economic value of the animal. These factors should be considered to give the owner an accurate prognosis and establish a treatment. An infected umbilical vein with liver involvement should be surgically removed or marsupialized promptly after diagnosis to stop the potential spread of microorganisms.

In the author's opinion, the antibiotic chosen for calves with septic arthritis should be aimed at treating *Mycoplasma* if no organism is isolated and the umbilicus is unlikely to be the cause. Otherwise, antibiotics should be effective on gram-negative organisms. Trimethoprim sulfadiazine, cefapirin, penicillin, and oxytetracycline have been demonstrated as very good intraarticular diffusion in cases of septic arthritis in calves following systemic administration. The duration of antibiotic treatment is empirical. Therapy should be continued for 2 to 3 weeks after clinical improvement (decreased lameness, improved quality of the synovial fluid). Conservative treatment with systemic antibiotics and antiinflammatory drugs alone is indicated if the course of the disease is short (less than 5 days). Other treatment alternatives have to be considered when the disease lasts more than 5 days. Local administration of antibiotics (intraarticular) has to be considered because of its capacity for providing concentrations above the minimum inhibitory concentration for a long period of time. Administering local antibiotics also requires a smaller volume, which is an advantage for toxic or expensive drugs. A local antibiotic is chosen based on the organism isolated and its innocuousness for the joint. Besides intraarticular administration, local intravenous administration under a wide tourniquet (Figure 18-20) and antibiotic-impregnated collagen implants are being used sporadically. Slow-release impregnated absorbable implants have shown promise in providing high local concentrations for an extended period of time, which would certainly improve therapeutic efficacy by minimizing use of systemic antibiotics.

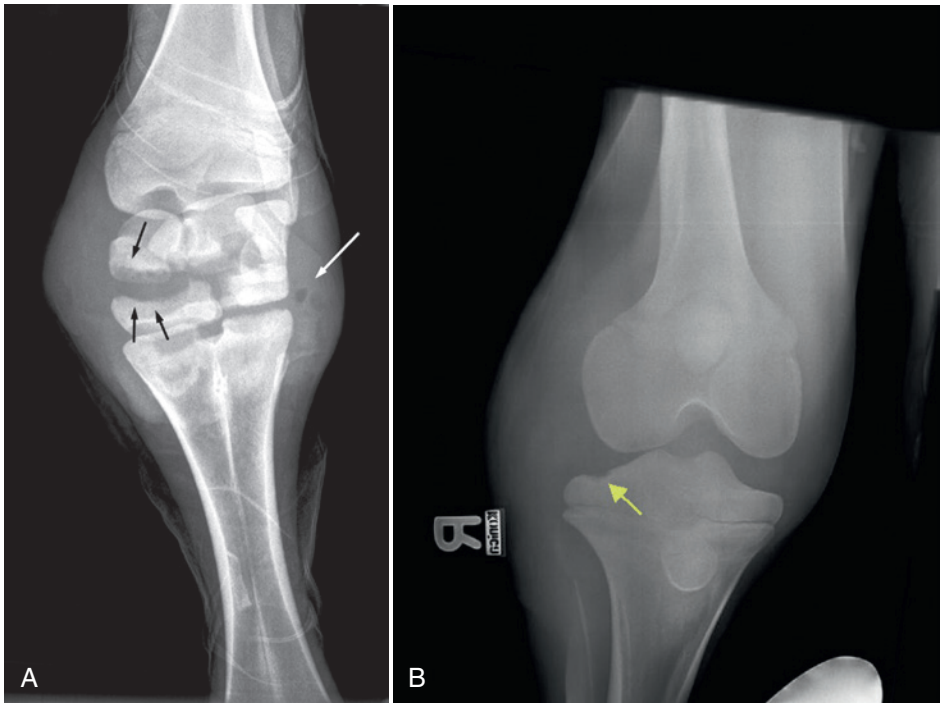


Figure 18-16 *A*, A craniocaudal radiographic view of a carpus from a young calf. There is severe soft tissue swelling with air (*white arrow*). The middle carpal joint space is increased with lysis of the subchondral bone (*black arrows*). *B*, A craniocaudal radiographic view of a stifle. There is soft tissue swelling and a small area of subchondral bone lysis on the lateral tibial plateau (*arrow*).

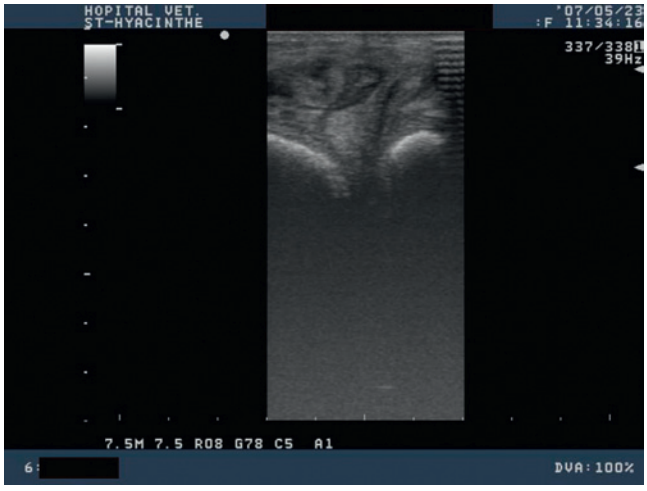


Figure 18-17 Longitudinal ultrasonographic view with a 7.5-MHz linear probe of a septic carpus. There is echoic material in the joint space and cavity.



Figure 18-18 Articular lavage of the antebrachiocarpal joint on a Hereford calf.

Long-term administration of antibiotics will affect withdrawal time and must be discussed with the client before starting therapy.

Joint lavage is easily performed in calves because they can be efficiently sedated, blocked, and immobilized. Needles, 18 to 14 gauge, are used to drain and thoroughly lavage the joints. As stated for adults, two needles are usually necessary, but joints with multiple compartments and large boundaries might need more. Arthroscopy can also be used but is certainly more expensive.

Clinical signs from acute septic arthritis should improve between 2 and 4 days after treatments are started. An arthrotomy should be performed to provide better drainage if the animal does not improve after two joint irrigations or the synovial fluids still have fibrin. General anesthesia is considered when treating more than one joint. Knowledge of each different articulation's anatomic boundaries and communication is essential before starting local intervention. If calves do not respond to arthrotomy, arthrodesis is recommended.

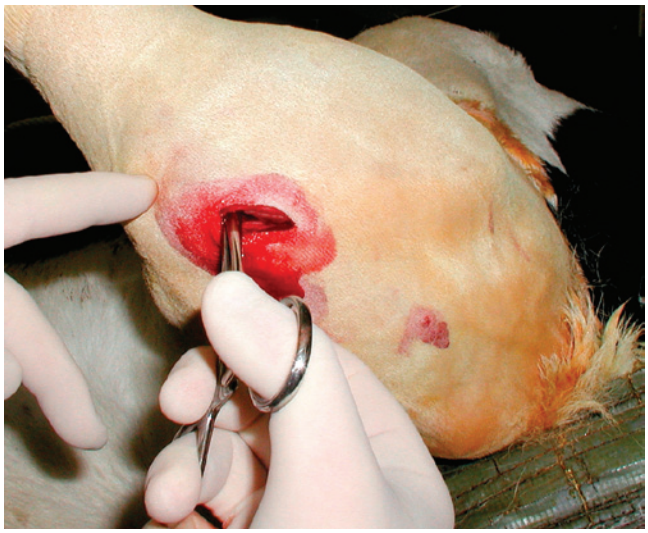


Figure 18-19 Arthrotomy with debridement of the antebrachiocarpal joint.

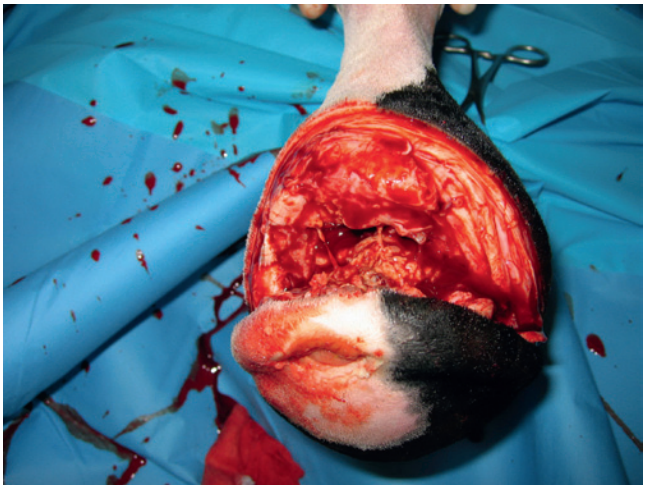


Figure 18-21 Transverse 180-degree dorsal incision over the infected carpal row. A part of the carpal bones are already removed.

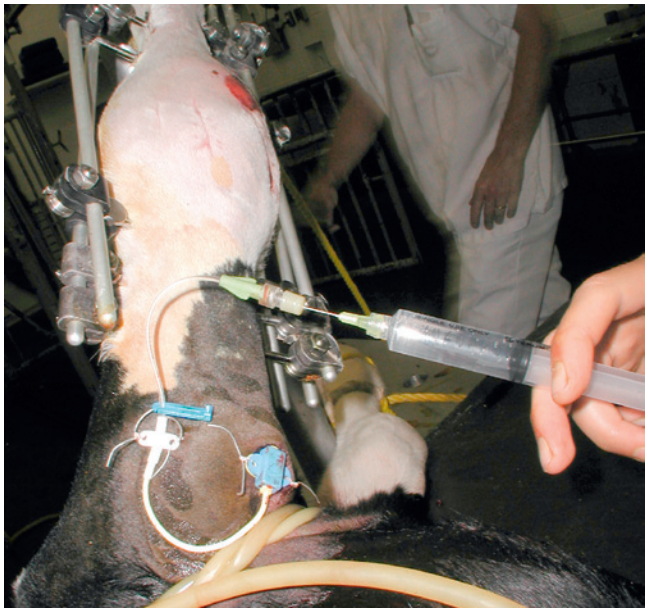


Figure 18-20 Regional perfusion of the carpus of a calf with chronic septic arthritis: local antibiotics were administered intravenously distal to a tourniquet. An arthrodesis was performed, and an external fixator was used to stabilize the joint.



Figure 18-22 The cartilage of the sound carpal bones, radius, or metacarpi is removed with a rongeur.

Arthrodesis

Arthrodesis is the final solution when no treatments have been effective or because chronicity of the disease prevents restoration of joint function. Articulations of the distal limb are easy to arthrodese (fetlock, proximal, and distal interphalangeal joints). Arthrodesis of the distal interphalangeal joint has been described extensively in the literature with a very good prognosis (see Arthrodesis of the of the DIP Joint by the Solar Approach in Chapter 15). Severe carpal and tarsal joint infections have also been treated with arthrodesis. In all cases, the joint is flushed with local antibiotics after debridement and parenteral antibiotics are continued for 3 weeks.

For high-motion joints such as the carpus and tarsus, the clinician must consider the facilities (stall or small pasture), value, and purpose of the animal before he or she proposes surgery to the owner. In carpal arthrodesis, the animal is positioned in lateral or, preferably, dorsal recumbency, and a transverse dorsal skin incision is made at the most distended portion of the joint (Figure 18-21). The incision is extended sharply to the joint surface, transecting vessels and extensor tendons. Often the extensor tendon sheaths are infected and need to be debrided. All infected tissue is curetted and removed. If one or more of the carpal bones are severely lytic and infected, they are dissected free and the entire row of carpal bone is removed. During debridement, one should take care not to disrupt the palmar ligaments and support of the joint or enter the carpal canal. Synovial membrane and surrounding infected tissues are removed through excision or curettage (Figure 18-22). The excessive skin (Figure 18-23) is trimmed and then closed with simple interrupted sutures, and a full leg cast or transfixation cast is applied. A cast should be maintained until arthrodesis (usually 3 months) and should be changed at an appropriate frequency (at least every 3 weeks for a calf and every 6 weeks for adults).

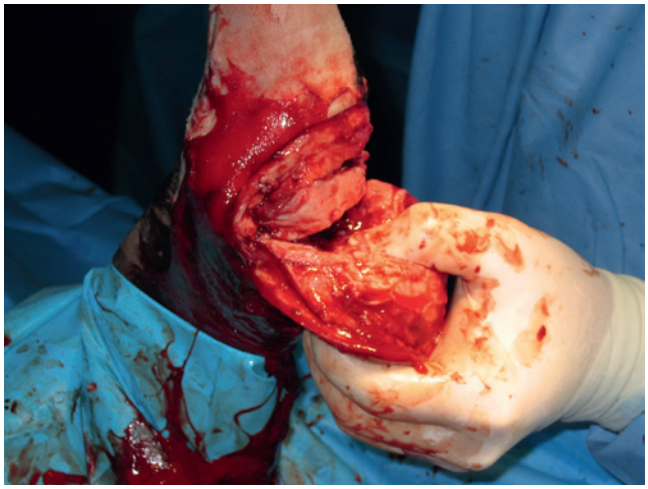


Figure 18-23 Excessive skin will have to be removed before closing the arthrotomy.

In tarsal arthrodesis, the animal is positioned in dorsal recumbency. Tarsal joint arthrodesis is performed as follows. For tarsocrural arthrodesis, a vertical skin incision is made on the most distended dorsomedial pouch of the tarsocrural joint. The incision is sharply extended until the joint is reached. A similar arthrotomy is made on the caudolateral-lateral aspect of the joint immediately between the lateral malleolus of the tibia and the tuber calcanei. A final vertical arthrotomy is made on the caudomedial pouch immediately caudal to the medial malleolus; the clinician must be very careful not to enter the tarsal sheath. The skin incision in the final vertical arthrotomy is extended with Mayo scissors to avoid inadvertent entry into the tarsal sheath. Thorough debridement is performed as described earlier. Fascial planes are closed when possible, and the skin is reapposed with simple interrupted sutures.

For distal tarsal joint arthrodesis, a vertical incision is made on the craniomedial side, centered on the target joint. The incision is extended to the joint, but it is far more difficult to identify the joint surface. The area is curetted as much as possible, and the infected joint capsule is resected. A 3.2-mm drill bit is placed parallel to the articular surface and used to remove as much surface as possible. The skin is closed with simple interrupted sutures. In both cases, a full leg cast is applied for approximately 12 weeks with regular cast changes (at least every 3 weeks for a calf and every 6 weeks for adults).

The antiinflammatory drugs are an essential part of the treatment for two reasons: pain management and to control the intraarticular inflammatory response. There is scarce literature on the efficacy of NSAIDs in cattle for the control of inflammation with septic arthritis. However, flunixin meglumine was reported to be effective in controlling pain in dairy steers with induced synovitis. Calves can be administered flunixin meglumine (1 to 2 mg/kg sid IV), aspirin (100 mg/kg bid orally), ketoprofen (3 mg/kg sid intramuscularly or IV), and meloxicam (0.5 mg/kg every 48 hours subcutaneously or IV). If NSAID treatment is prolonged, calves should be monitored for abomasal ulcers, especially if they are not eating or drinking properly. Corticosteroids (dexamethasone) have been successfully used in treating septic arthritis in children despite the controversy. In specific cases, their strong antiinflammatory properties exceed their immunosuppressive activities. Short-term systemic and intraarticular injection can be considered if joint swelling and high leukocyte count are still present with a negative culture.

PROGNOSIS

Rapid intervention after the onset of clinical signs increases the chance of recovery. The prognosis is poor with more than two infected joints. Joint lavage is very effective in acute cases. Eighty percent of 20 calves responded to joint lavage that required two or more flushes (Jackson et al., 1998). Chronic septic joints contain a lot of fibrin that is not easily removed, even through multiple arthrotomy sites. Ankylosis of the joint, muscle atrophy, and tendon deformities (contraction) complicate an animal's rehabilitation, even after the infection is controlled. This should be considered before establishing a treatment plan. An animal with chronic septic arthritis with bony lesions does not have a good prognosis for complete recovery and becoming a productive animal. Arthrodesis is an option for full recovery in low-range motion distal joints like the interphalangeal and fetlock joints. Pain-free arthrodesis of the carpus that permitted full weight bearing was obtained in 69% of 72 cattle treated.

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PATELLAR LUXATION

Norm G. Ducharme

Patellar luxation causes a significant gait deficit, which brings it to the attention of the veterinarian early in the course of disease. It may be a congenital condition associated with malformation of the femoropatellar joint—most commonly hypoplasia or osteochondrosis of the lateral trochlea. A femoral nerve deficit is associated with difficult parturition, especially breech presentation, and will present with a similar gait deficit because of the loss of quadriceps function.



Figure 18-24 A Holstein-Friesian calf with Grade III patellar luxation. Note the crouch position in the affected limb. (Courtesy of Dr. Michael Schramme.)

Additionally, loss of normal quadriceps muscle activity coupled with the normal lateral pull of the gluteobiceps muscle may also result in lateral patellar luxation. Finally, direct trauma to the stifle joint that tears the femoropatellar ligaments or causes a distal femoral fracture may also result in patellar luxation.

CLINICAL PRESENTATION AND DIAGNOSIS

Affected calves are unable to extend the stifle joint, and the pelvis is lowered on the affected side (Figure 18-24). While walking, the animal is able to bear weight but cannot normally extend the stifle, thus creating an obvious gait deficit with the calf in a unilateral or bilateral crouch position. The animal prefers to lie down, and weaker calves will be unable to rise without assistance. The ability to stand and walk depends on the calf's age and strength, the quadriceps muscle function, and whether the condition is unilateral or bilateral. Even calves with bilateral disease are often able to stand and be ambulatory to some extent.

Femoral nerve damage and trauma (femoropatellar ligament rupture, patellar fracture, or distal femoral fracture) may result in a dysfunctional quadriceps unit. On physical examination, one should attempt to differentiate patellar luxation from femoral nerve damage or trauma. Femoral nerve damage generally has a history of difficult assisted birth; excessive pulling stretches the nerve and causes various degrees of nerve damage, ranging from neurapraxia to axonotmesis. Given this etiology, the condition is often bilateral. On clinical examination, there may be a small area of skin denervation on the medial aspect of the distal femur, which is the dermatome of the femoral nerve through the saphenous branch. This can be detected by pinching the skin in the area with a hemostat. However, because of the femoral nerve "blurred" dermatome and the general hyposensitivity of young calves, this clinical sign is difficult to detect. As time progresses, either return to function occurs or the quadriceps muscle progressively atrophies. A dysfunctional quadriceps unit usually has femoral nerve damage diagnosed as the cause by exclusion. Absence of function of the quadriceps can lead to patellar luxation. Recognizing this diagnosis is important because either surgical treatment is not needed or would have a very poor prognosis if femoral nerve function does not return.

Direct trauma to the stifle joint is a rare cause of patellar luxation and is usually easily identified by marked periarticular edema and by fibrous tissue production as part of the normal healing process in response to injury in chronic cases. Sonographic examination helps establish the loss of femoropatellar ligament integrity. In addition, radiographic anomaly can also be detected if a fracture is present. The amount of pain the calf exhibits and the periarticular swelling are key hallmarks of trauma-induced patellar luxation or dysfunction of the quadriceps unit. Also, congenital luxation of the patella is almost exclusively lateral, whereas luxation associated with direct trauma can result in lateral or medial luxation. Pain is not a feature of congenital patellar luxation or femoral nerve deficit.

Patellar luxation is identified by first localizing the patella between the index finger and thumb and noting its position more lateral (or medial) to the lateral (or medial) trochlea. Normally, a patellar luxation should not be inducible. In Grades I and II patellar luxation, luxation can be induced with the stifle in full extension (see the section on Classification of Patellar Luxation in this chapter). Likewise, patellar luxation can usually be reduced with the stifle in full extension. In more severe case, the patella can be observed or felt to luxate laterally during flexion of the stifle.

Radiographic examination (lateral, craniocaudal; Figure 18-25*A* and *B*) of the stifle joint allows confirmation of the diagnosis and an estimation of the degree of osteoarthritis. If present, distal femoral fractures can be identified. In addition, the anatomic conformation of the lateral and medial trochlea and the trochlear groove can be assessed through a skyline view (Figure 18-26).

CLASSIFICATION OF PATELLAR LUXATION

In small animals, the patellar luxations are classified from I to IV. The following classification modification is proposed for farm animals:

I. Intermittent patellar luxation causes the calf to crouch occasionally on the affected limb while the animal walks. The patella easily luxates manually at full extension of the stifle joint but returns to the trochlea when released.
II. There is occasional patellar luxation with the associated gait deficit described in I. The animal is capable of full stifle extension most times. On physical examination, the patella can be easily luxated manually with the stifle joint at full extension and does not readily return to normal position.
III. The patella is permanently luxated. The animal is unable to extend the stifle, so it walks in a crouch position. During physical examination, one can reposition the patella, but it does not stay in place when the joint is flexed. The depth of the trochlear groove varies.
IV. The patella is permanently luxated. The animal is unable to extend the stifle, so it walks in a crouched position. During physical examination, one cannot reposition the patella. Radiographically, the trochlear groove is flat or absent, and the lateral trochlea has been deformed by the overlying patella (see Figure 18-26).

MANAGEMENT

Patellar luxations due to femoral nerve damage are managed conservatively. The femoral nerve deficit may resolve within 30 days. The calf should be placed in a box stall with excellent footing or in a small outside pen so that it gets limited physical activity. An antiinflammatory agent such as meloxicam (0.5 mg/kg every 48 hours subcutaneously or IV) can be administered for a few days. Because the prognosis is poor if the quadriceps function does not return, surgical

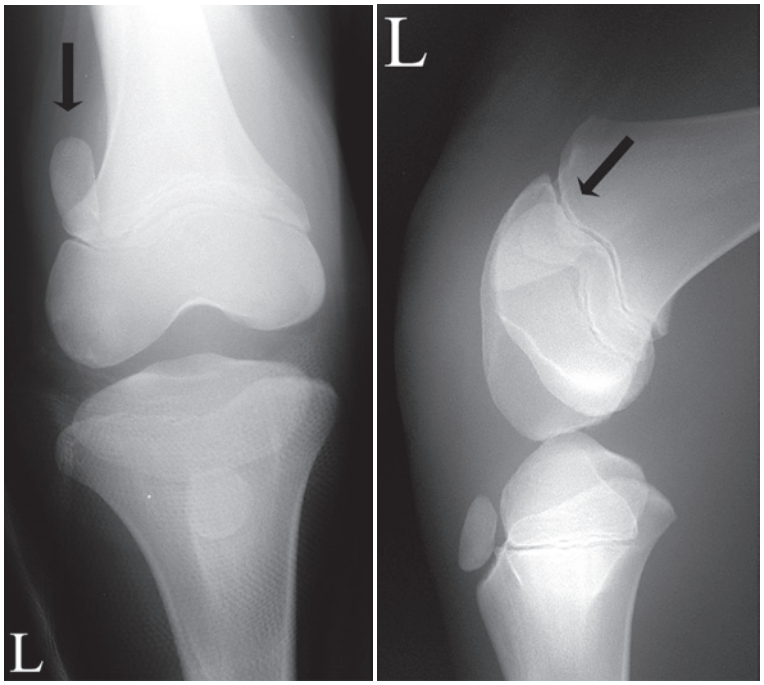


Figure 18-25 Radiograph of a 2-month-old Bison calf with patellar luxation in the left hind limb. *A*, Craniocaudal view; note lateral position of the patella (*arrow*). *B*, Lateral view; the patella (*arrow*) is not seen dorsal to the trochlea groove but overlaps the trochlea because of its lateral position. (Courtesy of Dr. Lisa Fortier.)

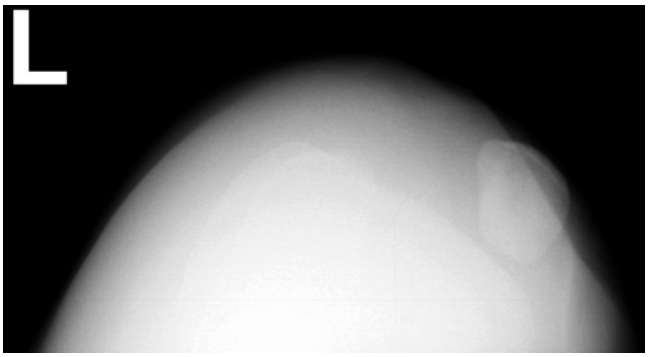


Figure 18-26 Skyline radiographs of a 2-day-old calf with laterally luxated patella. Note the normal-shaped medial trochlea and absence of trochlear groove and lateral trochlea. (Courtesy of Dr. Anthony Pease.)

treatment is not recommended if the muscular function does not improve.

In other cases of patellar luxation, the grading system can serve as a guideline for a treatment plan. Grades I and II are left untreated because most animals can have a normal productive life without treatment other than good footing and avoiding competition for food. Grades III and IV require surgical treatment (Figure 18-27).

The timing of surgery to treat patellar luxation is influenced by several factors. The patella, femoral trochlea, and trochlear groove ossify over the first 3 months of a calf's life. The presence of the patella within the patellar groove appears important to developing a normal depth to the patellar groove. Therefore Grade III luxation should be treated early, so normal femoropatellar joint development occurs. Furthermore, untreated patellar luxation does lead to



Figure 18-27 Skyline radiographs of a 4-year-old female reindeer with traumatic medially luxating patella. Note the normal-shaped medial trochlea and absence of trochlear groove and lateral trochlea.

degenerative osteoarthritis and progression to Grade IV luxation, so early treatment is preferable. However, delaying surgical treatment in a newborn calf for a few weeks may be wise because of the risk of neonatal infection. If femoral fracture or other direct trauma to the stifle joint is the cause of luxation, surgical treatment should be done as early as allowed by soft tissue condition.

Surgical management of a lateral luxation is through lateral release, and medial imbrication is preferable in early Grade III. However, a trochleoplasty should be performed in chronic Grade III where the patellar groove did not form normally and is too shallow. Lateral release, medial imbrication, and recessive trochleoplasty are always required in Grade IV luxation. In addition, tibial crest repositioning to reestablish the line of tension of the quadriceps axial to the femoropatellar joint can also be done in a Grade IV luxation, especially in lesser or lower weight animals. The morbidity of tibial crest transposition (i.e., implant failure and/or nonunion) dictates avoidance of this procedure in heavier animals.

The surgical procedure is done with the calf in lateral recumbency under general anesthesia with the affected limb uppermost. Preoperative use of antibiotics (cephalosporin and penicillin) is recommended. The affected limb is placed in an 80-degree abducted position because access to the medial and lateral aspect of the femoropatellar joint is required. After appropriate draping, an S-shaped incision that starts 5 cm proximal to the patella and extends first medially is made on the cranial aspect of the stifle joint until 5 cm distal to the tibial crest (see Figure 15-48). The incision is extended with scissors through the loosened areolar subcutaneous tissue and superficial fascia until the strong periarticular fascia is encountered. The goal of the procedure is to release lateral traction and reinforce medial soft tissue pull on the patella. The attachment of the gluteobiceps tendon on the lateral aspect of the patella is identified and transected (Figure 18-28*A* and *B*). Immediately underneath the gluteobiceps tendon (which joins with the lateral distal patellar ligament) is the lateral femoropatellar ligament (note: this is *not* the lateral patellar ligament). At this point, the patella should be easy to replace in its normal anatomic position, but it will probably not stay if the joint is flexed.

The medial aspect of the joint is then imbricated as follows. With the limb in full extension, a first row of nonabsorbable suture material (No. 2 or 5 polyester) is placed in an imbricating suture pattern (Lembert pattern) at the midlevel of the medial femoropatellar ligament and extended from the dorsal aspect of the patella distally to the tibial crest (see Figure 15-50). The limb is then placed in the normal unabducted position and flexed through a complete range of motion multiple times to confirm the absence of luxation. The joint should be able to flex almost completely without luxation. If luxation still occurs, a second row of imbricating sutures is placed over the first row. Additional medial imbrication sutures can be placed in a stepwise fashion to maintain the stifle joint's range of motion. Often the lateral joint capsule is opened during transection of the lateral femoropatellar ligament because of its close proximity to the joint capsule. For medial luxation, the same procedure is done except that the medial femoropatellar ligament is released and imbrication is performed laterally (Figure 18-29).

Additionally the patellar groove should be deepened if a very shallow patellar groove is present. The pitfall of these procedures is that the lateral or medial trochlea may fracture if too much bone is resected abaxially. Trochleoplasty may be performed using a recession trochleoplasty (wedge or rectangular) or by curettage of the trochlear groove. The femoropatellar joint capsule is incised between the middle and lateral distal patellar ligaments. The joint is opened from the insertion of the lateral patellar ligament on the patella to the tibial crest between the middle and lateral patellar ligaments. The limb is placed in extension and the patella is luxated medially. For the wedge resection technique, a

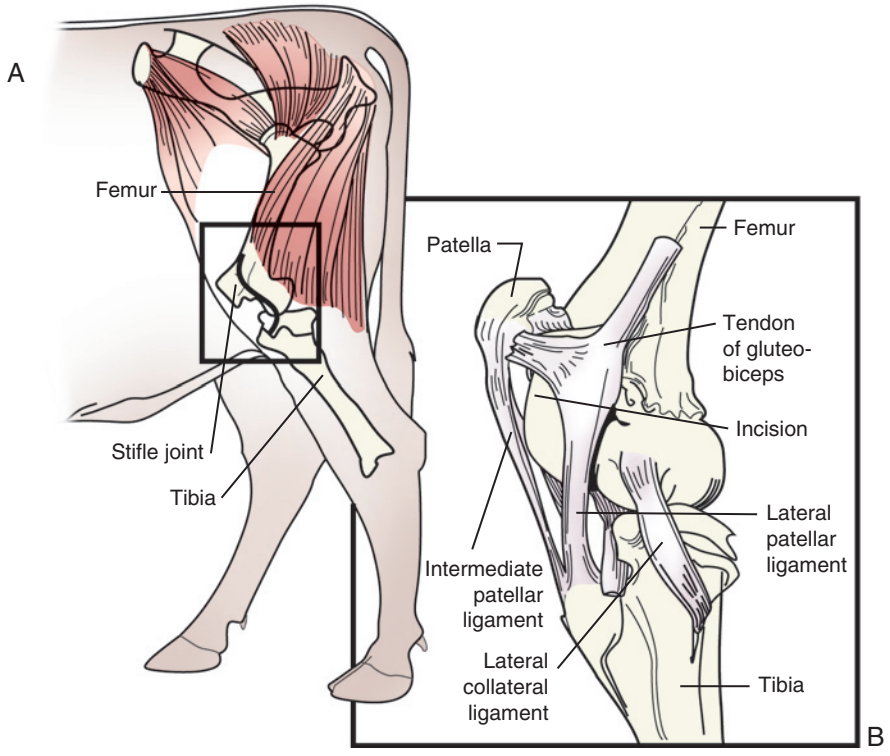


Figure 18-28 Schematic representation of, *A*, lateral release and, *B*, medial imbrication techniques.

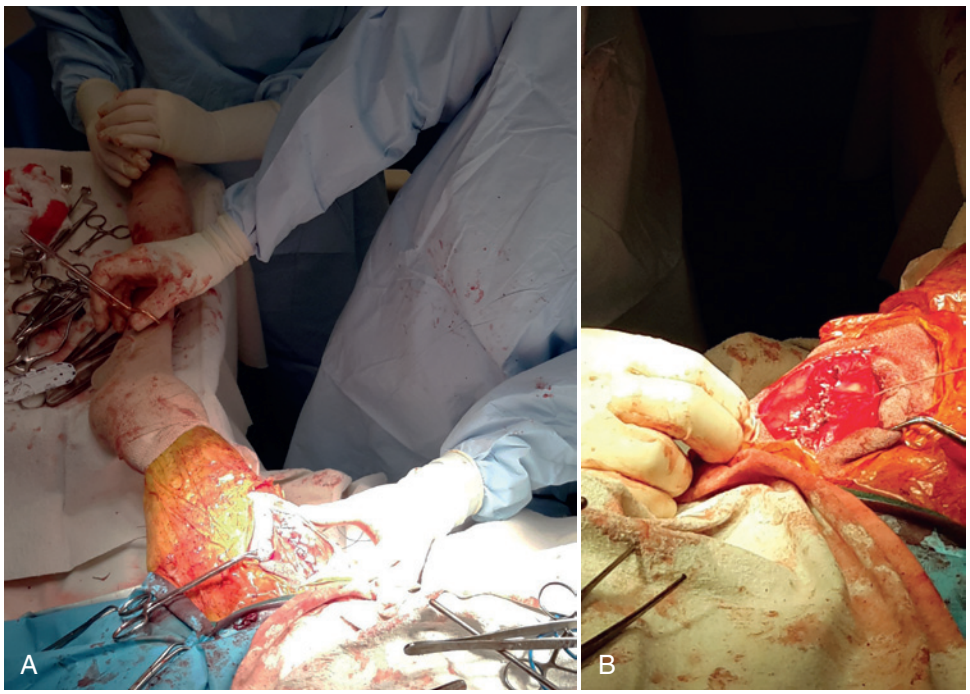


Figure 18-29 Intraoperative views (overview *A*, close-up *B*) of lateral imbrication in the animal in Figure 18-28. (Courtesy of Dr. Fernanda Manzano de Campos.)

reciprocating saw is used. Two angle osteotomies are created in the femoropatellar groove to create a triangular fragment of bone that is excised and placed in a moist sponge. A second set of osteotomies are created 4 to 5 mm parallel and abaxial to the first ones. This creates two bone sections (one lateral and one medial) for removal and disposal. The previously excised triangular bone fragment is replaced into the patellar groove without fixation. The rectangular trochleoplasty is performed by creating two parallel incisions on the abaxial surface of the trochlear groove. One should make sure the wall of the osteotomies is at a 90-degre angle to the floor of the trochlear groove and carefully maintain 75% of the medial and lateral trochlea width to prevent postoperative trochlear fractures. Using an osteotome, the surgeon joins two vertical osteotomies by a 90-degree osteotomy at the floor of the trochlear groove, and the rectangular segment of bone is removed. Using a burr or curette, the surgeon deepens the floor of the trochlear groove, and the previously removed rectangular segment of bone is replaced. The advantage of the rectangular recession trochleoplasty is that the medial and lateral trochlea width is more accurately preserved.

If chondromalacia of the patellar groove is present, preserving its overlying cartilage is no longer needed. In those cases, the trochlear groove is deepened with an air-powered surgical instrument.

Closure

Upon completion of the procedure, the joint capsule and overlying retinaculum are closed with a simple interrupted or cruciate pattern. The subcutaneous fascia is closed with a simple continuous pattern, and the skin is closed in an appropriate pattern. A stent is sutured on the skin to decrease tension on the incision, and an adherent impervious drape is placed over the incision.

Postoperative Care

The stent is kept on for 7 to 10 days if dry. If not, the area is protected from the environment with sponges covered with an adhesive drape or other acceptable bandage. Antibiotics are continued for 5 to 7 days because of the tendency to develop seromas and the possibility of ascending infection associated with incisional leakage. Postoperatively, skin sutures are not removed until 14 days, and the animal is restricted to a box stall for 2 to 3 months.

The prognosis is fair to good in unilateral cases. Bilateral cases are operated on 8 weeks apart and have a less favorable prognosis because of the increased morbidity associated with bilateral procedures. Femoral nerve degeneration associated with patellar luxation carries a grave prognosis unless neural regeneration restores normal quadriceps function.

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MUSCULOSKELETAL SYSTEM: SPASTIC PARESIS (ELSO HEEL)

Norm G. Ducharme and David Freeman

This progressive neuromuscular disease characterized by spastic contractions predominantly of the gastrocnemius muscles (unilateral or bilateral), but other muscles in the hind limbs and even the back may be affected. It was first reported to be a heritable disease in an East Friesian bull (Elso II) and since then has been observed in many breeds and also in goats. The pattern of inheritance is generally thought to be multiple recessive genes with incomplete penetrance. Therefore no affected animals should enter the breeding stock until genomic studies allow identification and possible treatment. The heritability is not known, but one author has reported that 10% of offspring of one bull were affected (Weaver). Other authors estimate the prevalence at less than 1%.

During these spastic contractions, the hock and stifle are hyperextended, and the more affected limb extends caudally (Figure 18-30*A* and *B*). This stance gives the impression the leg is too short, and this disease has also been referred to as *short leg*. If the spasms persist, the hyperextended limb can only be advanced in a swinging motion while walking, because the hock and stifle are extended. The condition can be unilateral or bilateral and is usually first manifested under 6 months of age. Occasionally, no clinical signs are noted until 1 or 2 years of age. It is unknown whether the disease is first manifested at that time or was previously missed. In unilateral disease, the animal keeps the nonaffected hind limb more axial to support its weight. This increased weight on the nonaffected limb eventually results in tarsal varus, giving a bowed leg appearance (Figure 18-31).

Physical examination reveals no pain or site of inflammation except in chronic cases where the persistent hyperextension results in joint inflammation of the hock and stifle. Chronic hyperextension also results in remodeling of the affected joint, and those signs can be identified radiographically. There is no resistance to passive manual flexion of the limb, unlike upward patellar luxation. The diagnosis is made based on the stance and gait of the animal. Although upward fixation of the patella looks similar, it is fairly easy to differentiate because of the jerky movement of the patella during unlocking and the absence of caudal movement of the limb in patellar fixation.

Spastic paresis was first thought to be a neurologic disease, but the absence of central or peripheral nerve, muscle, or tendinous lesions histologically suggests that it is primarily a functional abnormality. Hypersensitivity of the myotactic reflex is the prevalent hypothesis; thus voluntary movements may stimulate the hyperactivity of the efferent innervation of the gastrocnemius muscles. Because of the stay apparatus (i.e., peroneus tertius or fibularis), the stifle



Figure 18-31 Heifers with unilateral spastic paresis in the right hind limbs. The contralateral limb supports the weight of the animals during the spastic episode.



Figure 18-30 Young heifers with spastic paresis. During spastic episode, the limb is extended and directed caudally (*A* and *B*).

also is hyperextended. It has been suggested that the caudal thigh muscles may also be affected.

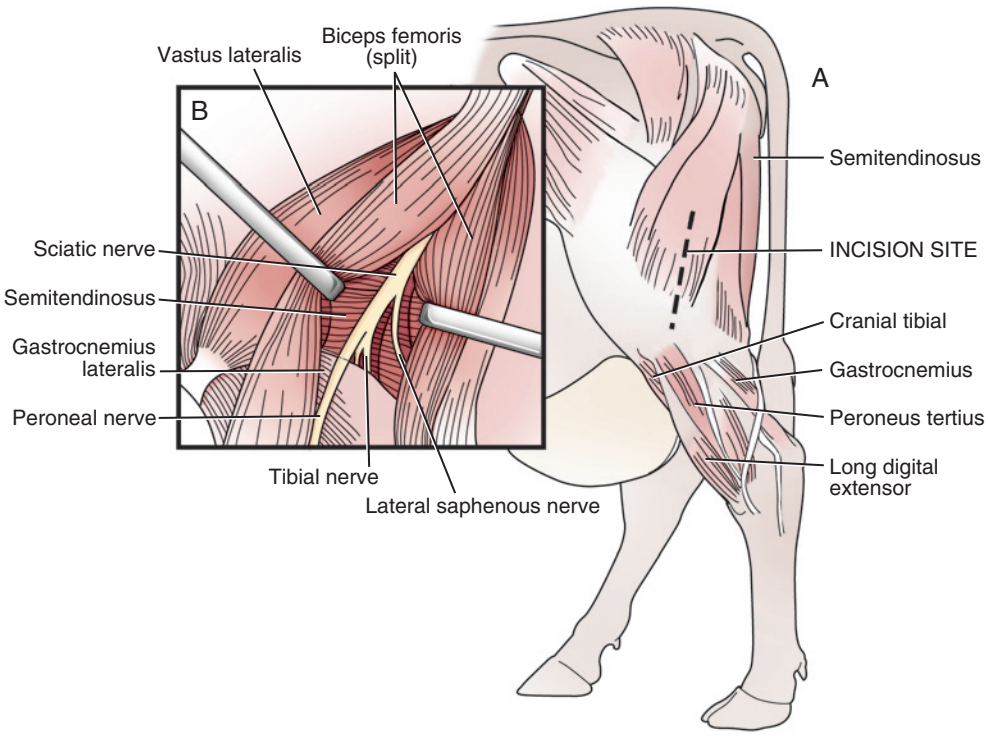
The disease progresses in untreated animals so they become increasingly recumbent, lose body condition, and need to be destroyed between 1 and 2 years of age.

SURGICAL TREATMENT

Treatment is recommended only to allow the animal to grow normally for slaughter purposes or for rescue centers. Affected animals should not be allowed to enter the breeding stock. There are no medical treatments, but two surgical principles have been described: partial tibial neurectomy and transection of the two insertions of the gastrocnemius tendons on the calcaneus.

General anesthesia is preferred for performing the surgical procedures, but sedation with xylazine hydrochloride and local anesthesia administered at the intended surgical site or epidural anesthesia are both also acceptable in young calves (see Chapter 5 for details on anesthesia). The owner should be made aware that in unilateral cases the disease may be manifested in the contralateral limb at a later date and require further treatment.

For *partial* tibial neurectomy, the calf is placed with the affected limb uppermost, and the caudal aspect of the stifle is prepared for aseptic surgery. The surgical incision is determined from a line drawn from the caudal aspect of the greater trochanter to the tibial crest with the stifle flexed (Figure 18-32*A*). Along this line, a 15- to 20-cm incision is made centered over the caudal aspect of the gastrocnemius muscle midway between the greater trochanter and the tibial crest at the level and immediately caudal to the femoral condyles. This incision on the caudal aspect of the stifle allows exposure of the gluteobiceps muscle. An incision is then made along the fibers of the gluteobiceps muscle along a depression that seems to separate the cranial from the caudal portions of this muscle (Figure 18-32*B*). The incision



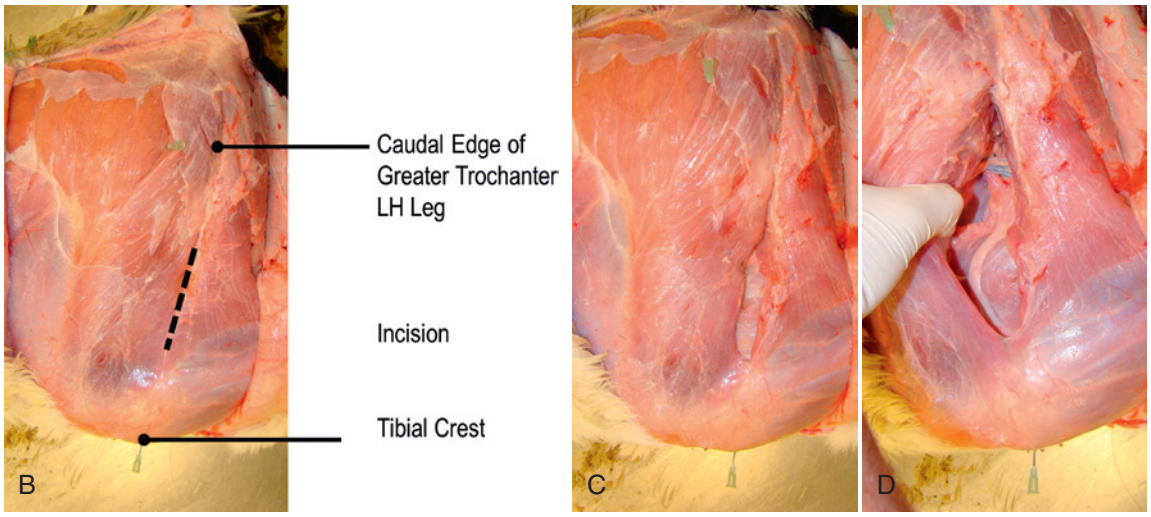


Figure 18-32 Schematic representation of a partial tibial neurectomy. *A*, The incision is made over the junction of the semimembranous and biceps femoris muscles at the caudal aspect of the stifle. *B*, The tibial nerve arises from a point idway between the most caudal aspect of the greater trochanter and the tibial crest and on a line between these two structures. In the figures, needles are inserted to define the greater trochanter and the tibial crest. C, After splitting the biceps femoris muscles, the tibial and peroneal nerves are identified. *D*, Retracting the biceps femoris muscles. LH, left hind.

is extended through by splitting the gluteobiceps muscle along the long axis of the fibers (Figure 18-32C). The branches of the tibial nerve that innervate the gastrocnemius muscles are identified after retracting the biceps femoris muscles (Figure 18-32*D*). Identifying the correct branches to transect is crucial. First, the peroneal nerve is identified as it courses over the lateral head of the gastrocnemius muscle; this nerve must be preserved. The branches of the tibial nerves to the lateral and medial belly of the gastrocnemius muscles are identified for careful dissection and their function verified using a nerve locator (1 mA, 1-3 Hz, pulse duration less than 1 second). The belly of each gastrocnemius muscle is stimulated separately and observed to detect whether it contracts and causes hock extension during stimulation. The nerve branches to medial and lateral gastrocnemius muscles are transected and a 2-cm section is removed. The transected nerves are ligated proximally with a nonabsorbable suture material to prevent axonal regeneration. The muscles and subcutaneous tissue are reapposed by using an appropriate-sized absorbable suture in a continuous pattern. Skin closure is routine. If general anesthesia or epidural anesthesia was used, the limb should be hobbled during recovery to prevent slipping and gastrocnemius rupture. Postoperative activity is restricted until suture removal at 14 days.

Reportedly, the problem is improved or completely resolves in nearly 80% of the animals. A slight chance of recurrence remains, presumably because some branches were missed or reinnervation occurred. Complications after the procedure are rare but include dropped hock and ruptured gastrocnemius tendon.

A tenotomy/tenectomy procedure's advantage is a simpler, less invasive technique with less chance of recurrence. The procedure can be performed with the animal standing under local anesthetic but is preferably done with the animal lying down under sedation or general anesthesia. If the animal is recumbent, the affected limb should be uppermost. The lateral aspect of the distal tibia over the Achilles tendon is prepared for aseptic surgery. A 7-cm skin incision is made over the craniolateral aspect of the Achilles tendon, a hand's width proximal to the point of the calcaneus (Figure 18-33*A*). The incision is extended through subcutaneous tissue until the Achilles tendon is reached. The superficial digital flexor tendon and superficial tendon of the medial head of the gastrocnemius muscle cross at the proximal level of the incision (Figure 18-33*B*). The superficial flexor tendon is identified (the gastrocnemius tendon attaches on the tuber calcaneus whereas the superficial flexor tendon continues past the tuber calcaneus toward the digit) and preserved. The fascia surrounding the Achilles tendon is incised longitudinally, and the superficial and deep tendon of the gastrocnemius muscle are elevated separately and transected to remove a 2- to 3-cm section of tendon (identifying and separating the tendon is easier with the leg in extension.) The tendinous sheet around the tenectomy site must also be transected and resected while the surgeon takes care to preserve the superficial digital flexor tendon and relevant vessels (tibial nerve and lateral saphenous vein). The subcutaneous tissues are reapposed by using an appropriate-sized absorbable suture in a continuous pattern. Skin closure is routine. Postoperative activity is restricted until suture removal at 14 days.

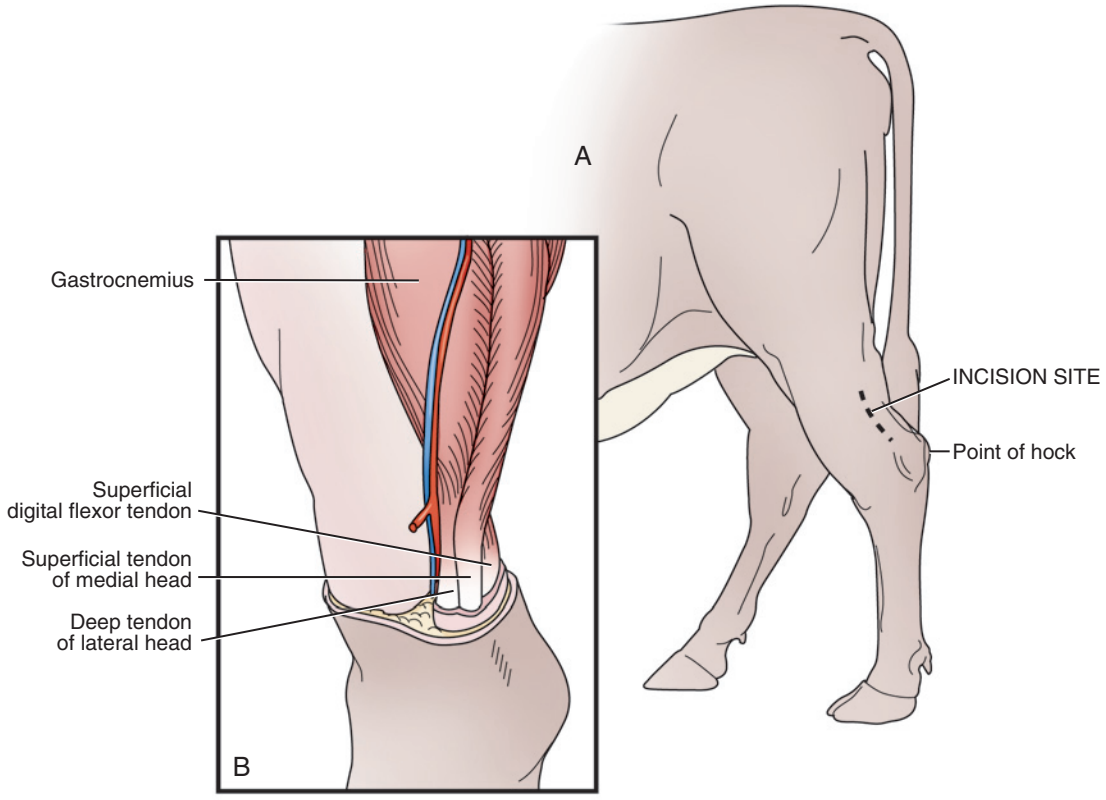


Figure 18-33 Schematic representation of a partial tenectomy of the gastrocnemius muscle. *A*, The incision is made above the hock over the cranial and lateral aspect of the Achilles tendon. *B*, The superficial digital flexor tendon is identified and avoided. The deep and superficial tendons of the gastrocnemius are identified and a section removed.

Complications associated with this procedure are rupture of the gastrocnemius muscle during recovery. Therefore a bilateral procedure should not be performed, but the procedure can be performed on the contralateral limb after 6 weeks. If gastrocnemius muscle rupture occurs, the hock must be immobilized in a cast for at least 6 weeks to allow sufficient fibrosis for repair (see Gastrocnemius Rupture in Chapter 15).

The tendon transection procedure is also highly successful and can be done more rapidly without the need for electrostimulation.

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CHAPTER 19

Miscellaneous Abnormalities of the Calf

Kyla Ortved
(The editors wish to acknowledge and thank prior author Dr. Gary M. Baxter)

UMBILICUS

The umbilicus in calves consists of the urachus, umbilical vein, and paired umbilical arteries (Figure 19-1). These latter structures are often referred to as the *umbilical remnants*. The urachus, umbilical vein, and umbilical arteries normally regress after birth to become a vestigial part of the bladder apex, round ligament of the liver, and lateral ligaments of the bladder, respectively. Infection (subcutaneous abscess or disease within the umbilical remnants), herniation (nonstrangulating or strangulating), or a combination of infection and herniation are the primary problems associated with the umbilicus in calves. Each of these problems usually causes enlargement of the umbilicus; therefore an umbilical mass is not always synonymous with an umbilical hernia. Infection of the umbilicus or umbilical cord remnants often occurs in the neonatal period as a result of environmental contamination, but the umbilicus may also be seeded with bacteria from a generalized septicemia/bacteremia. Common bacterial isolates from umbilical infections in calves include *Trueperella pyogenes* and *Escherichia coli*. Umbilical hernias are the most common bovine congenital defect, with a reported incidence between 0.65% and 1.04% (Hayes, 1974). They can occur in any breed, although they appear to be most common in Holstein-Friesian cattle. They are often classified as uncomplicated versus complicated, depending on whether a secondary infection exists.

UMBILICAL HERNIAS/MASSES

Umbilical masses in calves may be divided into five categories:

1. Uncomplicated umbilical hernias
2. Umbilical hernias with subcutaneous infection/abscesses
3. Umbilical hernias with umbilical remnant infections
4. Umbilical abscesses/chronic omphalitis
5. Urachal cysts/ruptures

Calves with an umbilical abscess or enlarged umbilical stalk may not have concurrent umbilical hernias but may have clinical signs similar to calves with hernias because of the enlarged umbilicus. However, a combination of the history, signalment, and physical examination of the animal is usually sufficient to accurately diagnose the problem and differentiate between calves with and without hernias. Visual inspection of the mass should be performed to evaluate the size, shape, color, and presence of drainage. Palpation of the mass for consistency, temperature, and presence of pain should be performed. The presence of a complete or incomplete hernial ring and reducibility of the contents within the mass should also be determined. Placing the calf in lateral or dorsal recumbency may facilitate deep palpation of the mass (Figure 19-2). Additionally, ultrasound may be performed to evaluate the umbilicus, which is especially beneficial in documenting abnormalities in the umbilical remnants (Figure 19-3). There is usually a good correlation between ultrasonographic and surgical findings of infected umbilical remnants in calves.

Uncomplicated Umbilical Hernias

Uncomplicated umbilical hernias are considered hereditary in cattle and most commonly occur in the Holstein-Friesian breed. Beef cattle appear to be at lower risk of developing umbilical hernias than dairy cattle. These hernias are usually present during the first few days of life and typically enlarge uniformly as the calf grows. The umbilical mass is completely reducible with a palpable circumferential hernial ring. The hernial sac may contain intestines (enterocele), abomasum (most commonly) and omentum, or all three (Figure 19-4). Calves with these hernias are usually in good condition and rarely show signs of gastrointestinal dysfunction.

Strangulation of the small intestine, omentum, or abomasum within the hernial sac is possible, although rare (Figure 19-5*A* and *B*). Affected calves usually demonstrate signs of abdominal pain and have metabolic derangements (hypochloremic, hypokalemic metabolic alkalosis) caused by sequestration of chloride and hydrogen ions within the abomasal lumen. Chronic hernias may also develop an abomasal-umbilical fistula in which chloride is lost from the abomasal lumen, resulting in dehydration and metabolic abnormalities (Figure 19-6*A* and *B*). Depressed, sick calves with metabolic abnormalities should be stabilized with fluids to correct the metabolic problem before surgery is performed.

Most calves presented for repair of umbilical hernias are less than 6 months old and have hernias less than 10 cm in length. Conservative treatment options for uncomplicated hernias include hernial clamps, elastrator bands, abdominal support bandages, local injection of irritants around the hernial ring, and daily digital palpation to irritate the ring. Hernial clamps, elastrator bands, and support bandages are only recommended when the hernia is less than 5 cm long, completely reducible, and free from evidence or history of infection. Support bandages are more effective in calves than foals because the bovine umbilicus is more cranial and the abdomen more pendulous, preventing caudal slippage of the bandage. Most umbilical hernias longer than 5 cm or demonstrating any evidence of pathology should be repaired surgically with an open herniorrhaphy.

Umbilical Hernias with Localized Abscesses/Subcutaneous Infection

Calves have a higher prevalence of infection associated with umbilical hernias than do foals. This difference may be related to improper care of the umbilicus, increased environmental contamination, and partial or complete failure of passive transfer. Unlike foals, calves with umbilical infections do not usually develop septicemia or a patent urachus. Instead the infection remains localized to the umbilical

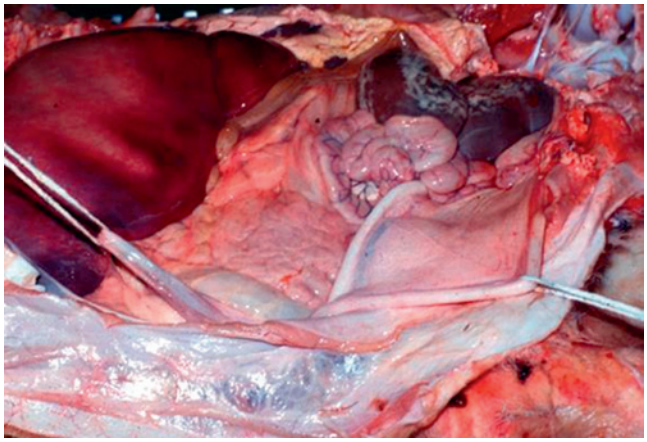


Figure 19-1 A fetus at postmortem showing the umbilical remnants going toward the liver (umbilical vein) and urinary bladder (umbilical arteries).



Figure 19-2 Palpation of the umbilicus with a calf in lateral recumbency can help discern the nature of the umbilical problem.

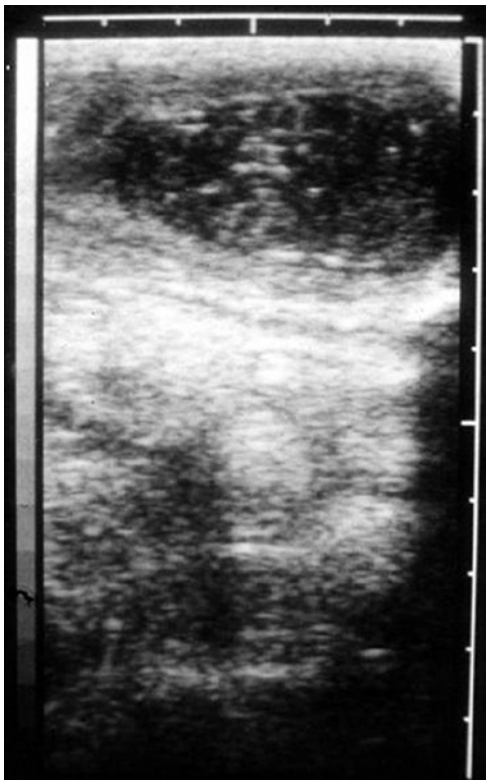


Figure 19-3 Ultrasound of the umbilicus in a 5-month-old Holstein heifer calf with a large umbilical abscess.

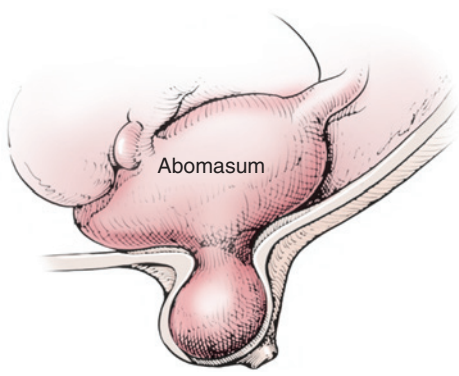


Figure 19-4 Schematic diagram of the abomasum protruding into an umbilical hernia.

area. In one study 45% of calves presented for repair of umbilical hernias had evidence of concurrent infection, such as umbilical remnant infections, omphalitis, and subcutaneous abscesses and cellulitis. Calves with an umbilical hernia associated with subcutaneous infection usually have a history of an enlarged umbilical cord since birth, but the umbilical mass is not present until the calf is several weeks old. The calves are generally in good condition, and careful palpation of the mass reveals a reducible dorsal hernia and a firm, nonreducible ventral portion attached to the skin (Figure 19-7). Although there may be local evidence of inflammation, drainage is usually absent, and the hernial ring is palpable. Many of these hernias may be acquired secondary to infection-induced weakening of the body wall.

Surgical removal of the abscess or area of cellulitis or fibrosis, together with repair of the hernia, is the treatment of choice. An open herniorrhaphy is recommended because the subcutaneous abscess may extend into one of the remnants of the umbilical cord, necessitating more extensive excision (Figure 19-8*A*-C). In addition, adhesions that involve the greater omentum or abomasum may be present and require resection. An open herniorrhaphy also facilitates closure of the abdomen by eliminating redundant soft tissue (the hernial sac) in the suture line and the need to invert the umbilical remnants.

Umbilical Hernias with Infection of the Umbilical Cord Remnants

Umbilical cord remnant infections include omphalophlebitis, omphaloarteritis, and infection/abscessation of the urachus. More than one umbilical cord remnant may be infected, and not all animals have a concurrent umbilical hernia. *T. pyogenes* is the most commonly isolated organism from infected umbilical cord remnants, but *E. coli*, *Proteus*, *Enterococcus*, *Streptococcus*, and *Staphylococcus* species may also be identified. Consequently, draining tracts should be cultured



Figure 19-5 *A*, Nonreducible umbilical hernia in a 3-month-old calf. *B*, Small intestine that was trapped in the nonreducible hernia. A resection and anastomosis were performed.



Figure 19-6 *A*, A 1-month-old calf with an abomasal fistula. The calf had a hypochloremic metabolic alkalosis. A belly bandage was applied and surgery was done the following day. *B*, The calf at surgery. The pyloric part of the abomasum is evident.

before surgery or the infected umbilical remnant or abscess cultured after excision.

The usual history in calves with umbilical hernias and remnant infections is intermittent purulent drainage from the umbilicus beginning at 1 to 2 weeks of age. The drainage is often followed by a rapidly enlarging mass several weeks later. These calves are often unthrifty and small for their ages and may have concurrent infectious diseases, such as septic arthritis, pneumonia, peritonitis, or bacteremia. A complete blood count may indicate hyperfibrinogenemia, hyperproteinemia, neutrophil-lymphocyte reversal, and mild anemia. The umbilical mass is usually large, broad-based, painful to palpation, and only partly reducible, and the hernial ring is incompletely palpable. In small calves, deep palpation of the abdomen with the animal in lateral or dorsal recumbency may reveal an enlarged, infected umbilical remnant. An infected enlarged umbilical vein courses dorsocranially toward the liver, and the infected urachus or umbilical arteries course caudodorsally toward the urinary bladder and internal iliac arteries, respectively. However, ultrasound of the ventral abdomen is the ideal method to document an abnormality in the umbilical remnants. In one study there was good to excellent correlation between ultrasound findings and actual physical (surgical or postmortem) findings of the umbilical structures. However, ultrasound was unreliable in documenting concurrent intraabdominal adhesions associated with these infections, which were present in 47% of the animals in the study. In foals there are reports of using laparoscopy to evaluate and, in some instances, ligate and/or resect umbilical cord remnants.

Umbilical hernias in calves complicated by infections of umbilical cord remnants have been reported to occur in approximately 24% of cases. This figure was calculated from animals presented for surgical repair on umbilical hernias and does not include calves that were successfully treated with conservative measures in the field. Therefore this percentage may reflect an overestimation of the true prevalence of infections of umbilical cord remnants among all calves with umbilical masses. However, umbilical remnant



Figure 19-7 A 3-month-old calf with an umbilical hernia and a draining tract with a fibrous cord ascending toward the urinary bladder.

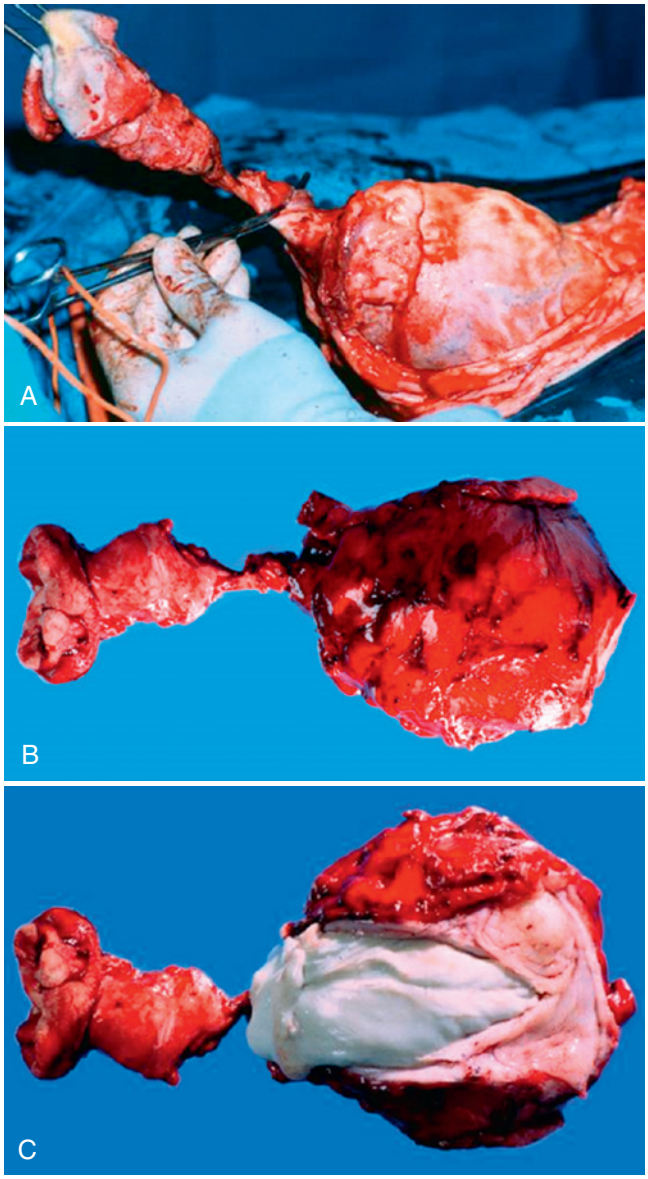


Figure 19-8 *A*, Removal of a draining tract at the umbilicus that leads to a large omental abscess. *B*, The abscess removed. *C*, The abscess opened.

infection should be suspected in calves with large umbilical masses, especially if the animal is unthrifty.

The urachus is the most frequently infected umbilical remnant associated with umbilical masses in calves (Figure 19-9). Dysuria, pollakiuria, pyuria, and cystitis are all potential sequelae to urachal abscesses/infections in calves. These clinical signs may occur because of direct communication between the abscess and bladder lumen or by mechanical interference with normal bladder filling and emptying. For all surgery that involves umbilical remnant infections, the surgeon should be prepared to extend the incision and drape the site accordingly.

In some of the urachal infections that extend to the bladder, the urachal stalk and lumen of the bladder are distinctly separated. Surgical excision of the infected urachus combined with repair of the hernia is the treatment of choice. Urachal infections that extend to the bladder require excision of the apex of the bladder and ligation of the umbilical arteries (Figure 19-10). The entire urachus, umbilical

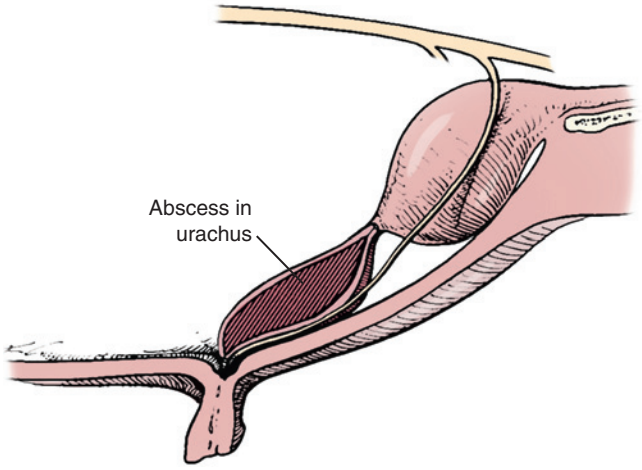


Figure 19-9 Schematic illustration of an infection within the urachal remnant. The urachus is the most commonly infected umbilical remnant.

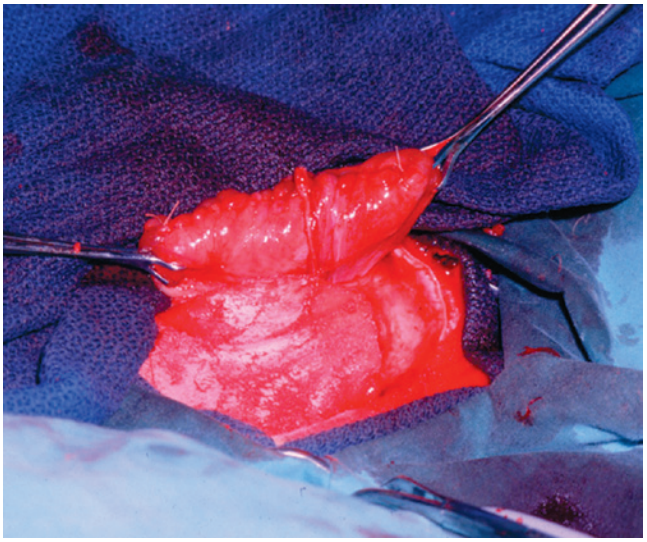


Figure 19-10 The urinary bladder oversewn following removal of a draining tract that involved the urachus, umbilical artery remnants, and apex of the urinary bladder.

arteries, hernial tissue, and overlying skin are removed en bloc to prevent contamination of the abdomen.

Omphalophlebitis may be localized along the umbilical vein or may extend the entire length of the vein and involve the liver. Infection that progresses to the liver can result in multiple liver abscesses, septicemia, bacteremia, and unthriftiness. Localized umbilical vein abscesses that do not involve the liver can usually be surgically ligated and removed en bloc (Figure 19-11). This is ideal and preferable if the infection is localized. Umbilical vein abscesses that extend to and involve the liver are handled by a marsupialization technique. The abscess is exited from the abdomen through a separate incision in the right-paramedian area or through the cranial aspect of the ventral median incision (Figure 19-12*A* and *B*). With either technique, the wall of the infected umbilical vein must be secured to the ventral body wall in a two- or three-layer closure to prevent leakage and peritonitis. The advantages of incorporating the vein within the existing ventral incision are that only one abdominal incision is required and the infected umbilical vein does not need to be passed intraabdominally to a paramedian position, whereas the disadvantage is the entire incision could become contaminated. After surgery, the marsupialized tract is irrigated with dilute povidone-iodine until closure by second intention. However, the tracts should not be lavaged under pressure, especially in calves younger than 2 months of age, because the lavage solution may enter the systemic circulation through the liver and cause serious adverse reactions. Both marsupialization techniques have been reported to be very successful at resolving umbilical vein infections in calves. In addition, the umbilical vein stalk may be subsequently removed en bloc at a second surgery once the infection has completely resolved. The authors have tried to avoid marsupialization in more recent cases by resecting as much of the infected tract and treating the animal with antibiotics for a longer period of time.

Omphaloarteritis is the least common infection of an umbilical cord remnant. Normally, the umbilical arteries retract into the abdomen at birth, thus minimizing the risk of infection. One or both arteries may be infected anywhere along their course. Intestinal strangulation is reported to be an uncommon sequela of omphaloarteritis. Surgical ligation and resection of the involved arteries, umbilical mass (and, at times, resection of the apex of the urinary bladder), and overlying skin during repair of the umbilical hernia is the treatment of choice. The omentum may be adhered to the arteries, requiring careful dissection and ligation.

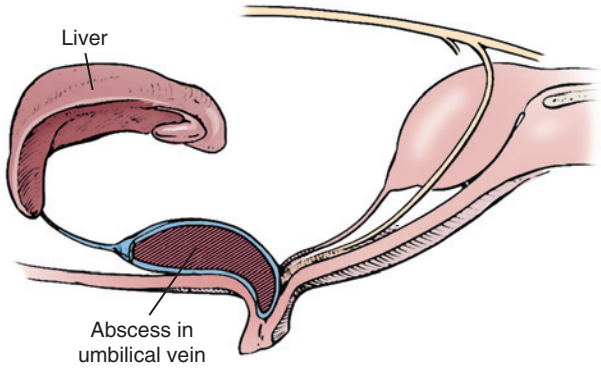


Figure 19-11 Schematic illustration of a localized infection within the umbilical vein. This abscess could be completely resected at surgery.

Umbilical Abscesses/Chronic Omphalitis

Umbilical abscesses are common sequelae to circumscribed omphalitis. The umbilical mass often occurs shortly after birth but may develop any time between birth and 2 years of age. Similar to calves with infections of umbilical remnants, these calves are often unthrifty and may have evidence of infectious diseases in organs remote from the umbilicus. The umbilical mass is usually warm, painful to palpation, nonreducible, and firm or fluctuant. No hernial ring is palpable and drainage is uncommon (Figure 19-13*A*). Diagnosis of an umbilical abscess is based on physical examination, characteristics of the umbilical mass, and aspiration of purulent material from the mass. Ultrasound may also be used to document the presence of purulent material within the umbilicus. Most umbilical abscesses will respond to drainage and lavage of the abscess cavity (Figure 19-13*B*-*D*). Systemic antimicrobials may or may not be indicated. Chronic infection of the umbilicus may lead to a thickened, fibrotic umbilical stalk that may appear similar to an abscess. The need for surgery depends on how well the infection responds to medical treatment and the cosmetic appearance required. If the abscess recurs, the possibility of the infection extending into the umbilical cord remnants must be considered, and



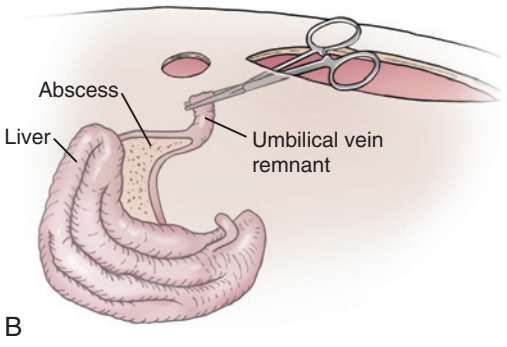


Figure 19-12 *A*, Marsupialization of a large, infected umbilical tract ascending to the liver and arborizing into the parenchyma. *B*, A schematic diagram of the marsupialization technique.



Figure 19-13 *A*, Large umbilical abscess that was nonreducible, warm, and painful. *B-D*, Draining the umbilical abscess after aspiration and confirming the presence of purulent material.

surgical removal is indicated. However, initial drainage of purulent material is essential.

An open herniorrhaphy with complete removal of the abscess is recommended. A fusiform incision is made around the border of the abscess, and the subcutaneous tissue is sharply dissected to expose the linea alba. The abscess cavity should not be entered. A small incision is made into the abdomen either cranial or caudal to the base of the abscess to permit digital palpation of the umbilical cord remnants. If the infection extends intraabdominally, the abdomen is opened further, and the involved umbilical remnants are removed along with the abscess. If the abscess is localized, the capsule and all adherent tissue are extirpated. The incision is closed as described for a routine herniorrhaphy.

Urachal Cysts/Ruptures

Several anatomic abnormalities of the urachus may occur in all species and have been reported in cattle. Urachal cysts have been found in calves with umbilical masses/hernias and should be included as a differential diagnosis in calves with nonreducible umbilical masses. Urachal cysts can be imaged with ultrasound and the diagnosis confirmed at surgery. In one calf, the urachal cysts ruptured into the subcutaneous tissues around the umbilicus subsequent to attempts to reduce the umbilical swelling. The subcutaneous urine caused severe tissue inflammation around the umbilicus with necrosis of a small area of skin. Rupture of the urachus into the subcutaneous space occurs in foals but is usually not associated with a urachal cyst. It is thought to be a result of traumatic foaling, with evidence of umbilical swelling and subcutaneous urine accumulation very soon after birth. The other main urachal anatomic defect is failure to involute or disappear after birth. The typical noninfected patent or persistent urachus with dribbling of urine seen in neonatal foals is very uncommon in neonatal calves. A persistent urachus consisting of a thin band of tissue has been reported to cause small-intestinal strangulation in an adult cow. Additionally, rupture of a persistent urachus that communicated with the lumen of the bladder resulted in uroperitoneum in a yearling bull. Similar anatomic or congenital abnormalities of the umbilical vein and arteries in calves have not been reported.

DIAGNOSIS

A tentative diagnosis of the cause of an umbilical mass in most calves can be determined from physical examination of the animal and close inspection of the umbilical region. Calves placed in lateral recumbency relax their abdomen, which permits deep palpation of intraabdominal structures. However, ultrasonography of the umbilicus is recommended in most cases to document the diagnosis and determine the site(s) and severity of the infection preoperatively in cases of concurrent infection. Enlargement of the internal umbilical structures and the presence of echogenic material (fluid and/or gas) usually confirms the diagnosis of infection within the umbilical remnants. However, normal ultrasonographic findings do not always indicate the absence of infection, and ultrasound cannot be relied on to always accurately assess the presence of intraabdominal adhesions.

SURGICAL MANAGEMENT

The appropriate management of patients with umbilical masses/hernias depends on accurate preoperative diagnosis. As previously stated, small, uncomplicated umbilical hernias and many umbilical abscesses may not require surgery. Uncomplicated umbilical hernias requiring surgery can often be repaired with the calf in dorsal recumbency using sedation (xylazine hydrochloride) and a local anesthetic. If infection or some other problem associated with the umbilical mass is identified or likely, surgery should be performed with the animal under general anesthesia because of the increased surgery time and potential for complications. Inhalation general anesthesia is preferred, but intravenous combinations such as xylazine hydrochloride-ketamine hydrochloride, valium-ketamine hydrochloride, or xylazine hydrochloride-ketamine hydrochloride-guaifenesin may be used to help reduce expense.

Proper preoperative management of abscesses, omphalitis, and infections of umbilical cord remnants may decrease the potential for contamination and the duration of surgery. Large abscesses should be drained or aspirated and treated medically with antimicrobials for several days before surgery to decrease their size and minimize the number of bacteria. Draining tracts should be lavaged and given time to heal before surgery, if possible. Otherwise, they should be oversewn at the beginning of surgery to minimize contamination. Infected umbilical remnants and abscesses should be resected en bloc if possible to prevent contamination of the abdomen and incision. If infection is confirmed or possible, antimicrobials should be given before surgery and continued after surgery if needed. Antimicrobials should be based on the results of a culture and sensitivity, but procaine penicillin and/or ceftiofur are effective against most bacteria associated with umbilical infections in calves.

Small, uncomplicated hernias in calves can be repaired with a closed herniorrhaphy (peritoneum is not opened) similar to that performed in foals. However, compared with a closed herniorrhaphy, an open herniorrhaphy often takes less time, is less traumatic, allows inspection of the abdominal viscera, and permits removal of the umbilical remnants if considered necessary. Before surgery, the external opening of the umbilicus and prepuce are oversewn to prevent contamination of the surgery site. A fusiform incision is made around the umbilicus using a scalpel. A combination of blunt and sharp dissection with or without electrocautery to control bleeding is used to expose the hernial ring. The abdomen is entered cranial or lateral to the umbilical stalk to permit digital palpation of intraabdominal structures. The scarred edge of the hernial ring is sharply incised together with the peritoneum. In cases with umbilical remnant infections, the umbilical vein and arteries are ligated above the site(s) of infection, and the urachus is excised along with the apex of the bladder. The bladder is closed routinely. Complete removal of the infected umbilical remnants in situ can usually be performed except with severe infections of the umbilical vein. Simple apposition of the unscarred hernial ring with minimal tension is thought to lead to ideal healing. Several suture patterns may be used, but simple interrupted, interrupted cruciate, or simple continuous patterns are used most commonly. In most cases absorbable suture material such as polyglactin 910, polydioxanone, or polyglycolic acid is recommended to close the body wall. In larger defects, tension-relieving sutures such as near-far-far-near placed at regular intervals may help appose the two sides. In an older animal, withholding solid food for 36 to 48 hours reduces the rumen volume and greatly facilitates body wall closure.

Large hernias (greater than 15 cm) and hernias unsuccessfully repaired previously are often candidates for mesh herniorrhaphy (Figure 19-14). Polypropylene (Marlex) or plastic (Proxplast) mesh products are the most commonly used, although plastic mesh is less expensive than polypropylene. In addition, plastic mesh is less elastic and decreases the amount of sagging seen after surgery. A fascial overlay technique is recommended for placing the mesh (McIlwraith and Robertson, 1998). Briefly, a semielliptical incision is made along one side of the hernial ring. The skin, subcutaneous tissue, and fibrous hernial sac are reflected across the hernial defect to expose the opposite hernial ring. Usually the peritoneum is adhered to the hernial sac and is incised. A double layer of mesh is placed either retroperitoneal or between the incised edges of the hernial ring (Figure 19-15). The mesh is secured circumferentially around the hernial ring with interrupted horizontal mattress sutures, making certain the mesh is taut. The reflected hernial fascia, subcutaneous tissue, and skin are placed over the mesh and closed routinely. Antimicrobial therapy should be used for mesh herniorrhaphies because of the increased risk of infection associated with mesh implantation.



Figure 19-14 The umbilical hernia in this Holstein calf had been repaired two previous times without success. The hernia was large, and a mesh implant was used to close the defect.

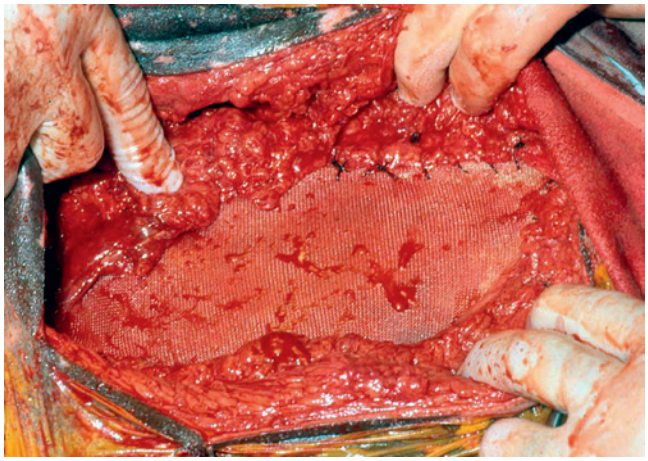


Figure 19-15 Placement of the mesh within the hernial defect in the calf in Figure 19-14. The plastic mesh was doubled, placed retroperitoneal, and secured to the hernial ring with nonabsorbable suture material. A fascial overlay technique was used for the mesh herniorrhaphy in this calf.

COMPLICATIONS

Postoperative complications of umbilical herniorrhaphy are more numerous in calves than in foals, probably because concurrent infection is more common in calves with umbilical hernias. Most complications are related to incisional problems such as suture abscesses, seromas, hematomas, and dehiscence. The majority of these problems usually do not affect the success of the surgery unless the local infection is severe enough to cause failure of the body wall closure and recurrence of the hernia. The more ventral location of the suture line and the greater weight distributed across it in calves compared with foals may lead to a higher risk of incisional dehiscence in calves. Abdominal support bandages may help prevent reherniation if the abdominal wall appears weak at surgery; however, good surgical technique and limited postoperative activity are the most important factors in preventing body wall dehiscence. Peritonitis is a more serious potential complication and is usually associated with severe contamination of the abdomen during surgery or with foci of intraabdominal infection that were incompletely removed at surgery. This complication is most likely in calves with umbilical vein infections involving the liver. Although these postoperative problems are possible, most calves do very well after umbilical herniorrhaphy with a favorable prognosis for a productive life.

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OTITIS MEDIA/INTERNA: CALVES

Thomas J. Divers and Norm G. Ducharme

(The editors would like to express their thanks to Dr. Brett Woodie, co-author of the previous edition.)

Otitis media interna (M/I) is a very common disorder of young dairy replacement calves and veal calves. The majority of cases seen are in calves 3 to 8 weeks of age. It can be a farm problem and may commonly occur concurrently with respiratory disease and occasionally with septic arthritis. *Mycoplasma* bovis is the organism most often implicated in the disease process, and the disorder is particularly common in veal calf operations and in dairy herds with *Mycoplasma* bovis positive bulk milk cultures.

Anatomical and Pathophysiological Considerations

The middle ear is comprised of the tympanic cavity and auditory tubes lined by mucous membrane. The tympanic cavity, located between the tympanic membrane and internal ear, consists of three parts: the atrium, the epitympanic recess (which contains most of the auditory ossicles), and the large tympanic bulla (Figure 19-16*A* and *B*). The function of the middle ear is to transmit sound waves that reach the tympanic membrane through the auditory ossicles to the internal ear. The internal ear consists of two cavities (membranous and osseous labyrinth) in the petrous part of the temporal bone that encloses a complex membranous membrane containing the auditory cells and distal ramification of the auditory nerve. The osseous labyrinth, immediately medial to the tympanic cavity, has three parts: the cochlea, vestibule, and semicircular canals. The membranous labyrinth lies within the osseous labyrinth; it contains supporting cells and hair cells. The distal extremities of the cochlear nerves are located at the base of the hair cells.

Dissemination of M. bovis to the middle ear is thought to mostly occur from the colonization of the oropharynx and extension into the tympanic bulla through the eustachian (auditory) tube. Chronic suppurative otitis media results from the bacterial infection. This causes inflammation, ulceration, and production of granulation tissue within the middle ear. This cycle of inflammation leads to destruction of the bony margins of the middle ear and damage to

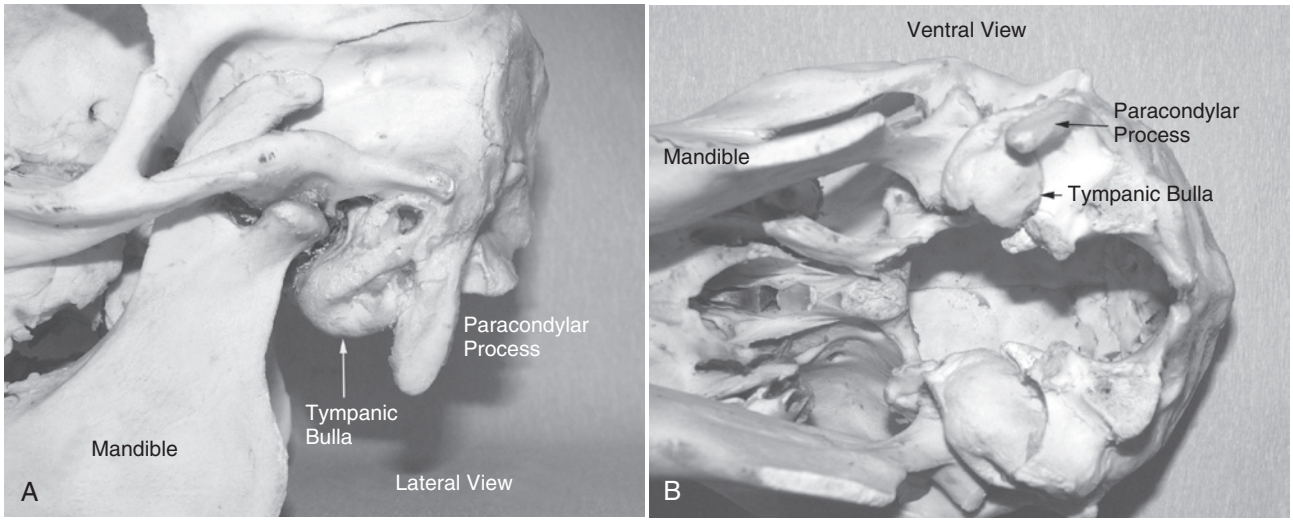


Figure 19-16 Anatomical specimen that shows position and relationship of tympanic bullae in calves. *A*, Lateral view; *B*, Ventral view.

vestibular and facial nerves within the inner ear (Figure 19-17*A*-*C*).

Clinical Signs

Facial nerve paresis and/or vestibular signs are the clinical signs of otitis M/I. The signs may be unilateral or bilateral. Facial paresis can be easily missed in the affected calf because, unlike in other species, no deviation of the muzzle is associated with facial paresis in the bovine. Instead, ear droop, diminished eyelid tone, epiphora, and "packing" feed in the cheek area are typical signs of facial paresis in the calf. Fortunately, exposure keratitis is not common. Otitis interna is a common sequela to otitis media in calves, and affected animals exhibit varying signs of vestibulocochlear dysfunction, including head tilt, horizontal nystagmus, staggering, circling, falling, and/or lateral recumbency. If the vestibulocochlear dysfunction is unilateral, head tilt and circling will be towards the side of the lesion, the quick phase of the nystagmus—if present— will be away from the side of the lesion, and when in lateral recumbency, the calf will lay on the same side as the lesion. Meningitis can occur as a complication of otitis I/M and, if severe, causes severe depression and opisthotonus. On rare occasion, meningoencephalitis of the pons and medulla on the affected side may occur; those calves may have difficulty standing and hold their head and neck in extension when helped to stand. Spontaneous regurgitation, dysphagia (especially associated with cud chewing), and loss of pharyngeal tone causing upper airway obstruction (i.e., nasopharyngeal collapse) may also occur as a result of extension of the inflammatory lesion and damage to branches of the nearby glossopharyngeal and vagus nerve. Bilateral peripheral vestibular disease may cause abnormally low head carriage without a head tilt. External discharge from the ear (otitis externa) is not common, but upon inspection of the external auditory canal, it is more commonly seen. A cough, nasal discharge, and other signs of pneumonia may be found in many of the affected calves.

Diagnosis

The diagnosis is mostly based upon clinical signs and signalment. *Mycoplasma* is commonly cultured from a tracheal wash sample or pharyngeal swab, but specificity of this finding is likely low because so many healthy calves also harbor the organism. In herd problems, M. bovis can often be cultured from the bulk tank. Confirmation of the diagnosis is seldom necessary but could be gathered by performing a CAT scan (see Figure 19-17*A*-*C*) or radiographs. Fluid density and lysis of the surrounding bones (e.g., scrolls) confirms the diagnosis. Recently, ultrasound examination of the bulla was found to have a modest sensitivity and high specificity for disease detection. A portable 7.5 MHz linear ultrasound unit was used with a fixed focus and frequency. Cerebrospinal fluid is often abnormal and caused by extension of the inflammatory reaction to the nearby meninges. Mononuclear pleocytosis is the most common cytologic finding.

Treatment

The treatment is antimicrobial therapy and supportive care in most cases. Enrofloxacin is effective for M. bovis and can be used if the calf also has pneumonia. Newer generation macrolides and Florfenicol are additional options. Tetracycline was once a very commonly used antibiotic for *Mycoplasma* spp. infection, but resistance is now common. Although beta lactam antimicrobials are not effective against *Mycoplasma* spp. because of their lack of a cell wall, penicillin may be an additional therapy to the above to prevent secondary infection with *Trueperella pyogenes*, which can occur in chronic cases. Regardless, 4 or more days of antimicrobial therapy is generally required before any improvement in clinical signs is noted. Prolonged treatment early in the course of disease and clinical signs often has a favorable outcome; more chronic cases have a poor prognosis with antimicrobial therapy alone. Supportive therapy includes feeding from the ground to help prevent aspiration pneumonia; flunixin meglumine for 1 to 3 days for antiinflammatory/antipyretic properties; good nutrition; and good ventilation. Antibiotic ophthalmic ointment should be applied to the eye on the affected side(s) three or more times daily. Surgery should be considered for valuable calves that do not show improvement within 7 days.

Ventral Tympanic Bulla Osteotomy

The calf is positioned in dorsal recumbency with the neck extended and the head secured to the operating table to prevent lateral deviation during surgery. The caudal aspect of the vertical ramus of the mandible is palpated, and the paracondylar process of the occipital bone is identified. The tympanic bulla is located dorsal and medial to these



Figure 19-17 CT scan of a calf with otitis media. This is a transverse CT image of the temporal region, acquired using a standard algorithm. *A* is displayed in a bone window (3200 window, 250 level) and *B* in a soft tissue window (375 window, 40 level). This examination illustrates bilateral otitis media with bilateral bulla otitis and right otitis interna. Evidence of otitis media: note the lysis of the wall of the tympanic bullae bilaterally (*A*) and presence of purulent exudate and granulation tissue (soft tissue density instead of air density) in the affected tympanic bulla (*B*). Evidence of otitis interna: lysis right petrous temporal bone (arrow, *A*). C is a CT scan of a 3-year-old Holstein cow with normal tympanic bullae. Note air density within the bullae. (*A* and *B*: Courtesy of Dr. Anthony Pease, Cornell University.)

structures. A 6-cm incision in the paramedian skin is centered between the vertical ramus of the mandible and the paracondylar process of the occipital bone. The platysma muscle is incised longitudinally the entire length of the skin incision. The mandibular lymph node is identified, and deep dissection is continued on the medial aspect of the node. Blunt dissection is used to separate the digastricus muscle from the hyoglossus and styloglossus muscles. The hypoglossal nerve is located on the lateral aspect of the hyoglossus muscle and must be avoided. Deep digital palpation confirms the ventral aspect of the bulla. It is a raised rounded structure. A periosteal elevator can be used to remove any soft tissue and muscle fibers from the ventral aspect of the bulla, if necessary. The external carotid artery is ventral and lateral to the tympanic bulla, and the glossopharyngeal nerve is medial to the bulla. Both of these structures must be avoided. Blunt self-retaining or handheld retractors are necessary to provide exposure of the tympanic bulla. The entire ventral aspect (floor) of the tympanic bulla should be removed with rongeurs forceps or an air drill. Samples for cytological and microbiological examination are taken. Any exudate present is removed with a curette. The tympanic cavity is lavaged with warm saline and suctioned. Care must be taken to avoid damaging the dorsal aspect of the bulla. A drain should be placed into the tympanic cavity and allowed to exit through the incision so that postoperative lavage can be performed. The drain can be secured with an absorbable suture in the deep layers of the incision and secured to the skin with a nonabsorbable suture. Absorbable sutures placed in a simple interrupted pattern are used to reappose the digastricus, hyoglossus, and styloglossus muscles. The skin incision is partially closed to allow drainage.

Postoperatively, the drain is removed on day 2 or 3, and the skin sutures are removed on day 14. Antibiotics are continued for 10 to 14 days. Dysphagia can be associated with the primary disease or result from inadvertent damage to the hypoglossal nerve. Treatment includes antiinflammatory agents such as flunixin meglumine and, if necessary, intravenous nutrition if the calf is already ruminating or forced intubation feeding for younger calves.

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PART IV

SHEEP AND GOAT

CHAPTER 20

Surgery of the Sheep and Goat Integumentary System

Meredyth Jones, Philippa Gibbons and Amanda Hartnack

SKINFOLD ABLATION

Skinfolds may become problematic in certain breeds of sheep, creating issues of moist dermatitis and fly strike in lambs. The two most common locations of these skinfolds are the neck and caudal thigh region. Cervical skinfold ablation may be required in some animals of the Merino and Rambouillet breeds, where selection for increased wool production has produced pronounced skinfolds in the neck region. Mulesing (skinfold ablation of the caudal thighs where fecal trapping is a concern) is performed in Australia and New Zealand, where constant vigilance against dermatitis and fly strike is required. This procedure is painful and associated with welfare concerns. Nonsurgical and genetic alternatives have been reviewed. Additionally, a topical lignocaine/bupivacaine/adrenaline spray has become commercially available in Australia that been shown to alleviate postoperative pain for up to 8 hours in lambs undergoing mulesing procedure and improve wound healing. Behavioral and physiologic responses to the pain of mulesing are ameliorated by the use of local anesthetic and nonsteroidal anti-inflammatory therapy used in combination.

Regardless of the site of skinfold ablation, the surgical procedure is similar and relatively simple. In cases where superficial or deep pyoderma is present as a result of prolonged moisture in the skinfold, it may be preferable to manage the infection by clipping the wool and applying local or systemic antimicrobials before surgical removal of the fold. It is recommended that heavy sedation be used to allow for reduced handling stress. A combination of butorphanol at 0.05 mg/kg, xylazine 0.1 mg/kg, and ketamine 0.2 mg/kg intravenously (IV) is a safe and reliable combination to provide heavy sedation in sheep and goats. The wool in the region of the surgical site is clipped and the skin prepared aseptically. The health of the skin in this area should be assessed to determine the full extent of resection necessary. Remembering that small ruminants are sensitive to lidocaine, local anesthetic is injected in a line-block fashion along the planned incision. A long, elliptical skin incision is initiated dorsal to the dorsal extent of the skinfold, continued ventrally just beyond the extent of the skinfold and compromised tissue, ending at a ventral point in a vertical line with the dorsal starting point of the incision. Care should be taken to have the dorsal and ventral endpoints far enough away from the skinfold that the ellipse formed is long and narrow, which minimizes puckering at the commissures. This incision is mirrored on the opposite side of the skinfold, joining it dorsally and ventrally. Once the full-thickness skin incision is complete, the dorsal or ventral point is elevated using thumb forceps and the skin dissected away from the subcutaneous tissues using scissors or scalpel blade. This dissection is continued until the skinfold is removed completely, with hemostasis provided as needed.

Depending on the size of the skinfold removed and the depth required, closure may be performed in 1 to 2 layers. Double-layer closure should be performed where a large skin defect remains or where there is potential dead space in the subcutaneous tissues. Absorbable suture is used to bring the subcutaneous tissues together in a simple continuous pattern and assist in minimizing skin tension. The skin is then apposed in a simple interrupted pattern. Postoperatively, systemic analgesics should be considered and antimicrobials effective against common skin and environmental flora administered, with extended withdrawals observed for extralabel use. Animals with a current tetanus toxoid vaccine should receive a toxoid booster at the time of the procedure. Those without known vaccination history should receive a tetanus toxoid at least 2 weeks before the planned procedure or 1500 units of tetanus antitoxin at the time of the procedure. If the procedure is performed during fly season, a fly deterrent safe for use around wounds is indicated. The skin sutures should be removed in 10 to 14 days.

PREDATOR ATTACK

Meredyth Jones

Sheep and goats are, unfortunately, frequently the victims of attack by predators. Wild carnivore attacks tend to result in rapid death, whereas domestic carnivores tend to cause significant damage but leave survivors. Often a flock or herd will experience losses or trauma to multiple animals, either as a single event or over the course of time. It is important for the veterinarian to advise livestock owners to seek counsel

concerning their rights regarding the control of predators and to adequately investigate and document morbidity and mortality where legal action may be sought. Investigation of predator attacks and options for control of predators have been reviewed.

When presented with individual or multiple animals that have been attacked, triage should sort the animals into three groups: those requiring immediate euthanasia, those requiring intensive cardiovascular support, and those that have relatively minor wounds for which treatment may be briefly delayed. Initial evaluation should include examination of mucous membrane color, auscultation of the thorax for the presence of breath sounds over the entirety of the lung fields, palpation of limbs for fracture, and initial evaluation of all wounds.

Extensive clipping may be required to find all wounds, and a sterile, water-based lubricant should be placed in each wound to prevent fiber from entering the wound. Wounds most frequently occur in the head and neck or hindquarter regions, with lesions over the thorax and abdomen also common. Wounds in these regions have the potential to penetrate the trachea, esophagus, pleural cavity, and peritoneal cavity (Figure 20-1). A hissing sound heard over a wound indicates penetration of the airway or pleural space. Lesions over the abdomen should be cleaned and gently probed to determine whether they extend into the peritoneal cavity. Wounds that penetrate body cavities are associated with potentially life-threatening sequelae, including pneumothorax and peritonitis, and owners should be advised of the need for aggressive therapy and diminishing prognosis as these are found. Subcutaneous emphysema is common in major trauma and, if present, it should be determined whether the air is coming from the wound itself or from the airway. Wounds of the hindquarters are frequently based in the area of the pelvis, with pelvic organ trauma possible. The extent of such damage must be immediately identified and the ability to correct this damage determined.

Where indicated, fluid therapy should be initiated promptly and the choice of fluid based on the need for blood component replacement or the need to maintain cardiac output. Fluid therapy is often indicated even in animals that have cardiovascular stability but with massive trauma due to the frequency of myopathies resulting from the attack. As these develop, myoglobin can be presented to the kidneys in large amounts and is nephrotoxic, making diuresis important as the tissue damage progresses. Plasma therapy is often required in cases of massive trauma, where large, contaminated wounds must be left open. These animals lose significant amounts of plasma protein through these defects, and it can be difficult to maintain plasma protein levels in animals with a significant percentage of their body surface involved.

Antimicrobials, analgesics, and antiinflammatory medications should be initiated once initial triage has occurred. Antimicrobials with good activity against anaerobes and with broad-spectrum activity are indicated where carnivore bite wounds have occurred. Beta lactams, specifically the penicillins and cephalosporins, used in combination are initially good choices. Analgesics and antiinflammatory medications are selected based upon clinician preference and injury severity, but attention must be paid to the kidneys, which are compromised during cardiovascular shock and impending myositis. Tetanus prophylaxis should also be provided.

Once the extent of injuries has been determined, wound management should be planned. Depending on the age of the wounds at presentation debridement is indicated, but all wounds, even fresh, should be treated as contaminated. As such, it is often contraindicated to close wounds sustained during predator attacks, particularly when continued tissue death, blood supply compromise, and tension will occur. Small wounds may be cleaned, debrided, lavaged, and left open for daily wound care, whereas larger wounds benefit from wet-to-dry bandaging until contamination is controlled. Wounds are covered with sterile gauze soaked in saline and 0.5% to 1% chlorhexidine and covered with a layered bandage (Figure 20-2). These bandages are removed daily and the wound cleaned, debrided, and redressed. Alternatively, sugar or honey bandages may be used. Sugar is an inexpensive wound dressing that aids in the debridement of necrotic tissue while preserving viable structures. A layer of granulated sugar 1 cm thick should be placed on the wound and the wound covered with a thick dressing. This dressing should be changed every 12 to 24 hours, or more often if strikethrough is seen. The wound should be lavaged with



Figure 20-1 This animal was one of nine attacked by domestic dogs. As these wounds over the thorax were being cleaned, a slight sucking sound was heard over one wound, indicating that the pleural cavity had been penetrated.

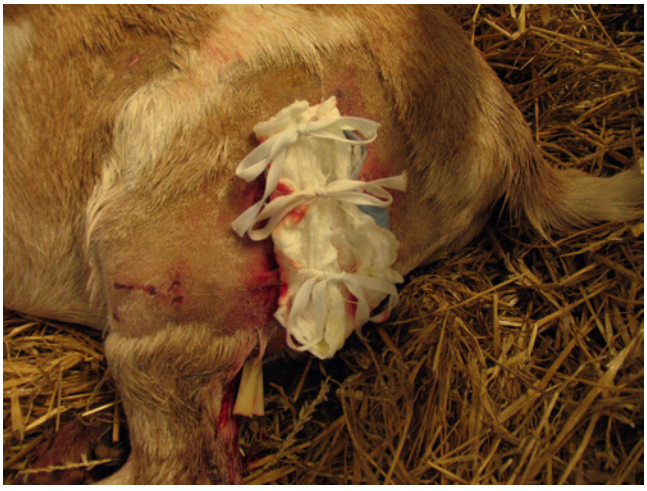


Figure 20-2 Wound management of a goat attacked by a dog. The outer thigh wound extends deep to the femur with significant muscle trauma. This wound is covered by a saline-soaked lap sponge and a stent bandage. The deep inner-thigh wound has a Penrose drain placed to facilitate the passage of exudate.

saline during each bandage change. In areas that are difficult to bandage, tie-over bandages should be placed. Once contamination and infection are under control, closure after final debridement and lavage may be attempted or the wound may be managed as open to heal by second intention. In these cases, a bed of granulation tissue will form over a period of about 2 weeks, after which wounds will contract, with reepithelialization becoming complete over time.

In some situations, due to the size or location of a wound, primary closure must be done even though it is not ideal. In these situations, drains should be placed in the deep tissues and some portion of the ventral part of the wound left open to allow for exudate to escape (see Figure 20-2). Closure of these wounds often occurs under tension, and vertical mattress, near-far-far-near patterns with or without rubber stents can increase the success of these closures.

The decision regarding hospitalization of animals is made based on the severity of the trauma and the ability of the owner to provide care at home. Sheep and goats have strong group instincts, and extended hospitalizations should be avoided unless medically necessary or a "buddy" can be provided. Although very stoic, sheep and goats are quite sensitive to the many negative physiologic effects of pain, and multimodal analgesia in combination with antiinflammatory agents are important in supporting the whole animal through significant trauma.

TAIL DOCKING

Tail docking is a management procedure performed in lambs primarily to control soiling of the tail with loose stools, leading to fly strike (myiasis) and maggot infestation. It is also believed that reproductive efficiency may be reduced in animals with long tails. In exhibition lambs in North America, it is common to dock tails very short to optimize the appearance of the hindquarters. Tail docking can be controversial and consideration must be given to animal welfare when the procedure is considered. Tail docking can be a defensible procedure due to the real concerns of fly strike in growing lambs, but the procedure must be performed in a way that minimizes the physiologic impact on the lamb.

Behavioral and physiologic markers of pain have been evaluated in lambs undergoing tail docking procedures both in conjunction with and independent of castration. Lambs undergoing tail docking by rubber ring, rubber ring plus Burdizzo clamp, and surgical removal of the tail exhibited behavioral changes and elevations of cortisol at the time of the procedure. In one study evaluating tail docking using electroencephalography, docked lambs (sharp knife) returned to brain activity similar to that of lambs handled while receiving no noxious stimuli 15 minutes after the procedure. There is no question that, in the absence of anesthesia, pain is perceived by the lamb at the time of docking. This pain appears to be minimized with either tail removal or crushing by Burdizzo to denervate the distal tail.

The second animal welfare concern associated with tail docking is the correlation of rectal prolapse to tail docking. An increased incidence has long been believed to be caused by damage to nerves of the perineum by short tail docking. A study published in 2003 evaluated three docking lengths in lambs managed in feedlots or on pasture. Short tail docks were located as close to the body as possible, long docks were performed at the distal insertion of the caudal tail fold, and medium docks were performed at the point halfway between. The short tail dock was associated with a 7.8% incidence of rectal prolapse, significantly higher than that of medium dock (4.0%) or long dock (1.8%).

Tail docking may be performed by a variety of means, including a hot docker, emasculator, Burdizzo clamp, rubber elastrator band, or sharp knife. In general, it is believed that the stress of this procedure is minimized by doing the procedure on lambs at 3 to 5 days when they are still with the dam. For commercial lambs, regardless of the procedure used, the lamb should be held in an upright position by an assistant with the hind limbs restrained well. The operator raises the tail in line with the spine without pulling up or out on the tail. The triangular caudal tail folds are visualized and their distal insertion into the tail used as the landmark for docking. A secondary criterion is that the tail should cover the vulva of ewe lambs. The tail is removed at this level by use of the selected instrument or a band is placed at this site (Figures 20-3 and 20-4). The lamb is immediately returned to the dam. Tetanus prophylaxis should be considered with all methods of tail removal, and in young neonatal lambs with a vaccinated dam, a tetanus toxoid booster is generally sufficient. In lambs where the vaccination status of the dam is unknown or believed to be insufficient, the



Figure 20-3 Tail docking of a 3-day-old lamb using a hot docker. The lower portion of the docking tool is a heated chisel, and the tool is used to cut the tail at the level of the insertion of the caudal tail fold.



Figure 20-4 Tail docking of this lamb is complete, and it should be noted that the tail is of sufficient length to cover the perineum.

procedure should be accompanied by the administration of 1500 units of tetanus antitoxin. The use of local anesthesia for this procedure may be considered, with the associated increased handling time and injection stress considered. In lambs destined for exhibition, show regulations regarding tail length should be sought, but veterinarians should encourage retention of as much tail length as agreeable.

Occasionally, an older lamb or adult may require tail docking because it was missed as a lamb or after tail trauma. In this situation, surgical amputation is indicated. It is recommended that adults be heavily sedated to allow for reduced handling stress. A combination of butorphanol 0.05 mg/kg, xylazine 0.1 mg/kg, and ketamine 0.2 mg/kg IV is a safe and reliable combination to provide heavy sedation in sheep and goats. A caudal epidural is effective at providing total temporary anesthesia to the tail and is performed by locating the sacrococcygeal intervertebral space and clipping and preparing the site. The tail is pushed ventrally and a 22- to 20-gauge, 1- to 1½-inch (2.54 to 3.81 cm) needle is inserted, nearly horizontally, through the skin and a drop of lidocaine or other local anesthetic placed in the needle hub. The needle is advanced to the epidural space, where negative pressure draws in the local anesthetic. The injection is then administered. If the drop is not pulled into the epidural space, the needle is advanced until administration requires little pressure on the syringe plunger. A dose of 40 mg of lidocaine is sufficient for most adult sheep.

If peri- and postoperative analgesia and antimicrobial therapy are to be used, initial doses should be given before the start of surgery and prolonged withholding times observed for extralabel use. The site of amputation is selected based upon consideration for the location of any trauma and the prevention of rectal prolapse, as mentioned previously. This location is clipped and surgically prepared, and the distal tail is wrapped to allow for handling during the procedure. A tourniquet may be placed proximal to the procedure site to control hemorrhage and facilitate visualization during the procedure. The intervertebral space at the desired docking length is identified and the skin of the tail drawn proximally. The caudal intervertebral spaces may be more readily identified while moving the tail back and forth laterally than up and down. Inverted V-shaped incisions are made just distal to the desired intervertebral space on each lateral aspect of the tail, creating V-shaped flaps dorsally and ventrally (Figure 20-5). The soft tissues are incised circumferentially until only the coccygeal vertebrae and ligamentous attachments remain. A scalpel blade is used as a probe to identify the intervertebral space and disarticulate the distal portion of the tail. Generally, there is little muscle and soft tissue in the region of the amputation, and subcutaneous sutures may not be required. The skin flaps are pulled distally over the exposed vertebra and sutured in an apposing pattern, such as a simple interrupted pattern. Depending on the housing environment and conditions postoperatively, a bandage may be placed. Animals with a current tetanus toxoid vaccine should receive a booster toxoid at the time of the procedure. Those without known vaccination history should receive a tetanus toxoid at least 2 weeks before planned procedure or 1500 units of tetanus antitoxin at the time of the procedure. Sutures should be removed in 10 to 14 days; a prolonged suture removal interval is frequently associated with suture tract infection.

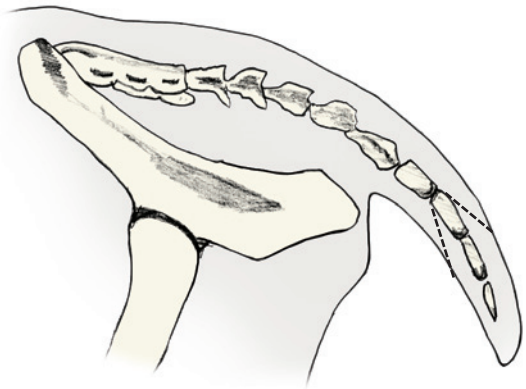


Figure 20-5 Schematic drawing of surgical tail amputation of older lambs or adult sheep. Inverted V-shaped incisions are performed on each lateral aspect of the tail to form dorsal and ventral V-shaped flaps, which are then apposed to cover the coccygeal vertebra.

CAPRINE DISBUDDING AND DEHORNING

Philippa Gibbons

Removal of horns in goats is a common veterinary procedure. Although there are polled goats bred, the polled gene is associated with intersex females and sperm granulomas and testicular hypoplasia in homozygous males. Most dairy goat associations require females to be dehorned for registration and showing purposes. Goats may also be dehorned to suit management purposes to reduce fighting or damage to property or following cornual trauma.

Disbudding

Disbudding of goat kids is preferred over dehorning of older animals due to potential difficulty achieving primary closure of the dehorning site, resulting in potential complications of osteomyelitis, sinusitis, and myiasis. Prolonged healing times may lead to decreased growth, sperm production, or lactation.

Disbudding of goat kids should be performed with a hot iron, preferably within the first 2 weeks of life. In the United Kingdom, it is a legal requirement for a veterinarian to perform disbudding of goat kids of any age. Cauterizing paste should not be used in goats due to the risk of corneal irritation and ingestion by the dam or other kids. Disbudding in goat kids has been associated with acute stress response and demonstration of pain. Therefore analgesia and/or anesthesia are necessary. Sedation of goat kids for disbudding can be achieved by administration of low-dose xylazine (0.025 mg/kg IV or 0.05 mg/kg intramuscularly [IM]) followed by reversal using tolazoline (1-2 mg/kg IM or SC), if recovery is delayed. It must be remembered that reversal of alpha 2 agonists also results in reversal of the analgesic properties of the drug. The kid can also be anesthetized using inhaled sevoflurane or isoflurane. Local anesthesia using lidocaine can also be used. The maximum tolerable dose of lidocaine in ruminants is 10 mg/kg. Lidocaine toxicity manifesting with seizures has been observed at 5.8 mg/kg IV. The toxic dose should be calculated and 75% used to perform the blocks. The small volume of drug required in kids can be increased by diluting out the lidocaine to 1% with saline. Caprine horns have additional corneal innervation compared with cattle. The horn is innervated by the cornual branches of the infratrochlear and lacrimal nerves as shown in Figure 20-6 and local anesthetic blocks performed at these sites. Alternatively, a ring block can be performed around the base of the horns. Nonsteroidal antiinflammatory medication should also be administered for their analgesic effects. There is no labeled analgesic or anesthetic drug in goats. Flunixin meglumine (2.2 mg/kg IV) or meloxicam (0.5 mg/kg IM) have been used in an extralabel fashion for disbudding goat



Figure 20-6 Anatomy of the caprine skull showing location of the nerves innervating the horn.

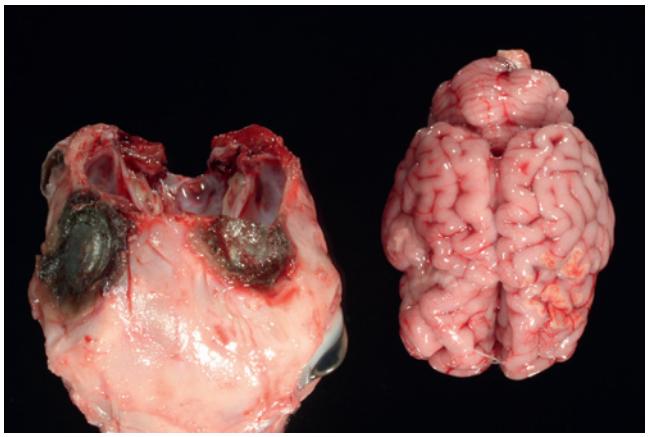


Figure 20-7 Gross necropsy findings from a kid who developed cerebral neurologic signs after disbudding. Note the thermal burns on the surface of the calvarium and the areas of cerebral cortical necrosis present on both hemispheres. In this case the cerebrum was adhered to the calvarium.

kids. Consultation with the Food Animal Residue Avoidance Database (FARAD) should be sought to determine appropriate withdrawal times in goats.

The hair should be clipped to facilitate visualization of the germinal tissue of the horn buds. Aseptic preparation of the dehorning sites is not necessary. The hot iron is applied to each horn bud and moved in a circular motion for 3 seconds. The head is then allowed to cool for 10 seconds. This is repeated 2 to 3 times until a copper-colored ring is achieved. The tissue inside the ring should also be cauterized. An additional semicircular burn can be performed caudal to the horn bud in males to cauterize the scent gland. The major complication of disbudding is heat meningitis as a result of prolonged heat and pressure on the horn bud against the thin calvarium (Figure 20-7). Kids with heat meningitis can develop cerebral signs including depression and sudden death, ataxia, blindness, and seizures within 24 hours of the disbudding procedure. Treatment may include corticosteroids (dexamethasone), antiinflammatories (flunixin meglumine), and antimicrobials (ceftiofur sodium, oxytetracycline, or florfenicol); however, these cases are frequently not responsive to treatment.

Success of disbudding depends on the size of the horns. Horn bases that are too large for the size of the iron or horn tips that are too long will prevent good contact with the hot iron around the corium and may result in scur formation. Horns too large for disbudding on goat kids can be removed surgically with primary skin closure (cosmetic dehorning). Successful closure can be achieved with horns of base diameter up to 4 cm. Animals with larger horns may have to have one horn removed at a time to achieve skin closure over the exposed frontal sinus. Due to the increased risk of sinusitis in goats compared with cattle, the frontal sinus should not be left open. Animals whose skin cannot be apposed should have a bandage applied until secondary closure has been achieved.

Surgical Cosmetic Dehorning

For surgical removal of horns too large for disbudding, goats are sedated using 0.2 mg/kg xylazine hydrochloride IV alone or with 2 mg/kg ketamine IV (intubation is recommended following ketamine administration). Alternative sedation dosages include an intramuscular combination of 0.05 mg/kg butorphanol, 0.1 mg/kg xylazine, and 0.2 to 0.3 mg/kg ketamine. Animals can also be induced using inhaled isoflurane or sevoflurane followed by intubation. Perioperative antiinflammatories should be administered before surgery, with flunixin meglumine (2.2 mg/kg IV) most often used. Due to the frequency of exposing the frontal sinus that has natural bacterial flora, the surgery should be considered clean contaminated and broad-spectrum preoperative antimicrobials administered. Ceftiofur sodium is labeled for pneumonia in goats at 2.2 mg/kg IM or subcutaneously and is an appropriate choice. Alternative antimicrobials used extralabel include ampicillin and tulathromycin. All goats should receive tetanus prophylaxis before surgery either with tetanus toxoid vaccine booster or tetanus antitoxin (1500 IU IM) in the absence of exposure to previous tetanus toxoid. At the end of the procedure, an alpha antagonist (tolazoline 2 mg/kg IM or subcutaneously; yohimbine 0.2 to 0.25 mg/kg or atipamezole 100 µg/kg) may be administered for reversal.

Once the animal is sedated, it is restrained in sternal recumbency on a table. The hair is clipped in a wide margin around the horns, up to the base of the ears and to the top of the eyelids. The surgical site is aseptically prepared using povidone iodine scrub and dilute povidone iodine rinse. Chlorhexidine and alcohol should be avoided due to the close proximity of the eyes. Lubrication can be applied to the corneas to prevent irritation. Lidocaine (maximum dose 10 mg/kg) is used for a ring block around both horns. Lidocaine 2% can be diluted 1:1 with 0.9% sodium chloride to provide an adequate volume.

Using a No. 10 scalpel blade, the skin is incised 1 to 2 mm into the haired skin from the horn base in an elliptical shape, taking care to remove the epiceras (horn-producing skin) to prevent scur formation, but maximizing the amount of skin left for closure over the exposed sinus. The skin is then undermined away from the skull on the rostral and medial and lateral aspects of the horns using a No. 10 scalpel blade (Figure 20-8). Undermining of the caudal aspect can be difficult to achieve. Gigli or obstetric wire is seated behind the horn, and a surgical assistant reflects the skin rostrally away from the wire (Figure 20-9). The horn is removed using gentle sawing pressure on the wire in a craniomedial or craniolateral direction depending on the orientation and growth of the horns (Figure 20-10). Care must be taken not to fracture the frontal bone. Following removal of the horn, hemostasis can be achieved by applying hemostatic forceps to large vessels and using a twist and pull technique. The superficial temporal vessels run craniolateral to the horn. The skin is then further undermined to expose the frontal bone using scissors or a No. 10 blade. The protruding cornual process



Figure 20-8 Cosmetic dehorning procedure with elliptical incision around the left horn and reflection of the skin back. Cosmetic removal of the right horn has been completed.



Figure 20-9 Seating the obstetric wire around the horn base with protection of the rostral skin from damage from the obstetric wire.



Figure 20-10 Post horn removal.

of the frontal bone is removed with rongeurs to facilitate closure of the skin over the exposed frontal sinus. Care must be taken not to allow bone dust or fragments to fall into the sinus. Closure of the incision is routine. In goats with large horns, tension-relieving sutures (vertical mattress or near-far-far-near) can be used to facilitate closure. The sutures are removed in 10 to 14 days.

Complications of cosmetic dehorning include incision dehiscence as a result of tension or infection, epistaxis, bone fragments in the surgical site, and bone sequestrum from excessive remodeling of the frontal bone. Mild epistaxis into the sinus usually resolves spontaneously within 24 hours after surgery.

Banding of horns as a method of dehorning has been performed in both cattle and goats. However, this technique has been associated with higher failure rate, prolonged healing times, and pain compared with other techniques in cattle. Therefore banding is not recommended as a method of dehorning in ruminants.

An alternative to removing large horns in adult goats is tipping of the ends of the horns down to ends 1 cm in diameter. Dehorning to this level may result in hemorrhage and sensation. Goats may need to have cornual anesthesia blocks performed and/or be sedated to perform tipping. Heat cauterization may be required to control hemorrhage. The horn should not be tipped so far that the sinus is opened.

DESCENTING BUCKS

Meredyth Jones

Bucks develop a characteristic odor as they mature that is an important part of the hormonal and behavioral aspects of reproduction. A buck's odor comes from a variety of sources, including multiple sebaceous scent glands and the act of urination on the forelimbs, head, and beard. Descenting is rarely performed in meat goats but may be requested by owners of meat or dairy bucks. Before performance of the procedure, however, owners should be informed that destruction or removal of the scent glands of the head only removes a single source of the buck's scent.

Descenting is most commonly performed at the time of disbudding of young bucklings. After hot-iron disbudding, the area caudomedial to each horn base is similarly cauterized to destroy secretory tissue. In mature bucks, surgical removal is required. Access to the glands is straightforward in dehorned or polled bucks but can be challenging in those with well-developed horns, depending on horn conformation. Heavy sedation, coupled with local anesthesia, is indicated for both restraint and analgesia. Once optimal sedation is achieved, the area caudal to the horn base location is clipped and cleansed. In bucks with horns that lie caudally over the back of the head, it can be difficult to effectively access the area of the glands with clippers. A straight blade or other smaller razor may be used, but in the author's experience depilatory creams can be very irritating to goat skin and should be avoided. Once hairless, the gland orifice is located caudomedial to the horn base at the base of the prominent, thickened skinfold. The area around this orifice is infiltrated with lidocaine or other local anesthetic and aseptic preparation completed.

An elliptical or crescent-shaped skin incision is made approximately 2 cm away from the external gland orifice and the incision deepened down to bone. Blunt and sharp dissection is then used to identify and delineate the gland, which can sometimes extend beyond this localized anatomic region. The incision may need to be extended as indicated by gland anatomy and the gland dissected free of the subcutaneous tissues.

The skin of mature bucks in this area is thickened, making primary closure a challenge. Attempts should be made to close the incisions, using No. 1 nonabsorbable suture material. If the incisions cannot be fully closed, they may be managed as open wounds and be kept clean. When the surgery is uncomplicated, systemic antimicrobials are generally not indicated, but antiinflammatory/analgesic medications may be beneficial. Animals that have not had a tetanus toxoid in the previous 6 months should receive tetanus antitoxin and/or receive a tetanus toxoid booster.

Postoperatively, animals should be fed on the ground rather than out of hay racks to prevent contamination of the incision, and they may need to be isolated from other bucks to prevent head-butting. Owners should be instructed to gently clean the incisions because serum or exudate can accumulate and to avoid ointments and other thick wound dressings. Fly control measures should also be employed. Sutures may be removed at 10 to 14 days postsurgery.

LUMPS AND BUMPS OF SHEEP AND GOATS

Veterinary practitioners are frequently asked to evaluate various cutaneous and subcutaneous masses in sheep and goats. Anatomic location and potential etiology are important considerations for both surgical planning and management with regard to individual and flock or herd health.

Lymphadenopathy

Although not cutaneous masses, sheep and goats are often presented with enlarged lymph nodes, which may initially appear to be cutaneous in origin. The readily palpable lymph nodes of sheep and goats include the parotid, submandibular, prescapular, prefemoral, and supramammary lymph nodes. When a mass in this area is evaluated, care must be taken during palpation to determine whether it is associated with the lymph node or is independent of the node. Enlargement of the peripheral nodes can occur as a result of infection with *Corynebacterium pseudotuberculosis* (caseous lymphadenitis) (Figure 20-11) or other bacterial or fungal pathogens, or neoplasia, including lymphoma. Regional lymph nodes may also become enlarged in response to any inflammatory process in that area of the body; however, reactive lymph nodes would rarely be presented as the primary client concern.

A fine-needle aspiration may be performed on any palpably enlarged lymph node and cytology performed. Gross appearance of the fluid and cytology are typically sufficient to determine whether the lymph node is enlarged due to abscess, with bacterial culture then indicated to determine the etiologic agent. When there is suspicion of caseous lymphadenitis, bacterial culture is important to determine the potential herd health and economic impact, as well as guide treatment due to the highly infectious nature of the organism. When cytology suggests neoplasia, wedge biopsy or lymphadenectomy with histopathologic examination may be required for definitive diagnosis.

The simplest and most common treatment of external lymph node abscesses involves lancing and drainage, followed by antiseptic flushing and removal of debris. This is typically followed by rapid contraction of the abscess cavity and healing. When the abscess is caused by C. *pseudotuberculosis*, however, this opening of the abscess allows for contamination of the environment and spread to other animals. When this procedure is elected, all materials used in the procedure should be discarded or sterilized and the animal quarantined until complete healing takes place.

An alternative method designed to minimize environmental contamination is abscess lavage through a needle. For this procedure, a 16-gauge, 3-cm needle is introduced into the abscess cavity and 0.9% saline is injected to disperse the abscess material. The cavity is then lavaged through the needle by withdrawing purulent material, discarding it, and introducing more saline to repeat the procedure. In one study using this procedure, outcomes did not differ between those animals undergoing open drainage with a single dose of subcutaneous penicillin or those undergoing needle distention lavage followed either by intralesional or subcutaneous tulathromycin. These results would indicate that this procedure is no more successful than open lavage, but its value may be in reduced environmental contamination, although this has not been evaluated.



Figure 20-11 Caseous lymphadenitis abscess of a regional lymph node near the neck of the scrotum of a goat.

Lymphadenectomy is a useful procedure for diagnostic and therapeutic purposes and is a mechanism for removal of a caseous lymphadenitis lesion and minimizing environmental contamination. It is important to inform owners in cases of caseous lymphadenitis abscessation that, although the lymph node is removed, the animal retains infected status. Animals undergoing this procedure should be under very heavy sedation with local anesthesia or be under general anesthesia. The skin over the lymph node should be clipped and prepared aseptically. The lymph node is isolated with one hand and a skin incision is made over the center of the node. Blunt dissection through the subcutaneous tissues is performed until the surface of the lymph node is reached and dissection is continued to free the lymph node from the surrounding tissues. Care must be taken not to pierce the lymph node capsule, particularly in the case of an abscess. At the hilus of the node, the vasculature should be isolated and ligated. Double-layer closure should be performed where a large skin defect remains or where there is potential dead space in the subcutaneous tissues. Absorbable suture is used to bring the subcutaneous tissues together in a simple continuous pattern and assist in minimizing skin tension. The skin is then apposed routinely. Postoperatively, systemic analgesics should be considered and antimicrobials effective against common skin and environmental flora used and extended withdrawals observed for extralabel use. Animals

with a current tetanus toxoid vaccine should receive a booster toxoid at the time of the procedure, whereas those without known vaccination history should receive tetanus antitoxin at the time of the procedure.

Lesions Not Associated with Lymph Nodes

Head

Sheep and goats may present with swellings or lesions on their heads that are not associated with the external lymph nodes. Diseases of the oral cavity are very common in these species, and a thorough oral examination should be performed on any animal with facial or throatlatch swelling. Malocclusion with packing of feed in the buccal space may occur in aged animals or those with tooth loss or trauma. Sharp points of teeth may traumatize the buccal mucosa, resulting in abscesses that are visible from the exterior.

Tooth root abscesses occur most commonly in the mandibular arcade and most often present as a swelling that opens and drains, heals up temporarily, and then breaks open again and again. These are typically unresponsive to antimicrobial therapy or will be only temporarily responsive. Oblique radiographs of the skull confirm the diagnosis and help determine the extent of the infection. Extraction of the offending tooth with curettage of the infected bone is indicated. Depending on the extent of bone involvement, fracture is a risk of the procedure. When possible, intraoral extraction should be accomplished. Alternatively, a ventral approach with a motorized burr may be required to remove the tooth and affected bone. Fracture, hemorrhage, and postoperative acid-base disturbances are potential sequelae. Acid-base disturbances can occur as a result of external salivary loss of bicarbonate through the surgical site. This can be reduced by packing of the site. Broad-spectrum antimicrobials and antiinflammatories should be provided peri- and postoperatively. There is more material on dentistry in Chapter 9.

Salivary mucoceles are cystic structures arising from the salivary ducts, usually as a result of trauma. The mandibular and sublingual glands are most often involved. Ultrasound examination reveals anechoic fluid, and to confirm the diagnosis, fine-needle aspiration after aseptic preparation reveals thick, yellow, or colorless saliva. These rarely cause any problem and are not often removed due to the risk of complications from vascular or nerve injury and generally low risk of complications from the mucocele itself. If performed, an incision is made over the mucocele and blunt and sharp dissection used to carefully isolate the mandibular and sublingual lymph nodes from surrounding structures. The duct is located at the rostral portion of the gland and should be ligated to prevent continued drainage after removal. The exact site of ligation and transection is guided by the location of the defect causing the mucocele. The glands are freed from the deeper tissues and removed. Closure is performed by closure of the dead space of the deep tissues, followed by muscle, subcutaneous, and skin closure. Depending on the depth of the remaining cavity, drain placement may be necessary.

Neck

Various structures may become abnormally enlarged in the cervical region, including wattle cysts, goiter, thymic hyperplasia, thymoma, and lymphoma. Certain vaccines or medications are known to be irritating and may result in localized reactions on the side of the neck, or abscesses may occur when injections are administered without proper hygiene. Additionally, oropharyngeal trauma may cause pharyngeal abscesses, which may be visible or palpable externally.

Wattle cysts appear at the location of a wattle near the throatlatch and may be present in animals that do not have wattles. They are filled with a colorless to yellow clear fluid and are nonpathogenic. If they are to be aspirated, great care must be taken to ensure asepsis to prevent abscessation. Wattle cysts may be removed for cosmetic reasons by incising over the cyst and dissecting it free of the surrounding tissues. The jugular vein lies below the cyst and must be protected during surgery.

Pharyngeal abscessation can occur as a result of oropharyngeal trauma, usually due to overzealous use of oral medication devices or coarse feeds with sharp stems. Ruminal and oral bacteria invade the mucosa and can form abscesses that can become quite large, to the point of obstructing the airway. These animals may present with an observable swelling in the throatlatch region or may present for dyspnea or anorexia. For these animals, a tracheostomy is often beneficial and provides opportunity for antimicrobial and antiinflammatory therapy to reduce the size of the abscess.

Goiter may occur in growing kids where dietary iodine deficiency occurs. It is readily resolvable through administration of a few drops of Lugol's iodine orally for 1 week or by dipping the doe's teats in iodine. Surgery is not indicated.

Thymic hyperplasia may occur in young goats, usually resolves by the age of 6 months, and is not of clinical concern. Thymoma and lymphoma may occur in older goats. Thymoma may have no clinical consequence but can grow so large as to cause compression of the esophagus or other structures. Lymphoma may also be diagnosed in this region and should be included as a diagnostic differential for masses in this area (Figure 20-12). Fine-needle aspiration of cells can help in differentiation of these masses.

Clostridial vaccines and certain antimicrobials have long been known to be irritating and produce lumps at the site of injection. These reactions occur as a result of inflammation, which results in eventual fibrosis and production of a knot-like mass. If the injection becomes contaminated with bacteria during or after the injection, an abscess may occur. Where a significant number of injection site lesions occur in a herd or flock, injection procedures and products used should be reviewed. Injection site abscesses are easily drained if necessary, and fibrotic lesions are of no clinical significance.



Figure 20-12 Small cell lymphoma in an aged goat. This neoplasm was differentiated from thymoma with histopathology.



Figure 20-13 This ewe was presented for routine foot trim. When positioned, an enlargement that included a portion of the mammary gland skin was noted, and mammary gland or subcutaneous abscessation was initially suspected. Ultrasound revealed a fetus within the mass. It is believed that the ewe had sustained body wall trauma and, as her pregnancy progressed, a portion of the uterus herniated and became entrapped in this ventral body wall hernia.



Figure 20-14 Advanced perineal squamous cell carcinoma of a doe. The perineum is a common location for squamous cell carcinoma in goats.

Thorax, Abdomen, and Perineum

Masses or swellings may occur on the body wall over the thorax and abdomen, often as a result of trauma. Hematomas and seromas form as a result of animals being bumped or head butted. These rarely cause a problem as long as they do not become contaminated. In general, suspected hematomas or seromas should not be aspirated with a needle, even in the most hygienic circumstances, due to the presence of a very hospitable environment for bacterial growth. These pockets will slowly resolve over time as the blood components are resorbed. Abscesses and acute or chronic injection site lesions may similarly appear over the body wall. Ultrasound is recommended to differentiate between seroma, hematoma, and abscess. Seromas are typically filled with anechoic fluid, whereas hematomas have a webbed appearance. Abscesses will be filled with fluid of mixed echogenicity and cellular debris. Hot packing and gentle massage or hydrotherapy can be used to facilitate resolution, with abscesses lanced once mature.

Body wall hernias are not as common as hematomas, or abscesses but occur with enough frequency that one must be mindful of the possibility to avoid incision on the presumption of abscess. Umbilical hernias may be congenital or acquired secondary to umbilical infection in neonates. Hernias in other portions of the abdomen most often result from trauma. Ultrasound is extremely helpful in determining the contents of an apparent mass on the abdominal wall because not all hernias are readily reducible. Omentum, gastrointestinal components, or reproductive organs may be identified in the hernial sac (Figure 20-13).

Squamous cell carcinomas have been found to be the most common epithelial neoplasm reported on histopathology in goats in North America. The etiology of squamous cell carcinoma is multifactorial, including genetics of skin pigmentation, ultraviolet light exposure, viruses, and age. A common presentation of squamous cell carcinoma in small ruminants is the perineal region (Figure 20-14), and it has been associated with the mulesing operation in sheep. Successful treatment of squamous cell carcinoma of the perineal region in goats has been achieved with surgical debulking and cryotherapy. Local recurrence and metastasis can occur.

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CHAPTER 21

Surgery of the Sheep and Goat Digestive System

Amanda Hartnack and Meredyth Jones

Gastrointestinal surgeries in sheep and goats are not commonly performed for animals in production settings; however, they should always be considered for individual patients of economic worth or for pet animals. Procedures that are performed most commonly include surgeries of the forestomach (reticulorumen) compartments and abomasum, rumen and esophageal fistula placement in research settings, and correction of intestinal obstruction or trauma and rectal prolapse.

SURGERY OF THE FORESTOMACH

Disease of the forestomach compartments (reticulorumen) can be fairly common in sheep and goat practice. Ruminal distention, rumen acidosis, rumen impaction, bezoar formation, foreign body consumption with subsequent impaction, and rumenitis/reticulitis are conditions that may require surgical intervention. Although ingestion of metallic objects is less common than in cattle, ingestion of other foreign materials may lead to obstruction. Ingested ruminal foreign bodies have been extensively reported in underdeveloped countries where forage material may be scarce. Cases of rumenolith formation as well as traumatic reticulopericarditis have also been reported in small ruminants. Rumenotomy may be necessary to remove obstructions or to lavage the rumen following rumen acidosis/grain overload.

Although surgery of the rumen is often performed under emergency conditions, the patient should be held off feed for 12 to 24 hours before surgery if possible. General anesthesia helps control animal movement and maintains a clean surgical field. Tracheal intubation may also help reduce the risk of aspiration pneumonia. However, if economics preclude general anesthesia use, a rumenotomy can be done with a local anesthetic and manual restraint. Sedation may be necessary. It is important to remember that sheep and goats are highly susceptible to lidocaine toxicity and use of diluted (1%) lidocaine may be necessary to achieve appropriate analgesic levels while remaining below the toxicity threshold of 10 mg/kg.

Surgery may be performed in the standing or recumbent patient, depending on surgeon preference and the status of the patient. If the surgery is to be performed on the recumbent patient, the patient is placed in either right-lateral recumbency or in sternal recumbency and the left flank prepared for aseptic surgery. For a rumenotomy, a 15-cm vertical skin incision is made 5 cm caudal to the last rib and 5 cm distal to the transverse processes of the lumbar vertebrae. If a foreign body is suspected, it is important to make the incision large enough to both locate and remove the offending object. The surgeon should remember that the rumen incision will be smaller than the skin incision once it has been properly sutured to the skin layer, and enlarging the incision at this point will be difficult. The underlying muscle layers (internal and external abdominal obliques and transversus abdominis) should be sharply incised. Blunt dissection of the muscles along their fascia planes (grid technique) is recommended if a small incision is desired, as in the case of rumenostomy. It should be noted that small ruminants have a more pronounced cutaneous trunci muscle than do cattle, and sheep and goat muscle layers are much thinner than those in cattle. Pronounced abdominal distention will further stretch these muscles, and care should be taken to avoid prematurely incising the rumen. The peritoneum should be elevated with Brown-Adson forceps and incised using scissors. Once the rumen has been visualized, at least 10 cm of rumen should be exteriorized and sutured to the skin of the wound margin with a simple continuous pattern around the entire incision margin using monofilament, nonabsorbable suture on a tapercut needle. To avoid a purse-string effect, a broken continuous pattern should be used. For the rumen-to-skin fixation, a bite is taken through the skin, and then a bite is taken through the rumen. Ideally the bites taken through the rumen are not full thickness. This suture pattern forms a seal that prevents rumen fluid from entering the abdomen and is important to minimize abdominal contamination. Once the suture placement is inspected and found intact, the rumen wall is incised within this margin. The surgeon should avoid traumatizing the rumen wall as much as possible. Other rumenotomy techniques have been described in both cattle and small ruminants, including rumen skin clamp fixation, rumen stay suture fixation, and ring fixation (Weingarth's ring).

Use of a wound ring drape may help to minimize contamination.[1] Once the rumen has been incised, it is possible to explore the reticuloruminal cavity. At this point, any foreign material is removed, and the cardia and reticuloomasal orifice are inspected and checked for patency. The abomasum can be palpated through the rumen wall for distention and normal location. The ventral floor of the rumen can be swept and grasped, checking for any adhesions.

Closure of the rumen occurs in two steps. First, the initial incision is closed using absorbable suture in a simple continuous pattern. At this point, gloves, surgical instruments, and gowns should be changed to avoid abdominal contamination. The wound should be flushed with copious warm saline to remove any remaining debris. Once wound cleansing has been accomplished, the rumen to skin suture should be removed and the rumen lavaged again before it is replaced into the abdomen. The second layer of rumen closure occurs now with absorbable suture in a Cushing pattern, incorporating the portions of rumen that had been sutured to the skin.

Closure of the abdomen is routine, although much smaller suture material (No. 0 or 1) can be used than in an adult cow. Each layer is closed in a simple continuous pattern with an absorbable suture, and lavage is performed between each layer. The peritoneum and transversus abdominis may be closed together, as can the internal and external abdominal

[1]Steri-Drape wound edge protector, 3M Health Care, St. Paul, MN, USA.

oblique muscles. The skin is closed with a nonabsorbable suture in a continuous pattern. The most ventral sutures should be placed in an interrupted fashion in case drainage of the wound is necessary. Appropriate antibiotics should be used for at least 5 days after surgery. Antiinflammatory drugs are commonly used, especially in goats (flunixin meglumine 1.1 to 2.2 mg/kg IV; meloxicam 0.5 to 1.0 mg/kg orally every 24 to 48 h). Clients should receive written notification of drug withdrawal times.

Rumenotomies to remove a foreign body have the most favorable prognosis. The most common items found in the rumen of small ruminants are plastic bags, rope, and large foreign bodies. A rumenotomy can also be performed for grain overload; however, the prognosis is guarded for this condition if longer than 12 hours' duration. Medical management of these cases through intravenous fluids, electrolyte monitoring and replacement therapy, probiotics, and oral alkalizers can be as—or more—successful. In addition to stabilization of the systemic and rumen pH, transfaunation can be an important tool for successful case management. Transfaunation per os generally requires 250 to 500 mL of collection fluid two to three times daily for 3 to 5 days. This fluid should be kept anaerobic, at rumen temperature, and out of light until inoculation occurs. Ideally, the time from collection to transfaunation should be less than 30 minutes.

Abomasal Surgery

Disease of the abomasum in small ruminants is much less common than in cattle and decidedly more difficult to manage surgically. Abomasal impaction, abomasitis, perforating abomasal ulcers, abomasal foreign bodies, and abomasal emptying defect in Suffolk sheep can potentially be managed with surgical intervention. However, in most instances medical management should be attempted initially. Unlike in cattle, displaced abomasum is extremely rare in small ruminants, though it has been reported.

On physical examination, heart and respiratory rates are often elevated. Feces are generally scant and melena may be noted. Depending on an individual animal's value and owner preference, a number of ancillary diagnostic tools may be helpful in the diagnosis of abomasal disorders in small ruminants. Ultrasound of the abomasum in the standing patient is simple and noninvasive. Fecal occult blood tests may be positive in cases of bleeding abomasal ulcers. A chemistry panel including plasma electrolyte concentrations may be valuable in assisting with diagnosis and determining medical therapy, as abomasal outflow obstruction typically results in hypochloremic hypokalemic metabolic alkalosis and eventual dehydration and azotemia. Medical management may include the following: large volume fluid replacement, correction of electrolyte imbalance, cholinergic drugs, and intravenous calcium and vitamin E/selenium—all of which have been used with limited success. Abomasal impaction is much more common in goats than in sheep. Pregnancy, poor-quality hay, and feeding a total pelleted diet can predispose goats to impaction. Abomasal impaction can also occur in goats confined to semidesert grazing of grassland/brush forage that contains a high percentage of awns, which form phytobezoars ranging in size from 2 to 10 cm. Patients present with inappetence, malaise, weakness, scant feces, and cranial right abdominal swelling/distention. An abomasotomy is generally corrective.

Abomasal emptying disease in Suffolk sheep commonly presents as impaction, but the etiology is different and has not been elucidated. It also does not consistently produce the hypochloremic, hypokalemic metabolic alkalosis typical of abomasal obstruction. Pregnant sheep on a diet high in concentrates are commonly affected with abomasal emptying defect. Medical management seems to be the most common treatment course, but an abomasotomy is occasionally attempted in valuable individuals with limited success.

ABOMASOTOMY

Once the decision has been made to perform an abomasotomy, the surgeon must decide which surgical approach to take. In small ruminants, surgery of the abomasum is performed in a recumbent position. Both the right-paracostal and ventral midline approaches will give the surgeon access to the abomasum; however, exteriorization is more easily achieved using the right-paracostal approach. General anesthesia is recommended, particularly in animals with distention and an increased risk of aspiration. It is possible, however, to perform these procedures under local anesthesia and sedation if general anesthesia is not possible for financial or other reasons. For the right-paracostal approach, the patient is positioned in left-lateral recumbency, and the right-paracostal region is prepared for aseptic surgery. A sharp 15-cm incision parallel to and 3 cm caudal to the last rib is made and extended along the costochondral junction. Subcutaneous tissues and muscle layers are sharply incised. The peritoneum is tented and entered sharply using scissors. After the peritoneum is entered, the incision site should be checked digitally for adhesions before proceeding. The greater curvature of the abomasum should be evident upon entry into the abdomen as the greater curvature normally lies in the paracostal position. At this point in time, the abdomen should be explored. If a distended abomasum is the only abnormal finding, or if an impaction or abomasal foreign body can be palpated, an abomasotomy is performed. Before incising the abomasum, the greater curvature is exteriorized as much as possible and isolated from the rest of the abdomen using laparotomy sponges. The size and position of the abomasal incision is dependent of the lesion being addressed. For abomasal impactions, a generous curved incision is made in the abomasal wall, and the impacted contents are emptied. Once the abomasum is empty, the site is rinsed with sterile fluids. The abomasum is closed in two layers, usually simple continuous in the first layer and Cushing in the second layer. Time is spent rinsing with copious fluids to free the area of debris as much as possible. Gloves are changed and the abdomen closed routinely.

Surgical Management of Intestinal Obstruction or Trauma

Economics frequently dictate management of intestinal obstruction or trauma in small ruminants. Animals with abdominal trauma often have a history of either dog attack or having been gored by a member of their herd (Figure 21-1). With the exception of traumatic injuries, symptoms of digestive system disease are often very vague. Inappetence, abdominal distention, diarrhea, melena, and a history of foreign body consumption are typical. Abdominal radiographs, ultrasound, abdominocentesis, and basic bloodwork may be useful ancillary diagnostics if available. If needed, exploratory surgery could be indicated for diagnostic purposes. General anesthesia with intubation is appropriate for an exploratory laparotomy in small ruminants, although much can be done with sedation and regional anesthesia if necessary. Suspected trauma, foreign body obstruction, intussusception, ileus, cecal volvulus, and torsion of the mesenteric root can all be indications for surgical intervention. Cecal volvulus and concomitant mesenteric torsion are a medical/surgical emergency. The patient is usually in extreme pain and rapid hypovolemic shock occurs. It is imperative that emergency surgery be implemented. Medical management may be attempted in animals with other



Figure 21-1 Goat presenting for traumatic injury secondary to being gored by a herdmate. (Courtesy of Dr. Andy Niehaus, The Ohio State University.)

conditions, including ileus. In some cases, supportive care for pain and fluid therapy can be corrective without the need for surgery.

EXPLORATORY LAPAROTOMY

The patient is placed in left-lateral recumbency, and the right-paralumbar fossa is prepared for aseptic surgery. A 10- to 12-cm vertical skin incision is made in the midparalumbar fossa. The muscle layers, which are much thinner than in the cow, are incised sharply in a vertical direction. The peritoneum is tented and incised.

Upon entering the abdominal cavity, the organs should be inspected in a thorough and organized manner. Great care should be taken manipulating the intestinal tract, as it can be quite fragile and much less forgiving in small ruminants than in adult cattle. Bowel resection for foreign body removal, intussusception, and ileus are performed as described in calves (see Chapter 17). In the case of foreign body obstruction, the affected piece of bowel is exteriorized, and moist laparotomy sponges are used to isolate the bowel from the abdomen before enterotomy. A linear incision is made over the foreign body, and the foreign body is removed. The enterotomy site is lavaged using sterile saline and closed in a Cushing pattern using small (3-0) absorbable monofilament sutures. Small ruminants are highly susceptible to peritonitis so care should be taken to be as clean and atraumatic as possible. Instillation of sodium carboxymethylcellulose may decrease adhesion formation. In cases of trauma, the abdominal cavity should be lavaged copiously with warm, sterile saline. Closure of the laparotomy site is in three or four layers. Both sheep and goats usually require postsurgical antibiotic therapy as well as pain control. Transfaunation or the use of probiotics may be indicated when long-term antibiotic use has been implemented.

Rumen, Abomasal, and Esophageal Fistulization (Cannulization)

Fistula placement may occasionally be requested for nutritional studies as well as the development of animals for herd/flock transfaunation (rumen cannulas only). Occasionally, cannulas are placed for enteral feeding in animals that cannot prehend food properly, as in cases of listeriosis. Due to the thin abdominal wall present in small ruminants, inert plastics are most commonly used for cannulas; however, rubber, polyvinyl chloride, and stainless steel are also occasionally used. Currently, there is one company[2] manufacturing cannulas for both small ruminants and cattle in the United States. Syringe cases can also be used to make rumen cannulas, and abomasal cannulization for research purposes in sheep and goats is generally performed with a Pezzer[3] (mushroom head) urinary catheter.

SURGICAL PROCEDURE

For rumen cannulization, the left-paralumbar fossa region is prepared for surgery and a local anesthetic administered as described for rumenotomy. The surgical approach when placing a rumen cannula is significantly different from the approach taken when a rumenotomy is to be performed. For cannula placement, a circular skin incision site approximately 1 to 1.5 cm smaller than the diameter of the cannula is made sharply. The muscle is dissected using the grid technique so that the holding capacity of the muscle layers is retained. Following skin incision, the external abdominal oblique muscle is sharply divided vertically, followed by blunt division of the internal abdominal oblique and transversus abdominis muscles parallel to their fiber directions. The peritoneum may be entered digitally or with a stab incision. At this point, the rumen is exteriorized and sutured first to the dermis and subcutaneous tissues using an absorbable suture material. A broken continuous pattern is appropriate. Once a good seal of rumen to skin is obtained, the rumen is incised and the mucosa sutured to the skin using a simple interrupted pattern of nonabsorbable sutures. It is helpful to use a cutting or a taper-cut needle for the suture lines in this procedure. Most often, the cannula is warmed in hot water before insertion to make the plastic more pliable. Postsurgical antibiotics are indicated as with the rumenotomy procedure described earlier.

Esophageal and abomasal cannula placements are less common requests, as they are used entirely for research purposes. Esophageal cannulas tend to be problematic in sheep because of wool growth. Myiasis and wool irritation are both common sequelae that need to be addressed.

The surgical technique is similar to rumen cannulization. General anesthesia is indicated, with tracheal intubation mandatory to help prevent aspiration pneumonia. The animal is placed in right-lateral recumbency, and a surgical site prepared in the midcervical region just ventral to the jugular furrow and to the left of midline. A stomach tube is placed in the esophagus and maintained as a landmark for the incision site. The skin is incised directly over the tube. Blunt dissection of the sternomastoideus and cleidomastoideus muscles allows visualization of the esophagus. It is important to remember the jugular vein, carotid artery, and vagosympathetic nerves all run close to the surgical site. Careful dissection is imperative. The esophagus should be incised to a length of approximately 10 mm larger than the size of the cannula stopper. The stomach tube will be visible within the esophagus. At this point, the esophageal mucosa should be sutured to the overlying muscle and skin in a broken continuous mattress pattern using a small-diameter absorbable suture. In this region, it is important that the sutures not be too tight because tissue necrosis can be a common sequela. At this point the cannula sleeve and stopper are placed. The skin incision cranial and caudal to the cannula should be

[2]Bar Diamond Parma, Parma, ID, USA. http://www.bardiamond.com.
[3]Pezzar, Davol, Arista Surgical Supply Co., New York, NY, USA.

closed with a nonabsorbable suture using a cruciate or simple interrupted pattern. As with other fistulization procedures, antibiotics are indicated. Regular application of wound-safe fly spray will help prevent myiasis. When this procedure is performed in sheep, the wool around the cannula site should be sheared regularly.

Abomasal cannulization of sheep and goats is described using the Pezzer[4] (mushroom head) urinary catheter. Other materials, such as silicone tubing, may be used as well. The site selection and approach are as previously described in the abomasotomy. The catheter is a 36 to 40 French Pezzer catheter that is inserted into the ventral aspect of the abomasum along the greater curvature.

The midventral aspect of the abomasum can be exteriorized from a paramedian or paracostal approach. Once the desired site is located, a circular purse-string suture pattern is placed with a 3-cm diameter using 2-0 to 3-0 absorbable material. A small stab incision, just large enough to insert the mushroom head of the Pezzer catheter (approximately 1 cm), is made into the lumen of the abomasum. The purse-string suture can then be tightened around the catheter. The catheter is exteriorized through the abdominal wall (right of midline) separate from the primary incision. Enough slack should be allowed so the abomasum can be replaced in normal position. As previously described, the incision sites are closed in three layers. Before repelling the abomasum back into normal position in the abdomen, the surgeon should flush the wound field with warm sterile saline. Gloves and instruments should be changed before closure. The catheter is sutured to the skin with nonabsorbable suture material. The catheter should be supported with a body bandage for the first 10 to 14 days. Antibiotics and nonsteroidal anti-inflammatory drugs are also indicated.

Rectal Prolapse

Rectal prolapse occurs in sheep more commonly than in goats, primarily because of the practice of short tail docking in exhibition lambs. Other conditions associated with rectal prolapse in small ruminants include enteritis (coccidia, *Salmonella*), dysuria, estrogenic feeds, obesity, lush forages, and coughing. It is important for the benefit of the herd or flock to identify the inciting cause of rectal prolapse in individual animals, as most of these inciting causes affect the whole herd. When tail docking length is believed to be the primary cause of rectal prolapse, owners should be educated about appropriate docking lengths and welfare considerations. An increased incidence has long been believed to be caused by damage to nerves of the perineum by short tail docking. A study published in 2003 evaluated three docking lengths in lambs managed in feedlots or on pasture. Short tail docks were located as close to the body as possible, long docks were performed at the distal insertion of the caudal tail fold, and medium docks were performed at the point halfway between. The short tail dock was associated with a 7.8% incidence of rectal prolapse, significantly higher than that of medium dock (4.0%) or long dock (1.8%).

Rectal prolapses are classified based upon either the tissue layers involved or by severity. A Class I prolapse is mild, with only a small amount of rectal mucosa protruding, which is often intermittent. Class II prolapses include all layers of the rectum in the prolapsed portion and may also be intermittent. Class III prolapses include all layers of the rectum and also include large colon, resulting in a large prolapse and significant discomfort and straining. Class IV prolapses include rectum and large colon and are constricted by the action of the anal sphincter. Class II prolapses are the most common prolapses presented to the veterinarian for correction.

Classification by Severity

By this system, Class I prolapses include tearing of the mucosa and submucosa. Class II include tearing of the muscular layers, whereas Class III prolapses have tearing of the mucosa, submucosa, and muscular layers, further subdivided by location of the tear. Class IV prolapses are full thickness, mucosa through serosa.

Once a rectal prolapse occurs, venous and lymphatic return begins to be compromised and swelling and edema rapidly occur. This accentuates the straining response, exacerbating the prolapse. Although rectal prolapses are generally not considered emergencies, they should be corrected quickly to minimize damage from outside trauma and continued tenesmus. Those that are actively bleeding or have significant tearing should be evaluated urgently.

Class I and II prolapses may generally be managed by nonsurgical means (Figure 21-2). Most of these prolapses may be manually reduced after gentle massage and a purse-string suture placed, which allows feces to pass. Umbilical tape is often used for the purse string. This can be placed following an epidural or local block, remembering the small ruminant sensitivity to lidocaine. Most of the purse-string suture should be buried under the skin, and it should be tied in a bow so that the size can be adjusted. In lambs with short tail docks, a purse-string suture is frequently accompanied by injection sclerotherapy, where an irritating substance (usually iodine based) is injected in a line within the pelvis along the serosal surface of the rectum to incite the formation of scar tissue, adhering the rectum into the pelvis to prevent future prolapse.

Recurrent and refractory Class II and all Classes III and IV prolapses require resection (Figure 21-3). Nonsurgical amputation is often selected in market animals and can be performed through the placement of a rigid plastic tube into the lumen and an elastrator band placed proximal to the prolapse in healthy tissue. This results in ischemic necrosis of the distal portion of the prolapse with scarring at the level of the band, which results in anastomosis. The rigid tube maintains a lumen for defecation pending the tissue slough.



Figure 21-2 Anatomic Class II rectal prolapse in a lamb with a very short tail dock. The mucosa is intact and there is minimal edema. This prolapse was manually reduced and maintained in place with a purse-string suture and injection sclerotherapy.

[4]Pezzar, Davol, Arista Surgical Supply Co., New York, NY, USA.



Figure 21-3 Anatomic Class III rectal prolapse. This prolapse was surgically resected to remove the damaged tissue and replace the prolapse.



Figure 21-4 Lamb placed in sternal recumbency with hind limbs pulled forward. This opens the lumbosacral space to facilitate placement of a needle for lumbosacral epidural anesthesia.

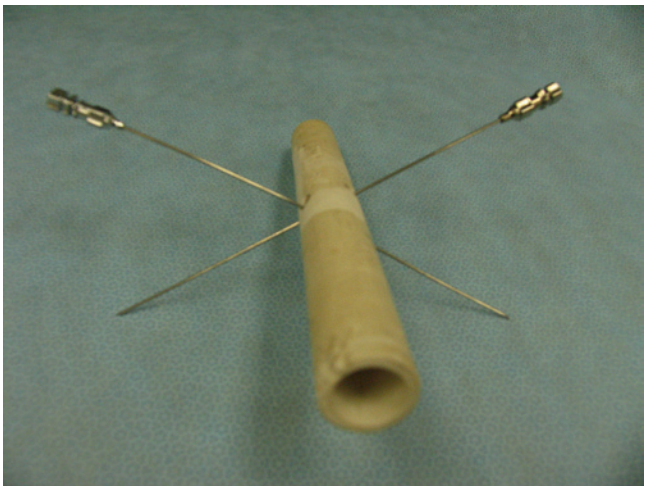


Figure 21-5 Polyvinyl chloride tube with offset paired holes drilled, which allow for cross pinning of the prolapse and facilitating the identification of the lumen.

Once the tissue has sloughed, the tube and band will fall off, and the rectum is reduced.

Surgical amputation is commonly performed and results in immediate reduction of the prolapse. The animal should be well restrained or sedated and a caudal epidural used to provide total temporary anesthesia to the tail. The sacrococcygeal intervertebral space is identified and the site clipped and prepared. The tail is pushed ventrally (if present) and a 22- to 20-gauge, 1- to 1½-inch (2.54 to 3.81 cm) needle is inserted, nearly horizontally, through the skin and a drop of lidocaine or other local anesthetic placed in the needle hub. The needle is advanced to the epidural space, where negative pressure draws in the local anesthetic. The injection is then administered. If the drop is not pulled into the epidural space, the needle is advanced until administration requires little pressure on the syringe plunger. A dose of 20 to 40 mg of lidocaine is sufficient for most large lambs and adult sheep or goats. Alternatively, a lumbosacral epidural may be performed using aseptic technique. The animal is sedated and placed in sternal recumbency with the hind limbs pulled forward (Figure 21-4). Standing behind the animal, the thumb and middle fingers are placed on the tips of the ileal wings and the index finger dropped down and the lumbosacral space identified. An 18- to 20-gauge, 1½-inch (3.81 cm) needle is inserted perpendicular to the skin and a hanging drop of lidocaine placed. The needle is advanced until the drop is pulled in to the epidural space. If using lidocaine 2%, 1 mL per 7 kg is administered at this site. If cerebrospinal fluid is obtained during the procedure, the needle should be withdrawn several millimeters into the epidural space. This will provide total anesthesia and loss of motor function to the pelvic organs and hind limbs.

After anesthesia is attained, a small-diameter rubber or plastic tube is drilled with an offset pair of holes to allow for needles or Steinmann pins to pass through it, forming an X (Figure 21-5). This tube is not required for this procedure but is extremely helpful in identifying the anatomy of the rectal layers during the procedure. This tube is placed into the prolapse, and long (6-inch, 15-cm) needles or Steinmann pins are inserted through the rectum, through the holes, and out the other side (Figure 21-6). The pins should be placed into healthy tissue, proximal to the planned site of amputation. This stabilizes all layers of the prolapse for amputation and maintains the lumen for anatomic orientation.

An incision is initiated where the mucosa is still healthy, usually about 1 to 2 cm away from the sphincter (Figure 21-7). This incision is continued circumferentially around the tube and continued until it is full thickness and the prolapse is removed (Figure 21-8). At this point, an anastomosis is performed between the two ends of the rectum that are now exposed. If the initial prolapse was too long initially for luminal tube placement, the inner portion of the prolapse may be grasped, the crosspins removed, and a tube placed at this point (Figures 21-9 and 21-10). The cut ends of the rectum are then sutured together using size 0 or 2-0 absorbable suture, preferably a monofilament on a taper needle. Maintenance of orientation to the anatomy is facilitated by the initial placement of three interrupted sutures at 12, 5, and 8 o'clock (Figure 21-11). The intervening spaces are then



Figure 21-6 Initial cross pinning of the prolapse. The length of this prolapse initially limited placement of a luminal tube, so cross pinning was performed to facilitate amputation of the distal portion with later placement of the tube. See later figures.

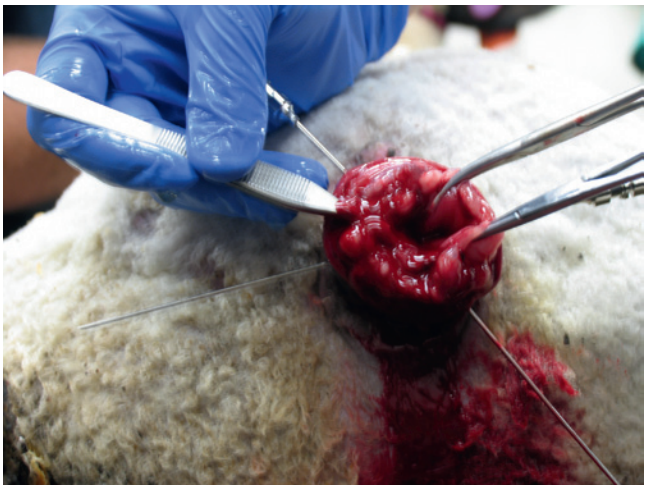


Figure 21-9 The inner large colon is grasped by hemostats and thumb forceps to maintain its exterior placement, and the cross pins are pulled to allow placement of the luminal tube.



Figure 21-7 Incision distal to the crosspins for amputation.



Figure 21-10 The luminal tube is placed and cross pins replaced.



Figure 21-8 Circumferential incision is complete, and the proximal large colon is kept from retracting into the abdomen by the crosspins.

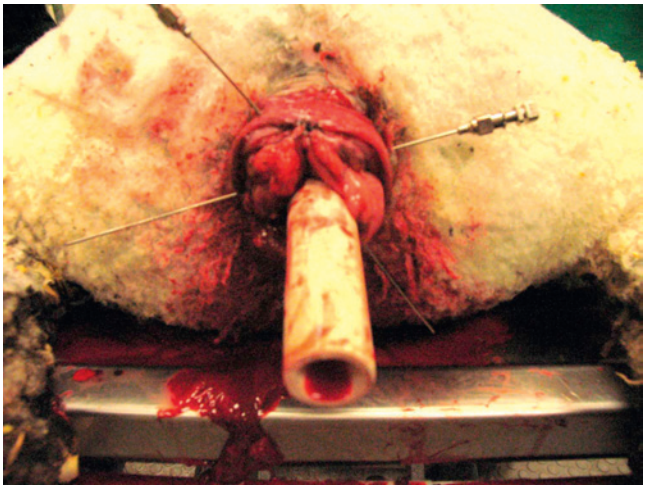


Figure 21-11 Initial 12 o'clock suture placed.

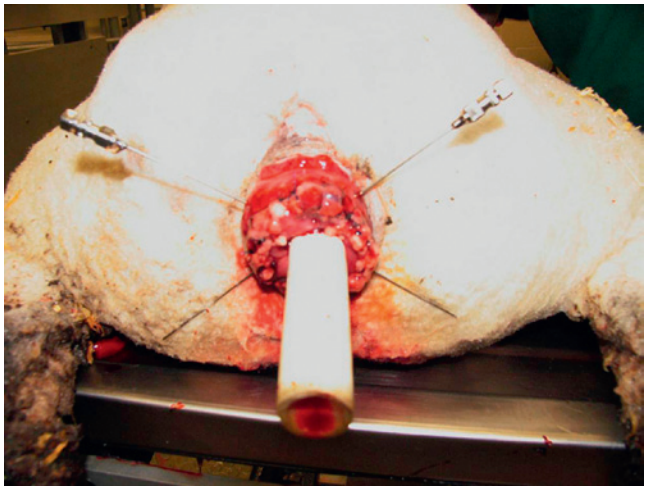


Figure 21-12 The anastomosis is complete and the pins and tube will be removed, allowing for replacement of the prolapse.

filled. A simple interrupted or cruciate pattern is most appropriate (Figure 21-12). Interrupted continuous lines, where a portion is sutured in a continuous pattern and the pattern is stopped and then restarted, may also be used but may be associated with an increased risk of stricture. Once the anastomosis is complete, the needles are pulled and the tube (if used) removed. The rectum is then replaced.

Analgesics and antimicrobials should be used before and after surgery, and measures should be taken to soften the feces to facilitate passage past the anastomosis. This may include administration of mineral oil or magnesium hydroxide or slightly increasing the legume or grain portion of the diet. Owners should monitor animals for general demeanor, appetite, abdominal contour, and fecal passage. Animals with increases in abdominal size, reductions in appetite, or evidence of constipation should be evaluated. Strictures, abscesses, peritonitis, dehiscence, and death are all potential postoperative complications.

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CHAPTER 22

Surgery of the Sheep and Goat Musculoskeletal System

Wade Walker

PATELLAR LUXATION IN SHEEP AND GOATS

Patellar luxation is a common cause of hind limb lameness in sheep and goats. The etiology is primarily thought to be congenital, although traumatic patellar luxations also occur. Unlike cattle that typically suffer from lateral patellar luxation, the predominant direction of patellar luxation in small ruminants is medial. In our hospital, medial patellar luxations often occur bilaterally in contrast to lateral luxations, which are typically seen unilaterally in relatively older animals. This suggests a congenital and traumatic etiology for medial and lateral patellar luxations, respectively, although this has not been scientifically elucidated.

Patients typically present with a history of progressive hind limb lameness and a stiff gait. Upon physical examination, they are often post legged or upright with external rotation of the hind limb. In more severe cases, patients present with an inability to extend the stifle or a history of prolonged recumbency and inability to rise. The small animal canine patellar luxation grading scheme is used (Table 22-1; see also Chapter 18). Grade 1 luxations are subclinical and can only be elicited upon palpation. Grade 1 luxations can often be managed medically with confined rest and physical therapy. Patients with grade 2 patellar luxation are surgical candidates depending on frequency of luxation and owner expectations concerning postoperative management and costs. Grades 3 and 4 patellar luxations require surgical intervention for appropriate function. Radiographic evaluation consists of three views (lateromedial, caudocranial, and skyline projections). On the lateromedial projection, the patella is transposed over the femoral trochlea if it is actively luxated (Figure 22-1*A*). The caudocranial projection is best to verify the direction of patellar luxation and the progression of osteoarthritis due to femoropatellar instability (Figure 22-1*B*). The skyline projection is performed with the stifle maximally flexed, x-ray tube dorsal and plate positioned on the cranial aspect of the proximal tibia (Figure 22-2). The skyline projection is used to determine the depth and curvature of the femoral trochlea and if sulcoplasty is indicated. A trochlear groove depth of 4 to 5 mm with biaxial triangular trochlea and a uniform subchondral bone plate is within normal limits.

Surgical Approach

The patient is premedicated with broad-spectrum antibiotics and antiinflammatories. General anesthesia is induced and the patient is positioned in dorsal recumbency with the affected hind limb suspended using a mobile hoist. Conversely, the hind limb can hang free if a surgical assistant is available for manipulation. The stifle is aseptically prepared, and the surgical field is draped including a sterile stocking net and vet wrap encompassing the entire distal limb. The quadriceps apparatus is critically assessed under a full range of motion including maximal internal rotation to determine the appropriate surgical intervention. A 12-cm curvilinear skin incision is centered longitudinally over the patella with the proximal and distal extents of the incision extending 2 cm lateral to midline. Stifle flexion allows the skin over the patella to separate for further visualization of the quadriceps apparatus. The vastus intermedius, patella, patellar ligament, tibial tuberosity, and tibial diaphysis should form a straight line. Often, the patellar ligament diverges medially from the line of the vastus intermedius and patella to the tibial tuberosity and tibial shaft. If misalignment is appreciated, a tibial tuberosity transposition is recommended.

Lateral Capsule Imbrication

Grade 2 patellar luxations are often managed with a lateral capsule imbrication and a medial retinacular release. After the initial incision is made with the patella reduced, a 4-cm longitudinal incision at the level of the patella is made through the joint capsule into the medial cul-de-sac of the femoropatellar compartment. The retinacular release is made distal to the medial femoropatellar ligament, encompassing the entire length of femoropatellar joint contact. The patella is distracted laterally in order to assess pathology of the cruciate ligaments, menisci, retropatellar surface, and femoral condyles. The patella is then manually reduced into the femoral trochlea and an 8-cm longitudinal incision is made beginning at the level of the tibial plateau 4 cm lateral to the patella. The incision is extended proximally through the vastus lateralis and lateral femoropatellar joint capsule. An approximately 2-cm lateral capsulectomy can be performed. The imbrication is made using several vertical mattress (or Lembert) sutures in deep and then superficial layers within the capsule and the fascia of the vastus lateralis. Occasionally, incorporation of the gluteobiceps fascia is necessary. Alternatively, a vest-over-pants pattern can be employed to obliterate 2 to 3 cm of the lateral periarticular space. In both techniques, a large nonabsorbable multifilament suture is used to complete the imbrication. Reduction of the luxation is confirmed under a full range of motion.

Tibial Tuberosity Transposition

Quadriceps apparatus misalignment is most readily appreciated with the distal limb fully internally rotated with slight flexion. If misalignment is appreciated, a tibial tuberosity transposition must be performed in order to maintain proper conformation. An oscillating saw is used in frontal plane from medial to lateral to perform a tibial tuberosity osteotomy starting at the tibial plateau and moving distally. A 1.5-cm osteotomy of the tibial tuberosity is usually achieved with a longitudinal distance of approximately 5 to 6 cm. The cranial tibial muscle is elevated off the lateral surface of the tibia to avoid iatrogenic injury from the saw. The periosteum of the distal tibial tuberosity at the end of the osteotomy is spared and used as a hinge for rotation and an additional anchor for the tension band. The tibial tuberosity is rotated laterally with the limb in maximal internal rotation until the patellar ligament forms a straight line with the more proximal aspect of the quadriceps apparatus. Reduction of the transposition is achieved with two converging –3.2-mm K-wires through the tibial tuberosity and the trans cortex tibial plateau. The K-wires are cut sparing the most superficial 1 cm of the wire. Special attention is made so that the articular surface of the tibial plateau is not penetrated. The

Table • 22-1

The Canine Patellar Luxation Grading Scheme Used in Small Ruminant Orthopedics

GRADE	DESCRIPTION
1	Patella can be manually luxated but returns to normal position when released.
2	Patella luxates with stifle flexion or on manual manipulation and remains luxated until stifle extension or manual replacement occurs.
3	Patella luxated continually. Patella can be manually replaced but will reluxate spontaneously when manual pressure is removed.
4	Patella luxated continually and cannot be manually replaced.

(Adapted from Roush JK: Canine patellar luxation, *Vet Clin North Am Small Anim Pract* 23:855-868, 1993.)

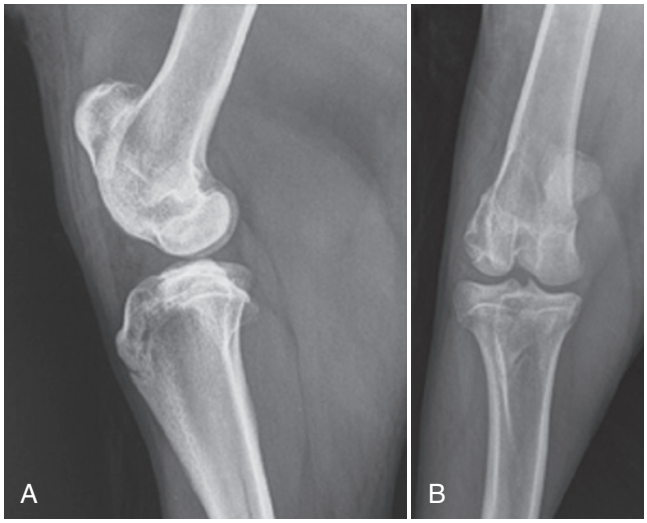


Figure 22-1 *A*, Preoperative lateromedial and, *B*, caudocranial projections of a grade 3 medial patellar luxation. Note the transposition of the patella with the trochlear ridges on the lateromedial view and the medial translocation of the patella on the caudocranial view indicating active patellar luxation.



Figure 22-2 Preoperative skyline view of the femoral trochlea in a grade 2 patellar luxation. The femoral trochlea is 4 mm in depth with sharply demarcated trochlear ridges and a smooth subchondral bone plate. Note the mineralized medial and lateral cartilaginous wings of the patella.

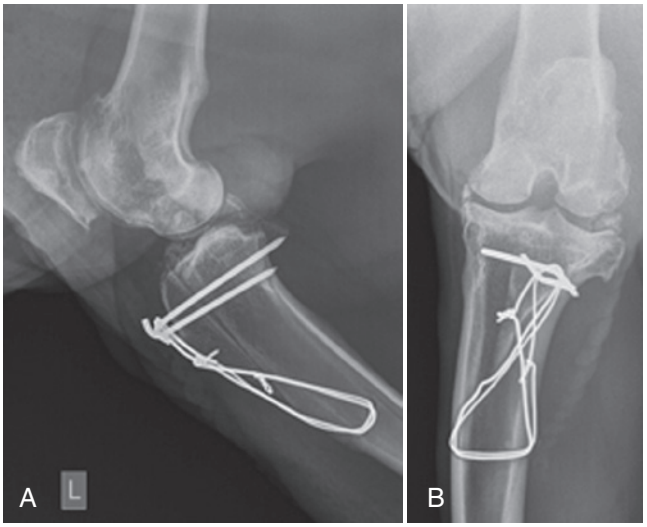


Figure 22-3 *A*, Postoperative lateromedial and, *B*, caudocranial projections after a tibial tuberosity transposition and lateral imbrication. The tibial tuberosity was transposed approximately 1 cm laterally in order to provide appropriate anatomic conformation.

tension band is completed using a 2.5-mm bit to drill a transverse hole in medial to lateral direction through the tibial diaphysis 3 to 4 cm distal to the osteotomy site. Two 18-gauge wires are passed through the hole and then around the K-wires in a figure-8 pattern. The K-wire stumps are bent proximally as they exit the tibial tuberosity. The wire is tightened so no slack is present (Figure 22-3). The wire ends are bent away from the skin to prevent future irritation. The tibial tuberosity transposition is always accompanied with a lateral imbrication. If an oscillating saw is not available, the osteotomy can be used with an osteotome and predrilled holes for guidance.

Sulcoplasty

A sulcoplasty may be indicated in cases of trochlear hypoplasia or flattening due to chronic instability. A trochlear block recession is made with an oscillating saw throughout the entire length of the trochlea. The block is placed in sterile saline, and a bone rasp is used to deepen the groove. The block is digitally replaced back into the trochlear groove and maintains reduction via cancellous bone friction with the trochlear ridges. Care is made to avoid abaxial osteotomies too close to the trochlear ridges or excessive deepening of the trochlear groove. Additionally, a V-wedge recession has been reported in camelids with success (Abuja). Sulcoplasty in small ruminants can be further complicated by

calcification of large medial and lateral cartilaginous processes of the patella (see Figure 22-2). In these cases, the retropatellar surface in juxtaposition to the trochlear ridges must be curetted in order to achieve patellar recession.

Postoperative Management

The subcutaneous and skin layers are closed individually in a simple continuous fashion. A stent is placed over the incision for 3 days postoperatively. Antibiotic coverage is maintained for 5 days postoperatively. The patient is maintained in small stall confinement for 6 weeks. After suture removal 10 to 14 days postoperatively, passive range of motion stifle flexion exercises are initiated two to three times daily until the end of the rest period. Rehabilitation is ceased 6 weeks postoperatively, and the patient is returned to its normal routine.

SUMMARY

Patellar luxation is commonly appreciated in small ruminant practice. Congenital anatomic abnormalities are the most likely etiology, although traumatic injury is also appreciated. Surgical repair is indicated with luxation grades 2 to 4 or when conservative management has failed. Clients must be warned of the potential of surgical failure as the recurrence of postoperative luxation in small animals is up to 48 percent. The aforementioned techniques are described for cases of medial patellar luxation. Similar but reverse techniques can be used in cases of lateral patellar luxations (see also Chapter 18). A tibial tuberosity transposition can decrease the incidence of postoperative failures and is necessary when the quadriceps apparatus is misaligned.

RECOMMENDED READINGS

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CHAPTER 23

Surgery of the Sheep and Goat Reproductive System and Urinary Tract

Ahmed Tibary, Lisa K. Pearson, David C. Van Metre and Kyla Ortved

ANESTHESIA AND RESTRAINT

Most elective surgeries in small ruminants can be performed using a combination of chemical and physical restraint. In nonemergency situations (e.g., teaser preparation in rams and bucks, laparoscopy), food should be withheld for 24 to 48 hours and water for 12 to 24 hours. Broad-spectrum antibiotics should be given 2 hours before surgery. Mild sedation can be obtained with 0.05 mg/kg xylazine. Goats are more sensitive to xylazine. Sedation of 30 to 60 minutes' duration may be obtained in goats with 0.01 to 0.02 mg/kg intravenous (IV) detomidine. Standing sedation may also be obtained with 0.01 mg IV detomidine and 0.1 mg/kg IV butorphanol. The combination of xylazine (0.01 to 0.02 mg/kg) and butorphanol (0.01 to 0.02 mg/kg) IV produces deep sedation for up to 60 minutes. Chemical restraints most commonly used include a combination of xylazine, telazol (tiletamine/zolazepam), and ketamine. A xylazine (0.11 mg/kg) and telazol (13.2 mg/kg) IV combination provides 90 to 120 minutes of anesthesia with good smooth muscle relaxation. Telazol (6.6 mg/kg) IV and ketamine (6.6 mg/kg) IV provide 20 to 40 minutes. Telazol (6.6 mg/kg), ketamine (6.6 mg/kg), and xylazine (0.11 mg/kg) IV provide 60 to 90 minutes of anesthesia time.

A lumbosacral epidural provides analgesia for more involved surgery (i.e., penile translocation, cesarean section). This is accomplished by injecting 2 mL of 2% lidocaine hydrochloride per 10 kg body weight or 1 mL of 0.75% bupivacaine per 4 kg body weight in the space between the last lumbar vertebra and the sacrum (lumbosacral foramen). An 18- or 20-gauge, 4-cm disposable needle is used for small-sized animals. Larger sheep may require a 9-cm spinal needle. No blood or cerebrospinal fluid should be seen. Onset of anesthesia occurs within 5 to 15 minutes and lasts 60 to 120 minutes. Lumbosacral epidural using medetomidine (0.01 to 0.03 mg/kg) diluted in sterile water to 5 mL produces analgesia of the peritoneum and flank extending to the thorax and fore limb for up to 120 minutes.

Epidural anesthesia in sheep and goats achieved with 2 mL of 2% lidocaine hydrochloride induces perineal anesthesia 1 to 3 minutes after injection and lasts 60 minutes. Ataxia may be seen with a larger volume of lidocaine. Xylazine (0.07 to 0.1 mg/kg) may be used with or without lidocaine to produce longer-duration analgesia.

General anesthesia is preferred for abdominal surgery (cesarean section, ovariectomy, hysterectomy), although sedation and regional anesthesia (achieved with a line block of 10 to 20 mL of 1% lidocaine) can be used. Higher doses of lidocaine may cause toxicity (apnea, respiratory depression, hypotension, and hypothermia). The maximum recommended dosage of parenteral lidocaine in small ruminants ranges from 6 to 10 mg of lidocaine per kilogram of body weight. An inverted-L block can be used for flank cesarean section.

SURGERY OF THE FEMALE REPRODUCTIVE TRACT

Cesarean Section

Cesarean section should be considered to manage dystocia when vaginal delivery is not possible. The most common indications for cesarean section in sheep are failure of cervical dilation (ringwomb), vaginal prolapse, and fetal maldisposition. In goats, the most common indication is fetomaternal disproportion, particularly in small breeds (i.e., pygmy or Nigerian dwarf goats). Occasionally the technique can be used to terminate pregnancy in ewes that are suffering from pregnancy toxemia or ketosis. Emergency situations requiring cesarean section include uterine torsion, ruptured prepubic tendon, ruptured uterus, and rectal or intestinal prolapse.

Restraint and Anesthesia

Cesarean section can be performed via either a ventral abdominal paramedian or midline incision with the animal in dorsal recumbency or via a left flank (paralumbar) incision with the animal in right-lateral recumbency. Standing left-flank approach has been described in sheep. Ventral midline or paramedian techniques are the preferred methods in sheep because the area does not have as much wool. This technique also provides easy access to both horns of the uterus, which is important because most ewes carry more than one fetus. A ventral midline or paramedian approach is preferred in cases where the uterus is compromised (i.e., uterine torsion or rupture) or there is a high risk for contamination. Cesarean section can be performed in the field under lumbosacral epidural and local anesthesia, although use of lumbosacral epidural anesthesia has been associated with a risk of shock as a result of pooling of blood in the viscera. Epinephrine (0.02 mg/kg IM) may be administered intramuscularly as a prophylactic measure.

The Ventral Abdominal Paramedian Approach

After anesthesia, the ewe is restrained in a dorsal position in a cradle with her legs extended. The surgical area, which extends from the umbilicus to the base of the mammary gland and laterally toward the mid-flank, is prepared by clipping the wool and aseptic preparation of the skin.

The 25-cm skin incision extends from the umbilicus toward the base of the udder. The incision should be made between the linea alba and subcutaneous abdominal vein, which is very prominent in late pregnancy. The approach is continued by using a combination of blunt and sharp dissection through subcutaneous tissues. The external rectus abdominis sheath is sharply incised, the rectus muscle bluntly separated along its fibers, and the internal rectus sheath tented, along with the peritoneum, and incised. The abdominal incision may be extended, if necessary, to allow easy exteriorization of the uterine horn. The surgeon should be careful not to incise the greater omentum, which lies deep



Figure 23-1 Paramedian ventral cesarean section: exteriorization of the uterus.

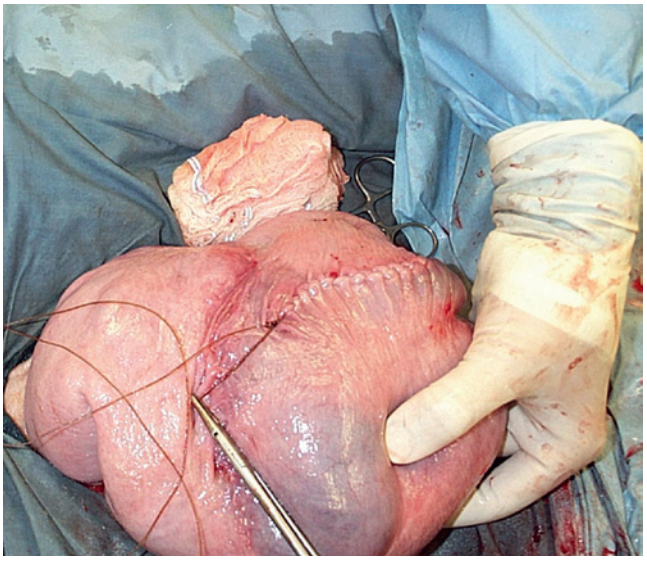


Figure 23-2 Cesarean section: closure of the uterus using a continuous inverting suture.

in the peritoneum. The greater omentum and abdominal viscera are retracted cranially to expose the uterus. The uterine horn is grasped and exteriorized gently to avoid perforation (Figure 23-1). Hysterotomy is performed on the greater curvature of the uterine horn, starting at the upper third and extending toward the uterine bifurcation. Care should be taken to avoid incising through placentomes, which prevents excessive bleeding. In most cases, ewes carry more than one fetus. Therefore a uterine incision large enough to allow a fetus in the other horn to be exteriorized through the same incision should be placed along the caudal aspect of the horn. If this is too difficult, a second hysterotomy may be performed on the other uterine horn. Depending on the presentation, the fetuses are exteriorized by traction on the front legs and head or on the hind legs. During exteriorization of the fetus, the surgeon should be careful not to tear the uterine wall. Excess fetal fluid should be removed from the uterus. The placenta should be removed only if it is already detached. The uterus is sutured with an atraumatic needle with chromic catgut (No. 0 or 1-0) or other synthetic absorbable suture in a continuous inverting suture pattern (Figure 23-2). If the uterus is compromised, a two-layer closure may be indicated. The sutured uterus should be checked for tears and lavaged copiously with sterile fluids before it is replaced into the abdominal cavity. Some authors suggest intrauterine and intraabdominal antibiotic therapy, but this is not usually necessary if the surgery is performed under aseptic or very clean conditions and systemic antibiotics are provided.

The peritoneum and internal rectus sheath are sutured in a single layer with synthetic absorbable sutures in a continuous pattern. Inclusion of the peritoneum in the first layer of closure is at the surgeon's discretion. The rectus abdominis muscle may be closed to decrease dead space. The external rectus sheath is the holding layer. This should be closed carefully with an absorbable suture. Subcutaneous tissues and skin are closed routinely. The size of the suture varies with the weight of the animal. Some surgeons advocate the use of nonabsorbable sutures to decrease the risk of herniation and provide better security.

Postsurgical care includes oxytocin if the cervix is open, systemic antibiotics (penicillin G 22,000 units/g, intramuscularly (IM) or subcutaneously (SC) every 24 hours or tetracycline 20 mg/kg IM or SC every 24 hours) and nonsteroidal antiinflammatory drugs (flunixin meglumine 1 mg/kg IV or 2.5 mg/kg IM every 12 hours) as indicated. The udder should be examined for milk letdown. Colostrum should be stripped for administration to the neonates. During the surgery, there should be an assistant designated to attend immediately to the newborn and provide neonatal care.

Left-Flank Laparotomy. This technique is recommended under field conditions and can be done quite easily with sedation and a line or an inverted-L block to provide regional anesthesia. In some cases, epidural anesthesia may help provide analgesia. The patient is placed in right-lateral recumbency and propped up to a 30-degree angle toward the surgeon with a cushion or roll of towels. The surgical site (paralumbar fossa) is prepared for surgery and draped. The 15- to 25-cm skin incision may be vertical or slightly oblique starting about 5 cm ventral to the transverse processes of the lumbar vertebrae and centered in the fossa (Figure 23-3). The incision may be continued through the muscle layers. Alternately, the muscle layers can be opened by blunt dissection along the muscle fiber direction in a grid fashion (Figure 23-4*A-D*). The peritoneum is incised in the manner described along the same incision of the transverse abdominal muscle (Figure 23-5*A* and *B*). The abdominal wall in term-gestation sheep and goats is very thin, and the rumen may be distended. Care should be taken not to penetrate all layers with an aggressive incision to avoid incising the rumen, intestines, or uterus. The surgeon locates the uterus by gentle palpation of the abdominal content. An exploration of the abdomen is always advised, particularly palpation of the cervical region and the broad ligaments to determine whether a uterine torsion is present. The uterus is exteriorized gently by grasping one uterine horn around the fetal metacarpal or metatarsal III near its tip. The uterus is incised along the greater curvature as described earlier (Figure 23-6*A*). Wet laparotomy towels may be placed around the uterus to avoid spilling of the uterine content into the abdominal cavity, particularly when dealing with dead or decomposed fetuses. Delivery of the fetus(es) and closure of the uterus are performed as described previously (Figure 23-6*B*). Lavage of the surface of the uterus and the abdominal cavity may be required. The transverse abdominal muscle and peritoneum



Figure 23-3 Cesarean section: flank approach, animal positioned in lateral recumbency and prepped for surgery.

are closed together with a simple continuous pattern using No. 1 absorbable suture. The internal and external abdominal muscles may be closed together. The skin incision is closed with nonabsorbable suture using an interrupted cruciate or a Ford interlocking pattern. The author prefers a flank laparotomy for cesarean section in goats.

Ventral Midline Approach. The ventral midline approach to cesarean section in small ruminants differs from the paramedian approach in that the skin and abdominal incisions are made directly over the linea alba. Incision of the skin starts at the base of the udder and is extended about 20 cm cranially toward the umbilicus. The subcutaneous tissue is incised to expose the linea alba, which should be evident as a small concave line. The abdominal wall is grasped with tissue forceps and tented, and a small incision is made on the linea alba (Figure 23-7*A*-C). The incision is continued through the linea alba and peritoneum, with scissors guided by the operator's index and middle fingers to avoid damaging the omentum or intestinal loops. Exteriorization of the uterus and delivery of fetuses is done in the same manner as described for the paramedian approach. The linea alba and peritoneum are sutured in an interrupted or continuous pattern with synthetic absorbable or nonabsorbable sutures. Subcutaneous tissues and skin are closed routinely. Postsurgical care is similar to the paramedian technique.

Postsurgical Complications and Fertility

Fetal and dam viability following cesarean section have been studied retrospectively in a few studies. Fetal viability ranges from 40% to 80% and depends primarily on the time to referral and the cause of the dystocia. Fetal viability is improved when surgery is performed within 2 hours of onset of the second stage of labor. Dam viability is usually very high (>95%) when the fetuses are delivered alive. Dam viability decreased significantly (<60%) when the fetuses were dead and autolytic.

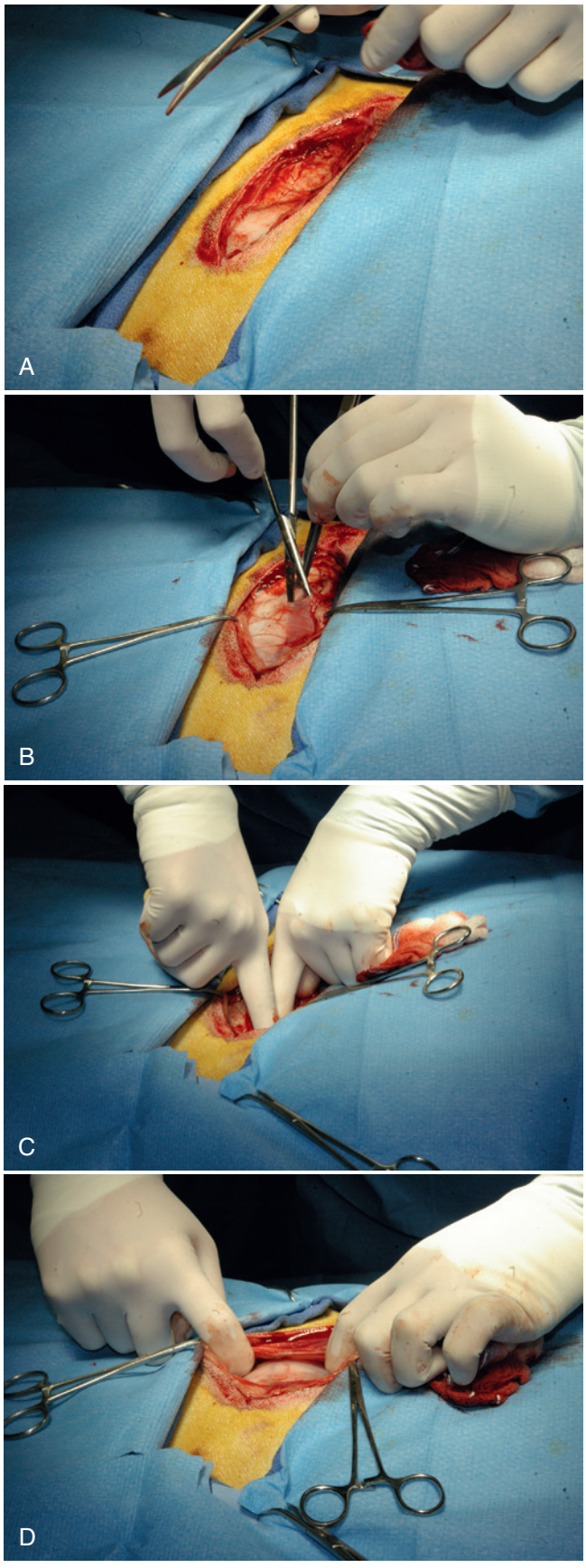


Figure 23-4 *A-D*, Cesarean section: flank approach, using a muscle grid technique.

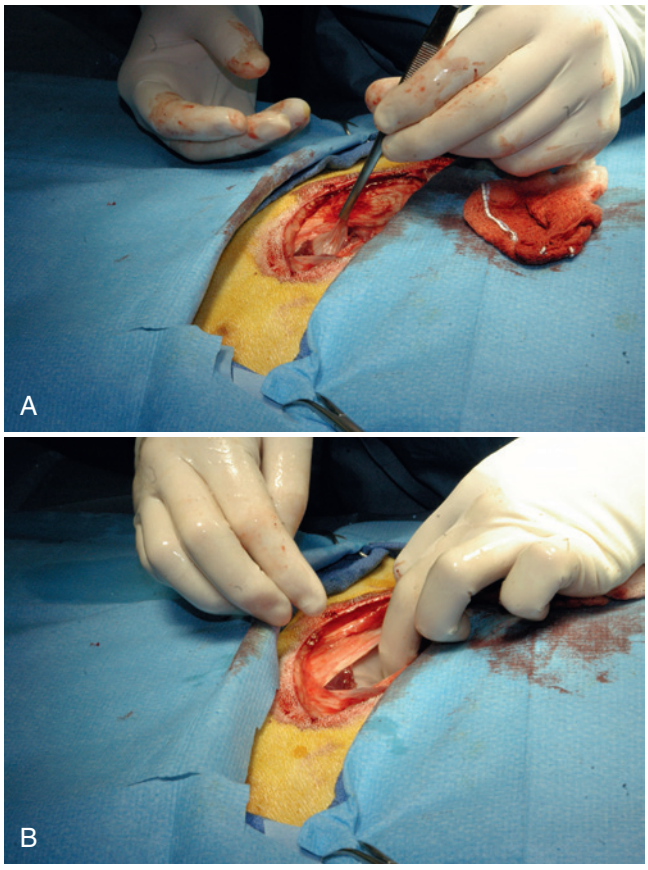


Figure 23-5 *A* and *B*, Cesarean section: flank approach, incision of peritoneum and exploration of the abdomen.

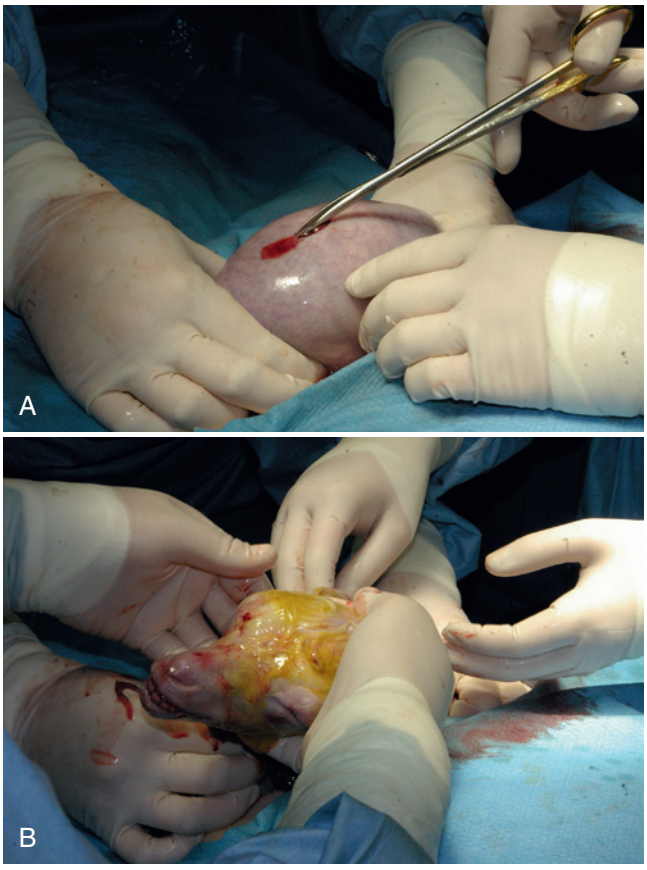
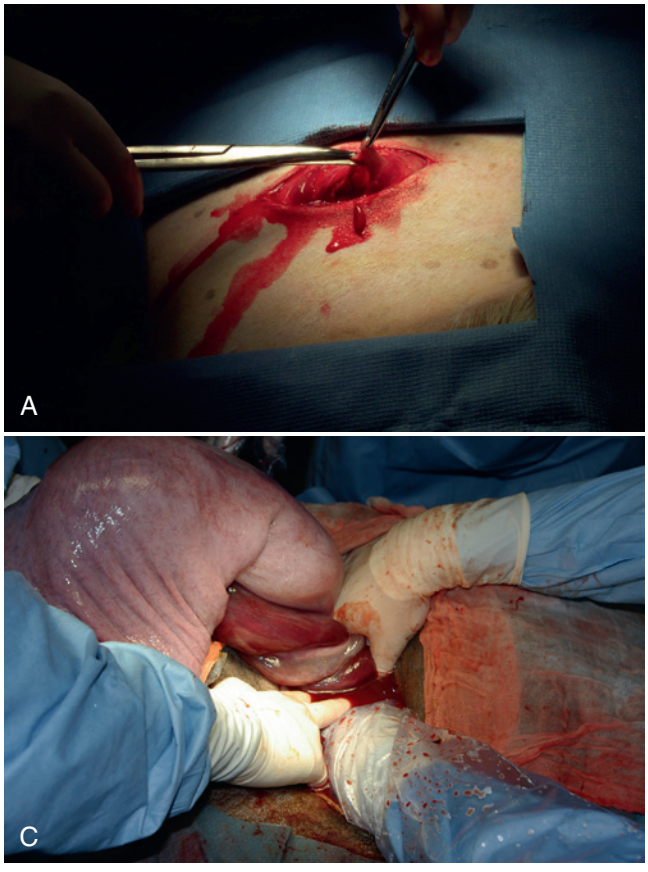


Figure 23-6 *A* and *B*, Cesarean section: flank approach, exteriorization of the uterus, and delivery of the kid.



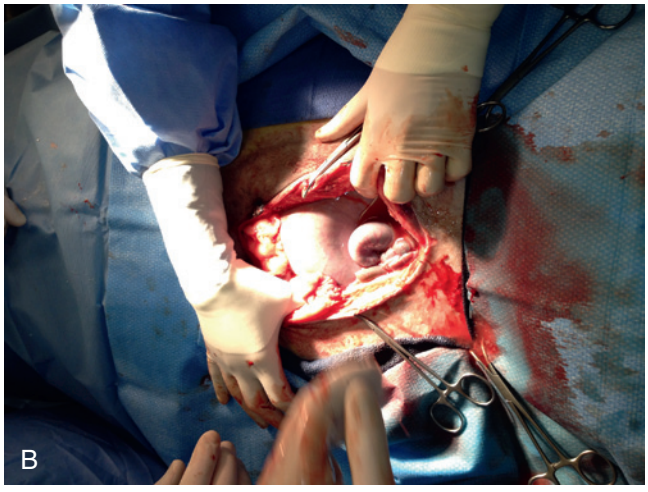


Figure 23-7 *A-C*, Cesarean section: ventral midline approach with exteriorization of the uterus.

Common postsurgical complications include retained fetal membranes, peritonitis, and incisional problems (i.e., infection and dehiscence). Routine administration of oxytocin (5-10 IU) intra- and postsurgically may reduce the incidence of retained placenta. Incisional complications are reportedly more severe with the flank approach because wound healing is much faster and better in the absence of large muscular structures (midline). Prognosis for fertility is very good when no complications are observed.

Ovariectomy and Ovariohysterectomy

Exteriorization of the female reproductive organs is required for many advanced reproductive techniques such as embryo collection and transfer, oocyte collection, uterine tube flushing, etc. An ovariectomy or ovariohysterectomy is usually performed for convenience to prevent sexual activity and eliminate pregnancy or to remove diseased organs (ovarian or cervical masses, chronic pyometra, uterine neoplasm, etc.).

An ovariectomy or ovariohysterectomy performed as an elective surgery should be done during the luteal phase of the cycle or during anestrus so that the uterus is relaxed and bleeding problems that would be associated with a toned, well-vascularized uterus during estrus are prevented. Ovariectomy is easily performed on the anesthetized animal placed in dorsal recumbency. A small 6- to 8-cm incision is made on the ventral midline just cranial to the udder and continued into the abdominal cavity as described for cesarean section (Figure 23-8). The surgeon introduces two fingers into the abdominal cavity. The urinary bladder is identified, and the uterus is recognized in its dorsal aspect by following one of the horns to the uterine bifurcation. Vaginal manipulation with a sterile tube speculum or blunt-ended rod by an assistant may help the surgeon locate the uterus. Once the uterine horn is grasped between the fingers, it is pulled toward the surgical incision. Both horns are exteriorized by gentle traction (Figure 23-9).

For ovariectomy, the vascular pedicle of the ovary is isolated by passing forceps through the mesovarium and making sure to incorporate the ovarian artery and vein. A No. 0 absorbable suture material is used to transfix the ovarian pedicle before transection (Figure 23-10). Large ovarian masses (i.e., granulosa theca cell tumor) (Figure 23-11) may require placement of overlapping transfixing sutures on the pedicle to prevent hemorrhage.

For hysterectomy or ovariohysterectomy, the mesometrium and round ligament of each uterine horn are transected after ligation of small blood vessels. Transfixation ligatures are placed proximal to the cervix; the surgeon should make sure to include the large uterine vessels located on each side. The uterus is transected at the level of the body between two hemostatic forceps (Figure 23-12). A circumferential transfixation ligature of absorbable suture material is placed close to the cervix. If the remaining portion of the



Figure 23-9 Ovariectomy/ovariohysterectomy: exteriorized uterus and ovaries.



Figure 23-10 Ovariectomy/ovariohysterectomy: transfixation of the ovarian pedicle.

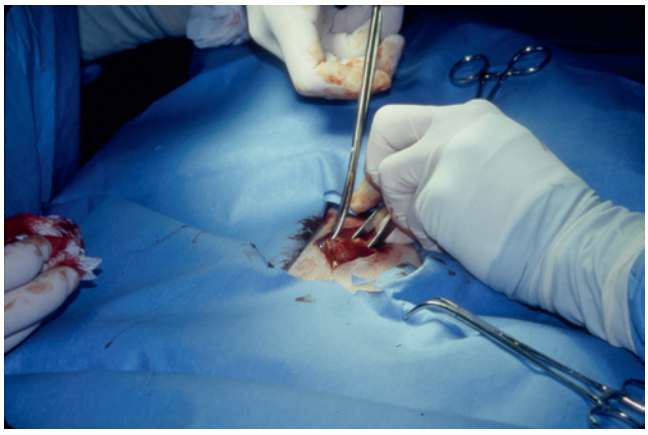


Figure 23-8 Ovariectomy/ovariohysterectomy: entering the abdomen.

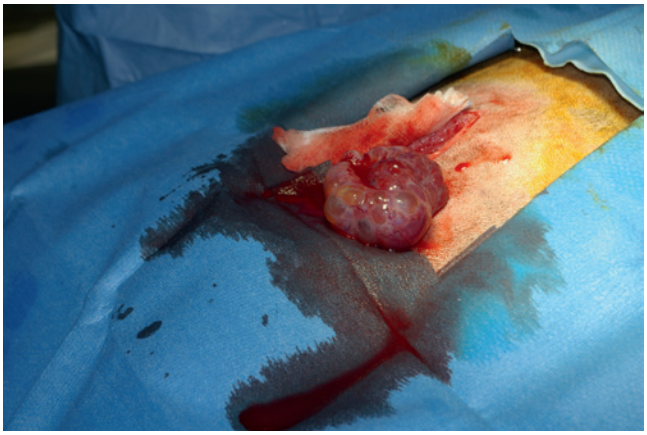


Figure 23-11 Ovariectomy: granulosa theca cell tumor.

uterine body is large, it should be closed with an inverting suture pattern before replacing it in the abdomen. Removal of one horn or part of a uterine horn (a partial hysterectomy) is sometimes used in research settings or for treatment of pathology confined to one side of the abdomen. The technique is similar to a total hysterectomy, although a flank approach would be possible. The vasculature supplying the ovary and ipsilateral horn is ligated and transected. The remaining uterus is closed with an inverting pattern. Some advocate a two-layer uterine closure. For successful reproductive performance, it is essential the remaining ovary and uterine horn are normal.

Ovariohysterectomy including the cervix is more challenging for the surgeon, particularly if the latter is diseased. However, the authors have successfully performed the technique in cases of large cervical leiomyomas. In these cases, the abdominal incision may need to be extended as far caudally as possible to expose the entire cervical mass. Large tumors are often associated with large blood vessels that require individual ligation or electrocautery (Figure 23-13).

Postsurgical care should include antimicrobial therapy and pain management. The most common complication of ovariectomy and ovariohysterectomy is intraoperative hemorrhage due to overt manipulation and rupture.

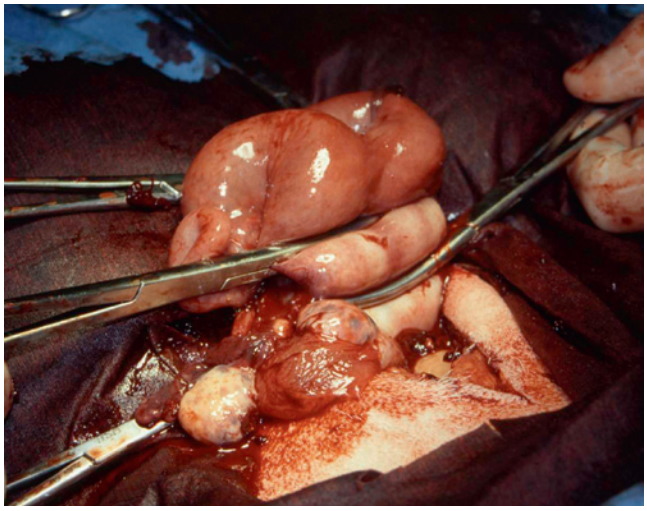


Figure 23-12 Ovariectomy/ovariohysterectomy: transection of the uterus at the level of the uterine body between two hemostatic forceps.

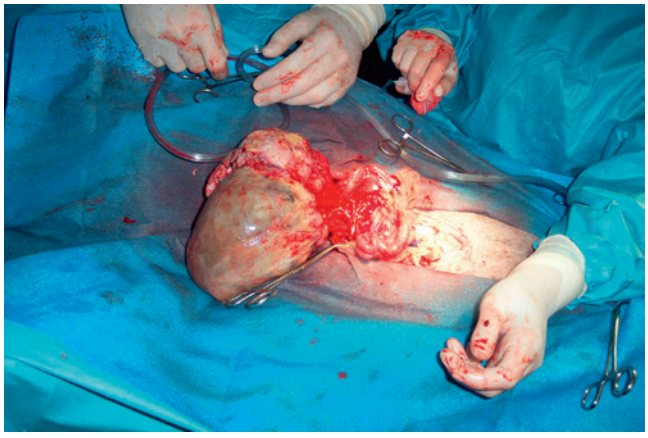


Figure 23-13 Cervical leiomyoma exteriorized at surgery.

LAPAROSCOPY

Laparoscopy is widely used in small ruminants as a tool for reproductive studies and application of reproductive biotechnologies such as intrauterine insemination, embryo transfer, oocyte collection, and ovulation rate determination. This technique can also be used for direct visualization of ovarian abnormalities, diagnosis of periuterine abnormalities, and evaluation of abdominal organs. Laparoscopic procedures to visualize and manipulate the female reproductive tract in small ruminants are easy to learn and present the advantage of being less invasive than complete exteriorization of the genital tract. The technique requires the use of a rigid laparoscope with a diameter of 6 to 10 mm and various lens angles, depending on the indication for the procedure. For most reproductive techniques, a 6-mm-diameter laparoscope with a 30-degree angle is sufficient. This allows a minimal incisional size for portal placements.

Laparoscopy is usually performed on the sedated or anesthetized animal in dorsal recumbency on a cradle that can be tilted. Animals should be fasted for at least 12 hours to reduce rumen fill and the possibility of regurgitation. Withholding food and water for at least 24 hours reportedly eliminates regurgitation during anesthesia. Many practitioners prefer just 3 to 4 hours' emptying in spring (green feed) or no fasting if ewes are on dry feed.

An area 25 cm by 25 cm cranial to the mammary gland is prepared by clipping and surgical scrubbing. For most reproductive procedures, two or three portals are necessary: one each for the laparoscope, a manipulation instrument, and special instruments (insemination gun, suture material) (Figures 23-14 and 24-15). For insemination and embryo transfer, only two portals are necessary: one each for the laparoscope and insemination gun. The site of the desired portals is infiltrated with local anesthetic before introducing a trocar and cannula. Abdominal insufflation with medical-grade filtered CO_2 helps avoid any trauma to the viscera. For simple techniques, the portals are created by making a small skin incision to allow trocar introduction. The trocar is advanced 4 cm subcutaneously before the abdominal cavity



Figure 23-14 Laparoscopic artificial insemination: location of the portals for the light source (*left*) and insemination gun (*right*).

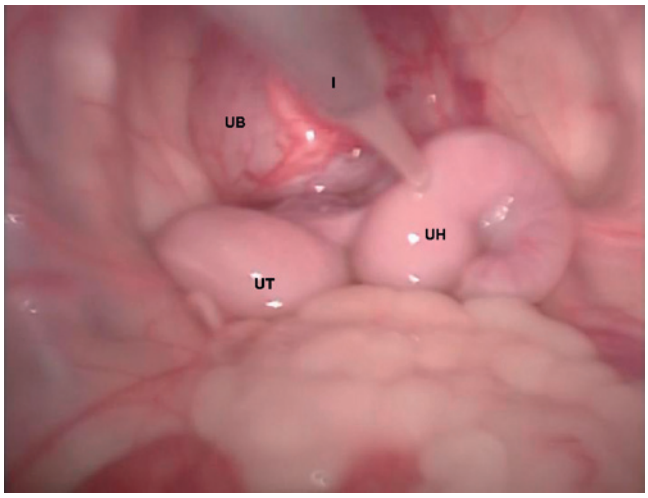


Figure 23-15 Laparoscopic artificial insemination: laparoscopic view of the urinary bladder (UB), uterus (UT), and insemination gun (I).

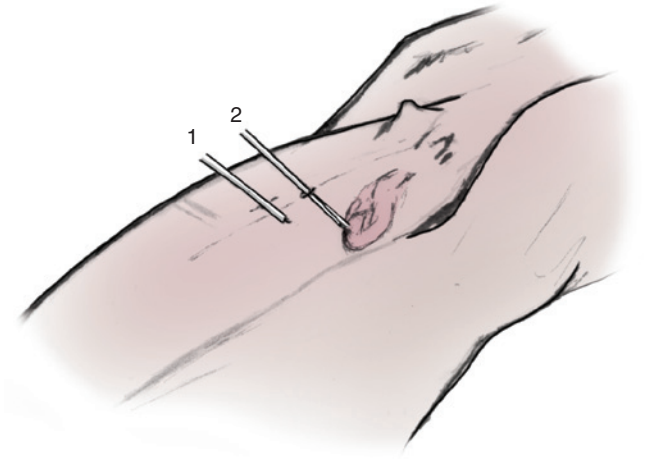


Figure 23-16 Laparoscopic-assisted embryo transfer. Schematic drawing of the placement of portals.

is penetrated by applying pressure on the abdominal wall muscle and peritoneum. This provides portals into the abdomen not directly aligned with the skin incision, which helps to prevent contamination of the abdominal cavity and maintain an air-tight seal. This technique does not require suturing the abdominal muscle after cannula removal. Visualizing the abdominal viscera requires insufflation with CO_2 (5-8 mm Hg) and elevating the hindquarters to a 40-degree angle (Trendelenburg positioning).

For embryo transfer, a sedation dose is obtained with xylazine and ketamine. The recipient is placed in a cradle at 45 degrees. A 2-cm incision is made on the ventral midline about 5 to 6 cm cranial to the udder. Babcock forceps 18 cm in length are introduced and used to grasp the uterine horn and bring it to the incision (Figure 23-16). The scope is removed, and the embryo is placed in utero by using a micropipette mounted on a tuberculin syringe to penetrate the uterine wall. The uterine horn is replaced gently, and the abdominal wall is closed.

Laparoscopic-Assisted Ovariectomy

Laparoscopic-assisted ovariectomy is a minimally invasive technique that reduces surgical time and complications compared with laparotomy. The technique requires two or three portals depending on the equipment used. In the three-portal technique, the laparoscope port is made by inserting a trocar in the linea alba about 30 cm cranial to the mammary gland. The other two portals are created 10 cm cranial to the udder and 5 cm laterally to each side of the linea alba to allow introduction of a 10-mm Babcock atraumatic forceps on one side and a 5-mm atraumatic grasping forceps on the other. The ovary is located, grasped from the pedicle, and exteriorized through the larger portal. Then it is excised after transfixation of the pedicle. The technique is repeated for the opposite ovary if bilateral ovariectomy is elected. The skin incisions are closed with nonabsorbable suture using an interrupted suture pattern.

The two-portal technique requires the use of a rigid laparoscope with a working channel for instruments. An 11-mm portal is created on the midline 10 cm cranial to the udder to accommodate a 10-mm rigid endoscope. The second portal is created by placing a 6-mm trocar 5 cm laterally to the laparoscope portal. A 33-cm Babcock forceps is introduced through the second port to locate the ovary and expose its pedicle. Once the ovary is exposed, a bipolar forceps with a simultaneous coagulation and cutting function is introduced through the channel of the endoscope and the pedicle cauterized and cut. The ovary is grasped and exteriorized through the endoscope portal. The procedure is repeated on the other ovary using the same portal.

An alternative method used by the authors utilizes laparoscopy to assist in locating and grasping the ovary. Once the ovary is grasped with atraumatic forceps it is elevated toward the linea alba where an incision is made, and Allis tissue forceps are introduced directly into the abdominal cavity to grasp and exteriorize the ovary (Figure 23-17).

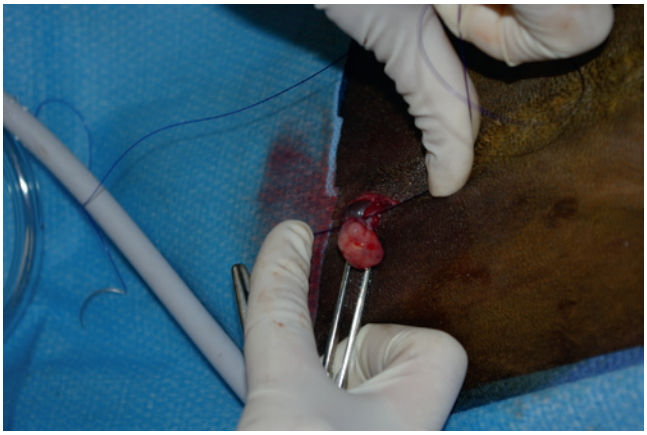


Figure 23-17 Laparoscopic-assisted ovariectomy. Exteriorization of the ovarian pedicle.

Complications of Laparoscopic Techniques in Small Ruminants

The major complications of laparoscopy in small ruminants include damage to abdominal visceral organs or to the reproductive tract, regurgitation, and respiratory or cardiovascular problems. Perforation of the rumen is a high risk in small breeds (i.e., pygmy goats) or if the fasting period has not been respected. Overt manipulation of the abdominal viscera may also cause intestinal rupture. Omental tears may cause intestinal entrapment, necrosis, and peritonitis. Respiratory and cardiovascular compromise may result from prolonged maintenance of the Trendelenburg position.

Surgical Embryo Collection

Embryo collection is generally performed under general anesthesia. An area similar to that described for cesarean section is prepared for surgery and draped. A ventral midline incision is made just cranial to the base of the udder and extended for 6 to 8 cm toward the umbilicus. The linea alba is exposed by blunt dissection and then incised. The uterus and ovaries are located and exteriorized as described earlier. The ovaries are inspected for numbers of corpora lutea. During the procedure, the uterine horn is lavaged repeatedly with sterile saline to prevent drying of the tissue. Each horn is flushed separately. A small incision is made at the base of the horn, and a Foley or Argyle silicon No. 8 or 10 catheter is introduced and maintained in place by inflating the cuff (Figure 23-18). A tom cat catheter is inserted into the uterine lumen at the level of the uterotubal junction (Figure 23-19). The uterine horn is flushed from the uterotubal junction toward the base with sterile, warmed, embryo-flushing medium (Figure 23-20). Suturing the uterus is unnecessary if the endometrium is not prolapsing through the uterine incision. After both horns are flushed, the uterus is returned to the abdomen and the linea alba is closed. Subcutaneous tissues and skin are closed routinely (for udder amputation see Chapter 16).

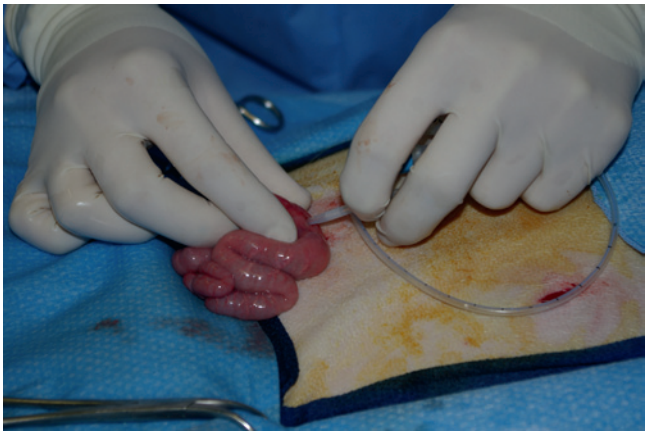


Figure 23-18 Surgical embryo collection. Uterine catheterization and placement of a Foley catheter.

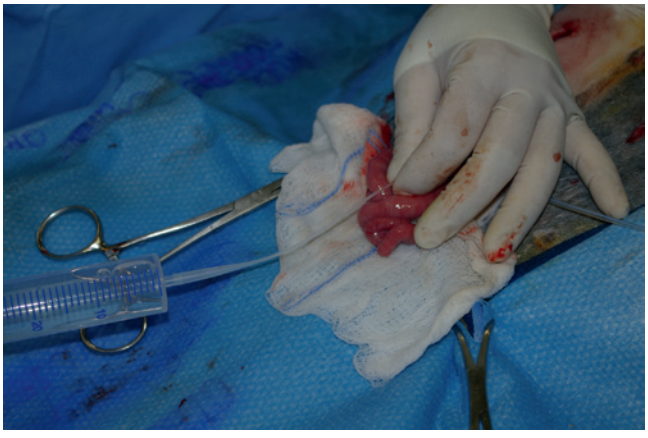


Figure 23-19 Surgical embryo collection. Uterine catheterization at the level of the uterotubal junction and placement of tom catheter.

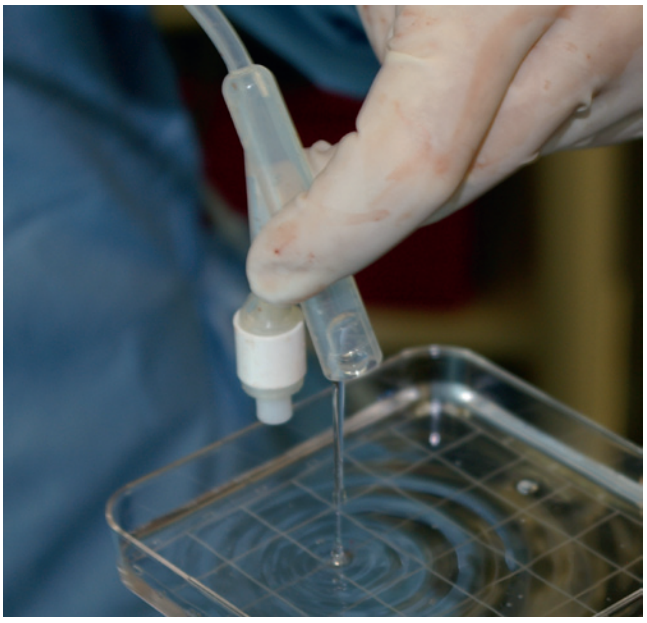


Figure 23-20 Surgical embryo collection. Uterine flushing.

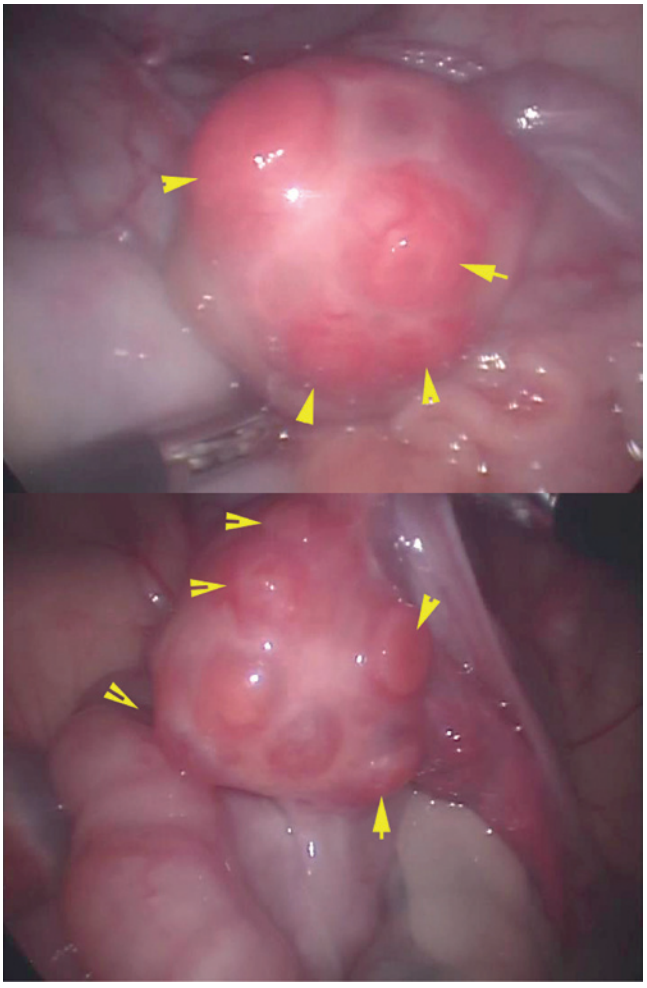


Figure 23-21 Laparoscopic-assisted embryo collection. Visualization of stimulated ovary (*arrows* indicate the corpora lutea).

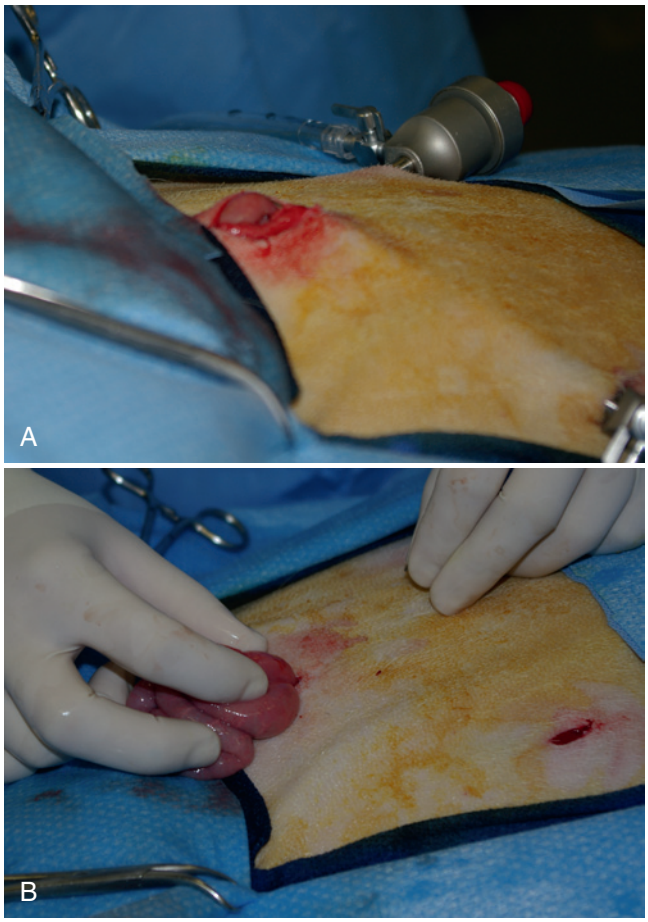


Figure 23-22 *A* and *B*, Laparoscopic-assisted embryo collection. Exteriorization of the uterine horns.

Surgical embryo collection may be facilitated by a laparoscopic-assisted technique. Portals are created as for artificial insemination. The uterus and ovaries are visualized, and the corpora lutea on each side are counted (Figure 23-21). One of the uterine horns is grasped using an atraumatic forceps and then elevated toward the linea alba just cranial to the udder where an incision is made to penetrate the abdominal cavity and exteriorize the uterus (Figure 23-22*A* and *B*). The embryo collection procedure is performed as describer earlier, and the uterus is replaced and the abdominal incision closed.

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SURGERY OF THE MALE REPRODUCTIVE AND URINARY TRACT

Ahmed Tibary and Lisa K. Pearson

Castration

Most small ruminants are castrated early in life at 2 to 3 weeks of age. Techniques used at this age are usually bloodless. Surgical castration of adult rams can be done under sedation/analgesia and local anesthesia. General anesthesia is recommended for adult goats or castrations performed because of testicular disease. Because of the large size of the testicular cord in these species, hemostasis is best accomplished with emasculators or by placing a transfixation ligature proximal to the pampiniform plexus. The distal third of the scrotal sac should be removed.

Young animals are usually sedated and restrained in a sitting position with the legs on the same side held together. The bottom third of the scrotal sac is excised and the testes are removed by stripping while maintaining pressure on the inguinal ring (Figure 23-23).

In the adult ram or buck, general anesthesia is recommended. The animal is placed either in lateral or dorsal recumbency. The scrotum and surrounding area are clipped and prepared for surgery. An incision is made on the lateral surface of the testis through the skin and tunica dartos. The testis and its envelopes are separated by blunt dissection. The vaginal tunic is excised to expose the testis. The cremaster muscle is separated from the vascular testicular cord. Each



Figure 23-23 Castration in a billy goat. The bottom third of the scrotum has been resected and the testes are stripped.

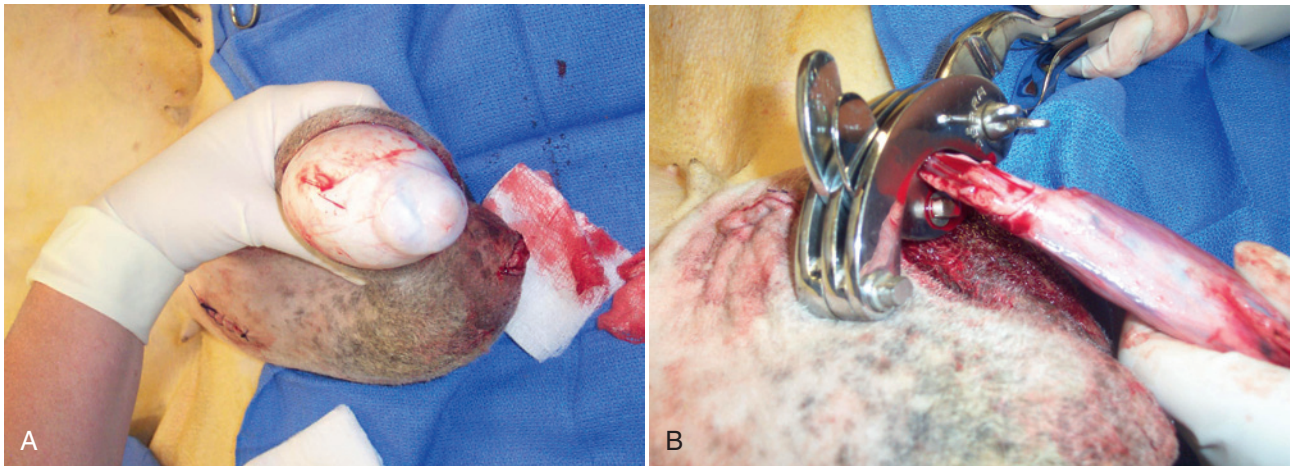


Figure 23-24 Castration in an adult ram. *A*, Exteriorization of the testis; *B*, Castration using an emasculator.



Figure 23-25 Inguinal hernia in a ram.

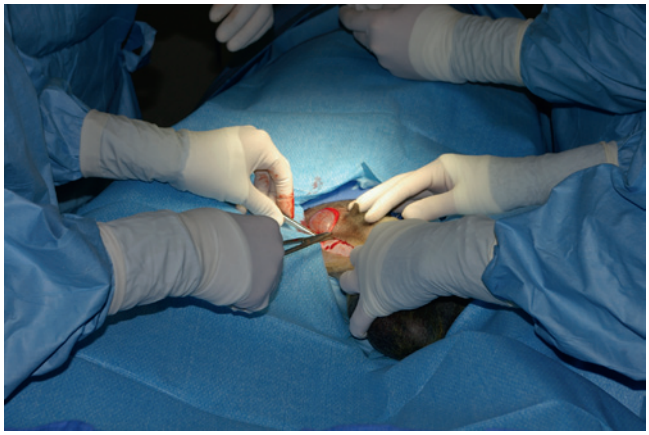


Figure 23-26 Approach to inguinal hernia repair and hemicastration in a ram.

of these structures is ligated by transfixation suture. Some practitioners prefer to ligate the spermatic artery and vein separately. The cord is transected distal to the ligatures. Use of an emasculator can be indicated if the testes are of normal size (Figure 23-24*A* and *B*). The vaginal tunic is transected distally enough to allow the tunics to be closed over the remaining cord. An inverting suture pattern is used with an absorbable suture material. The tunica dartos muscle is closed over the wound with a simple continuous pattern. Excess skin may be trimmed. The subcutaneous tissues and longitudinal skin incision are closed. Bandaging the scrotum is recommended if bleeding is observed. Alternatively the incisions can be left to close by second intention if preferable or if the conditions are unsanitary.

Inguinal and scrotal hernias are relatively rare in small ruminants (Figure 23-25). The condition is often congenital and suspected to be hereditary. However, inguinal hernia in adult rams may result from trauma. The structures involved in the hernia may be evaluated by ultrasonography. The hernia sac often contains small intestines and a large amount of peritoneal fluid. Unilateral castration and hernia repair may be considered in valuable males if the condition is not congenital. Surgery is performed under general anesthesia. The inguinal area and scrotum are prepared for surgery and draped (Figure 23-26). A skin incision is made over the inguinal area of the affected side and extended distally over the scrotum. The tunica dartos and scrotal fascia are incised and the hernial sac (tunica vaginalis communis) is exposed. The vaginal tunic is carefully opened and the content exposed (Figure 23-27*A*). The intestines are replaced in the abdominal cavity through the inguinal ring (Figure 23-27*B*). The testicle on the affected side is removed using an open castration technique as described earlier. The vaginal tunic is excised after ensuring hemostasis (Figure 23-28*A*). The inguinal ring is closed with a simple interrupted pattern using absorbable suture (Figure 23-28*B*). Excess scrotal skin is removed and the subcutaneous tissue is apposed and closed with a simple continuous pattern. The skin is closed using a simple interrupted suture with nonabsorbable material. Postoperative care includes antimicrobial therapy and nonsteroidal antiinflammatory therapy.

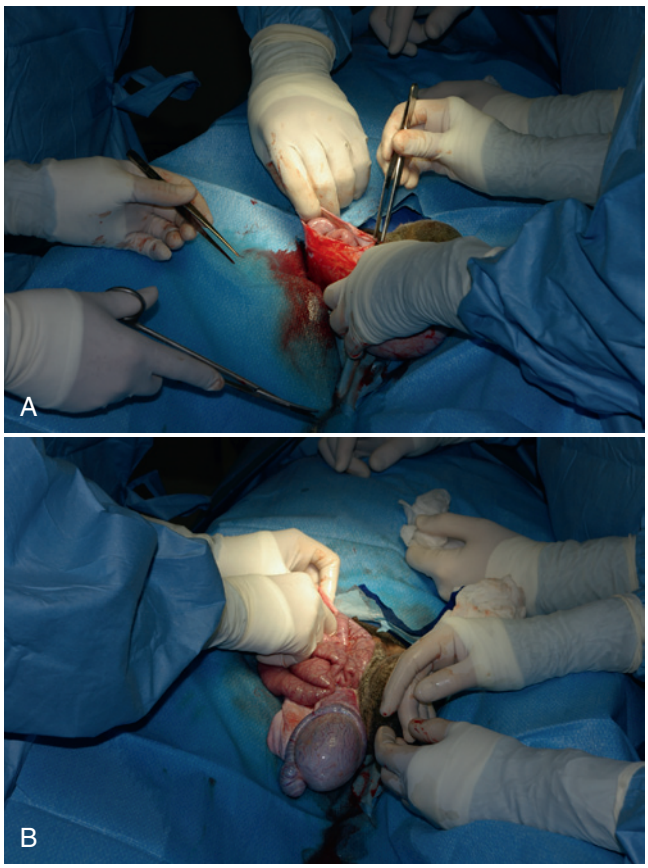


Figure 23-27 *A* and *B*, Inguinal hernia repair. Incision of hernia sac. Note the exposed small intestine loops.

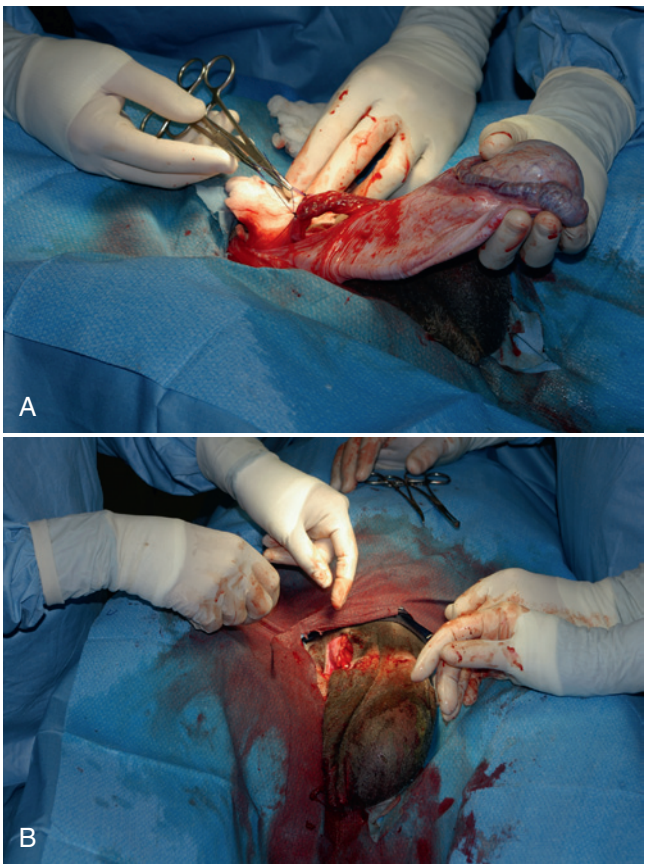


Figure 23-28 *A* and *B*, Excision of the testis and closure of the inguinal ring.

Cryptorchid Castration

Cryptorchidism is considered an inherited defect in sheep and goats. The reported incidence varies between 0.5% and 18.0% in rams. This wide variation in incidence reflects breed and regional differences. In goats, cryptorchidism is often associated with intersex conditions. The right testis is affected more often than the left. Although inguinal cryptorchidism has been reported to occur, in the authors' experience all cases were complete abdominal cryptorchids. Transabdominal ultrasonography of the inguinal region may aid in identification of the retained testis.

Cryptorchidectomy may be performed through a flank, inguinal, or parainguinal approach under general anesthesia. The retained testis is often in proximity to the vaginal ring and may be retrieved using a spay hook. In some cases direct exploration of the abdominal cavity is necessary. Another alternative in companion goats is to use a laparoscopic approach. The animal is placed in dorsal recumbency under general anesthesia and prepared as described for general laparoscopic insemination in the female. The laparoscope portal may be placed over the umbilical scar. The intraabdominal testis is located, and the second portal is placed laterally to the prepuce and used to introduce grasping forceps. The testis is grasped and elevated toward the inguinal area where a small parainguinal incision is made to exteriorize the testis.

A complete laparoscopic technique for cryptorchidectomy has been described and requires the use of three ports. The laparoscope portal is placed as described previously, and two instrument portals are placed on each side about 5 cm from the prepuce. One portal is used to grasp the testicle whereas the other is used to introduce a laparoscopic, bipolar, electrocautery forceps. The spermatic cord is cauterized and transected, and the testis is removed through the grasping instrument portal. The portal may need to be enlarged at this point. Portal sites are closed with a simple interrupted suture. The skin is closed in a cruciate pattern.

Vasectomy

Vasectomy is a management technique in bucks and rams used to provide teaser animals and estrus synchronization through the "ram effect." The surgery can be performed on rams after sedation and local anesthesia. General anesthesia is recommended for bucks because of their tendency to become agitated and vocal, which may disturb owners if surgery is done on the farm. Vasectomy has also been performed in rams after lumbosacral spinal analgesia. Rams can be restrained in the sitting position. Dorsal recumbency is the preferred position in goats.

The scrotal skin is prepared by clipping and surgical scrubbing. Surgical drapes are placed around and underneath the scrotum. A 3- to 4-cm vertical incision is made on the medial aspect of the cranial surface of the scrotal skin above the testicular cord. The spermatic cord is freed by blunt dissection and exteriorized with the help of hemostatic forceps (Figure 23-29). The vas deferens can be easily identified by palpation or visually by its white color and the presence of adjacent vein and artery. The vas deferens is exteriorized using forceps or a spay hook through a small nick made in the vaginal tunic (Figure 23-30). A 3-cm portion of the vas deferens is removed after ligating each end (Figure 23-31 *A* and *B*). The vaginal tunic does not need to be sutured.

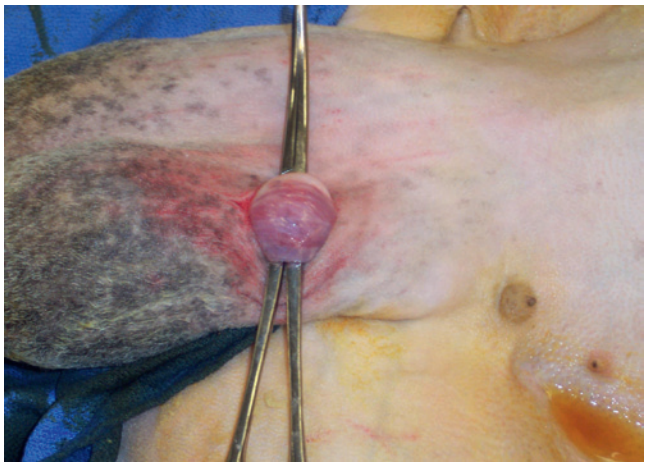


Figure 23-29 Vasectomy in a ram: exteriorization of the spermatic cord and identification of the vas deferens.



Figure 23-30 Exteriorization of the vas deferens using a spay hook.

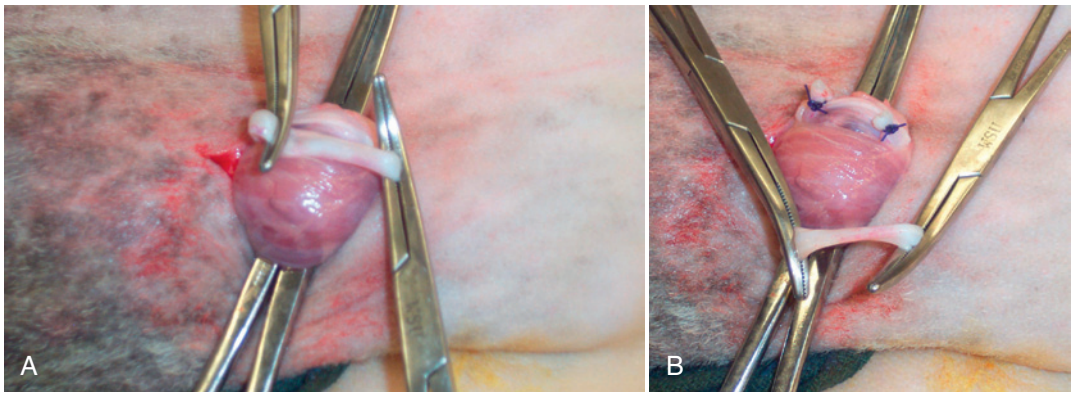


Figure 23-31 Vasectomy in a ram. *A*, Ligature, and *B*, removal of a portion of the vas deferens.

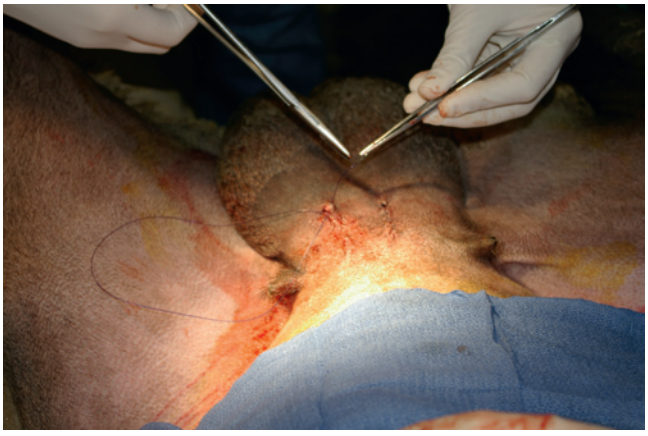


Figure 23-32 Vasectomy: skin closure.

The skin is sutured or stapled, and the same procedure is repeated on the other side (Figure 23-32). Excised tissue should be submitted for histologic confirmation. Flushing and observing spermatozoa under the microscope are other quick ways to confirm that the excised tissue was in fact the vas deferens.

Fertility is reduced but may be retained for up to 4 days following vasectomy. Although sperm may be present in the ejaculate for up to 20 weeks, concentration and motility are severely reduced by 1 week after vasectomy. Vasectomized rams or bucks can be used safely 3 weeks after surgery. Complications of vasectomy are rare and include surgical site infection and development of sperm granuloma.

Epididymectomy

The animal is prepared as for castration. A local block is provided by infusing 2% lidocaine in the ventral scrotal skin directly over the caudal epididymis. The testis should be held firmly within the scrotum to better visualize the prominent tail of the epididymis (Figure 23-33). The skin is incised (2.5 to 3 cm) on the ventral, posterior aspect of the scrotum (just above the caudal epididymis). Using blunt dissection, the veterinarian isolates the epididymis and holds it with an instrument or stay suture. The tail of the epididymis is transected after ligating each border with a nonabsorbable suture material. The skin is sutured by using a simple interrupted suture pattern. Semen should be collected at least three times before the male is used as a teaser.

Translocation of the Penis

The objective of this surgery is to translocate the preputial opening laterally to render vaginal intromission of the penis impossible during normal erection and mounting behavior.



Figure 23-33 Epididymectomy in a ram: the testis is held firmly within the scrotum, and an incision is made over the prominent tail of the epididymis.



Figure 23-34 Translocation of the penis: skin incision around the preputial orifice continuing caudal toward the sigmoid flexure.

It is preferable to perform penile deviation under general anesthesia or deep sedation/analgesia. The animal is placed in dorsal recumbency, and the area from the umbilicus to the base of the scrotum is clipped, scrubbed, and draped for surgery. Special attention should be given to thoroughly flushing the prepuce with dilute iodine solution. A skin incision is made about 1.5 to 2 cm around the preputial orifice and continued caudally toward the sigmoid flexure (Figure 23-34). The prepuce is entirely freed from the skin and surrounding tissue with blunt scissors. Placing a catheter in the prepuce helps orient the surgeon. Once the desired length of the prepuce is completely freed, a site in the left abdomen ventral to the fold of the flank is selected at a 45-degree angle from the base of the penis to create the new preputial location. A circular skin flap is removed at this site (Figure 23-35). A closed long forceps is used to create a



Figure 23-35 Translocation of the penis: removal of a circular flap of skin at the site where the preputial opening is to be relocated.



Figure 23-36 Translocation of the penis: skin suture and appearance after translocation of the organ.

subcutaneous tunnel that extends from the circular skin incision to the base of the scrotum. The freed prepuce is placed in a sterile plastic sleeve, grasped with the forceps, inserted into the subcutaneous tunnel, and transferred to the new location. The surgeon must be sure that the organ does not twist. The preputial opening is sutured to the skin with synthetic nonabsorbable suture material in a simple interrupted or horizontal mattress pattern. The midline abdominal skin incision is closed routinely (Figure 23-36). Postoperative care includes systemic antibiotics. Ventral edema may develop in some animals and may persist for a few days. Urination should be verified and the patient should be examined carefully if there is a large amount of persistent preputial edema. Skin sutures may be removed 10 to 14 days after surgery.

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UROLITHIASIS

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Urinary calculi, or uroliths, cause disease in ruminants through trauma to the urinary tract and obstruction of urine egress. Calculi are mineral/mucoprotein aggregates that may be a single mass or multiple masses that measure several millimeters in diameter or numerous fine, sand-like particles that pack together to fill the urethral lumen. Urolith compositions largely depend on geographic location and diet but most commonly include calcium phosphate, calcium carbonate, and struvite (magnesium ammonium phosphate).

Obstruction of the urinary tract typically occurs in the urethra of male and castrated male ruminants and swine. The distal sigmoid flexure is the most common obstruction site in steers and bulls. Uroliths tend to obstruct the urethra at the level of the sigmoid flexure and/or the distal penile urethra of swine. In sheep and goats, the urethral process or vermiform appendage is the most common site of urethral obstruction. The distal sigmoid flexure is also often obstructed in small ruminants, commonly by multiple calculi. Common clinical signs in partially or completely obstructed animals include depression, mild bloat, anorexia, colic, stranguria, and/or abdominal distention. Vocalization is common in small ruminants.

Obstruction of the ureter and/or renal pelvis is very uncommon in ruminants and swine. Urinary tract infection is not a common concurrent finding in ruminant and porcine urolithiasis, although prolonged partial urethral obstruction, prior urethrostomy, or urethral catheterization may increase the risk of concurrent infection.

A diagnosis of urinary obstruction can generally be easily made through physical examination, rectal examination (when possible) and ultrasonography. Physical findings often include depression, lordosis, abdominal distention, brachycardia, and/or an inflamed and reddened penis. Blood or crystalline material may be adhered to the preputial orifice. Transabdominal ultrasonography reveals a large, fluid-filled bladder. Tears in the bladder wall can sometimes be visualized; uroperitoneum is seen in cases of bladder rupture.

PREOPERATIVE CONSIDERATIONS

Evaluation of the hemogram as well as the acid-base and electrolyte status of urolithiasis patients is warranted if the animal is debilitated or if general anesthesia is planned. Ruminants with acute (<24 hours) urethral obstruction, without bladder or urethral rupture, typically show mild hemoconcentration secondary to dehydration and mild to moderate prerenal and postrenal azotemia. If present, derangements of acid-base balance and serum electrolytes are usually mild in these animals.

Animals with rupture of the urinary bladder or urethra are more debilitated and dehydrated and typically have more profound hemoconcentration and azotemia. Hyponatremia and hypochloremia are consistent derangements. However, acid-base status, serum potassium, and serum calcium concentrations tend to vary and are less easily predicted. Animals with a history of long-standing (>24-48 hours) urinary obstruction may also show severe electrolyte and acid-base abnormalities. Correction of these abnormalities should be attempted before general anesthesia because they may precipitate potentially fatal cardiac arrhythmias. Complete correction, especially of hyperkalemia, can be difficult in completely obstructed animals. Intravenous administration of 0.9% saline is indicated for volume repletion without exacerbating hyperkalemia. Animals that are severely volume depleted (>8%-10%) may benefit from hypertonic saline solutions. Supplementation of serum sodium levels is important as hyponatremia potentiates cardiotoxicity of hyperkalemia. In cases of severe hyperkalemia, 5% to 10% dextrose can be administered at a dose of 0.5 mL/kg to hasten stabilization.

Administration of intravenous fluids to an animal with urethral obstruction may induce diuresis and increase the likelihood of bladder or urethral rupture. However, this risk is acceptable when it is weighed against the need to stabilize an animal before general anesthesia. Cystocentesis (ultrasound guided is preferred) may be performed in small ruminants, calves, and swine if the surgeon decides to postpone surgery and administer intravenous fluids. The advantages of cystocentesis include improved patient comfort and temporary reduction of the risk of necrosis or rupture of the bladder. The disadvantages include uroperitoneum, induced by persistent urine leakage from the bladder at the cystocentesis site and potential rupture at the site of cystocentesis. With cystocentesis, the clinician controls the location and size of the bladder defect to a focal stick point; otherwise the bladder could rupture in a less manageable location or in a larger area if fluids are given without cystocentesis. Another option is percutaneous, ultrasound-guided placement of a Stamey, Malecot-tipped catheter into the bladder with subsequent fluid diuresis. Unfortunately, this runs the risk of tube displacement, peritonitis, and adhesions to other viscera and is not recommended as a surgical option.

If possible, ultrasonographic evaluation of the kidneys is warranted for animals with chronic (>24 hour) urethral obstruction. The presence of severe hydronephrosis with a loss of visible cortical tissue in both kidneys warrants a poor prognosis for restoration of normal renal function.

Preoperative administration of an antimicrobial agent that concentrates in the urine (e.g., beta-lactams) is prudent. Examples of appropriate choices are procaine penicillin G, 22,000 IU/kg IM or SC every 12 hours, ampicillin 11 mg/kg IM every 24 hours, and ceftiofur (2.2 mg/kg IV or IM every 12-24 hours). Postoperative antimicrobial therapy should be dictated by the procedure chosen, slaughter-withholding considerations, the status of the patient, and the tissues involved. Administration of potentially nephrotoxic antimicrobials should be avoided, and nonsteroidal antiinflammatory drugs should be used with caution, especially in azotemic patients. Flunixin meglumine (1.1 mg/kg IV every 24 hours) is used in our hospital routinely, with due consideration to maintaining adequate renal perfusion through fluid therapy.

In cases requiring general anesthesia, preoperative administration of epidural anesthesia may reduce the concentration of inhalant anesthetic required for surgery. In cases of urinary bladder rupture, slow drainage of urine from the abdomen before surgery may decrease abdominal volume and facilitate ventilation in the recumbent or anesthetized animal.

If an animal is to be culled, slaughter should be delayed for 4 to 6 weeks after surgery for animals that are suffering from bladder or urethral rupture. This delay allows debilitation and uremia to pass and provides ample time for healing of tissues damaged by urine. In cases of urethral rupture, small stab incisions into the skin of swollen areas around the perineum, prepuce, and ventral abdomen may facilitate urine drainage. A sterile instrument can be inserted into the stab incisions to gently spread the skin apart, thereby opening fascial planes for better drainage of extravasated urine.

POTENTIAL COMPLICATIONS

The owners of the animal should be informed that urolithiasis may reoccur postoperatively, and the risk of recurrence increases if the dietary and management changes needed for prevention are not consistently practiced. In our hospital, we recommend complete discontinuation of grain feeding (or markedly reduced in meat goats) and feeding of grass hay and ammonium chloride if the animal will tolerate it. It has been shown that small ruminants require a high dose of ammonium chloride (450 mg/kg/day) to maintain a urine pH <6.5 for 24 hours, which is necessary to prevent formation of struvite and calcium uroliths (Mavangira et al, 2011). However, administration of high-dose ammonium chloride is difficult due to its unpalatability. Ewoldt et al (2006) recently reviewed long-term outcomes in 50 goats, and 13 had good short- and long-term survival, with 86% of animals alive >12 months after discharge; reobstruction occurred in <20% of cases. The authors also found that serum potassium levels <5.2 mEq/dL, no free fluid in the abdomen, and no history of urethral process amputation before admission were all associated with improved survival. Relevant anesthetic and surgical complications should be described when counseling owners before surgical intervention. Although rare, postoperative renal failure due to hydronephrosis and/or severe volume depletion should be mentioned in a discussion of potential complications. Uremic animals may have impaired coagulation. At least 2 months of postoperative sexual rest must be enforced in breeding males undergoing urethral surgery because earlier return to sexual activity may result in dehiscence of a urethral closure.

SURGICAL TREATMENT

Urethral Surgery

General Considerations

Most surgical procedures that involve the urethra can be performed under local or epidural anesthesia in field conditions. All are usually appropriate for animals intended for slaughter. However, stricture of the urethra in breeding animals may occur as a complication of a urethral incision, and fibrosis in the tissues surrounding the penis may limit penile extension during erection. Except for urethral process amputation and urohydropulsion, surgical procedures involving the urethra carry a guarded to poor prognosis for breeding.

In cases of bladder rupture, urethral surgical procedures do not allow direct repair of the bladder defect. Bladder wall defects, particularly those located on the bladder dorsum, may seal within 2 to 4 days without primary repair, provided the urethral obstruction is relieved or bypassed to allow urine egress. Aggressive fluid and electrolyte therapy—as well as intermittent abdominal drainage—are necessary supportive measures in such cases. Laparotomy and bladder wall repair are indicated if uroperitoneum persists for several days after urethral surgery.

Urethral Process Amputation

The urethral process, or vermiform appendage, is a 1- to 2-cm extension of the urethra and integument off the distal aspect of the glans penis of sheep and goats. It is essential to examine the urethral process during clinical evaluation of a small ruminant with potential urethral obstruction. The diagnosis can be confirmed visually or by palpating a calculus within the urethral process. If a calculus is found in the process, amputation may result in restoration of urine outflow. Removal of the urethral process does not adversely affect fertility in the long term, although hemorrhage from the amputation site may adversely affect semen viability for several days. Therefore 1 to 2 weeks of sexual rest is warranted in breeding animals that undergo this procedure. Prepubertal animals may possess a persistent frenulum large enough to limit exteriorization of the penis.

Urethral process amputation can be expected to restore urine outflow in approximately one half of small ruminant urolithiasis cases, according to data from two reports (Haven et al, 1993; Van Metre and Smith, 1991). Failure to restore urine outflow after amputation indicates the presence of additional calculi in the lower urinary tract, frequently located in the area of the sigmoid flexure and bladder. If the process is not obstructed, the owner may elect removal to prevent future obstruction at that site. Urethral process amputation also facilitates retrograde passage of a urinary catheter to determine the site of urethral obstruction.

If needed, sedation can be performed with intravenous diazepam (0.1 to 0.2 mg/kg IV), and the sheep or goat is propped up on its rump. The penis is grasped through the skin at the level of the sigmoid flexure immediately caudal to the sheath and cranial to the scrotum or castration scar. The penis is forced cranially, and the preputial orifice is forced caudally. The glans is thus exteriorized and grasped with a gauze sponge. If manual exteriorization fails, Allis tissue forceps or long hemostats can be introduced into the preputial cavity and used to grasp and exteriorize the penis. In larger rams and bucks, epidural anesthesia may facilitate exteriorization by eliminating penile sensation and the pull of the retractor penis muscles.

Once the glans penis is exteriorized and secured, the surgeon can use scissors or a scalpel blade to amputate the process at its base, while the surgeon carefully avoids damage to the glans. The hemorrhage that results from amputation is self-limiting. After amputation, urination is usually spontaneous and voluminous if the obstructing calculus or calculi have been removed. If urination does not occur, the surgeon may pass a urinary catheter to determine the location of the obstruction. Lidocaine infusion into the urethra before catheterization—as well as lubrication of the catheter—may reduce patient discomfort during catheter passage. Catheter passage within an inflamed urethra may be difficult, and the surgeon should weigh the benefits of catheterization against the potential added trauma and risk of urethral rupture. In ruminants, swine, camelids, and cervids, retrograde passage of a urinary catheter into the bladder is extremely difficult because the catheter usually enters the urethral recess at the level of the ischium.

When urethral process amputation is successful in restoring urination, the animal owners should be cautioned to monitor the animal closely because recurrent urethral obstruction caused by additional calculi appears to be common. Imaging studies (ultrasonography, radiography) of the bladder and urethra may aid in detecting additional uroliths in these cases.

Urohydropulsion

Retrograde passage of a urinary catheter into the urethra, followed by sterile saline flushing (urohydropulsion), is

commonly used in small animals to dislodge urinary calculi and flush the obstructing calculi or mucoid plug retrograde into the bladder. In farm animals, passage of a catheter in the retrograde direction allows the surgeon to determine the location of the urinary obstruction, which may guide subsequent surgical management, particularly if urethrotomy or urethrostomy is anticipated. However, use of urohydropulsion has inconsistent, limited data about the relief it gives from urethral obstruction in farm animal species. This procedure may be more successful if a solitary calculus is responsible for the obstruction.

The catheter size used varies with the size and species of the animal involved. For mature bucks, wethers, and rams, a 5 to 8 French polypropylene catheter is usually appropriate, although the length of most standard canine catheters may not be adequate to reach the perineal segment of the urethra in larger breeds. A 10 or 14 French, rubber, or polypropylene catheter or 100- to 200-cm-long, sterilized polypropylene or rubber tubing may be needed to catheterize the urethra of larger bulls and steers. The catheter tip should be coated with sterile lubricant before introduction. In small ruminants, amputation of the urethral process facilitates catheter introduction and passage. A small volume of lidocaine may be flushed into the urethra to reduce discomfort during passage. If urohydropulsion is to be attempted, the surgeon should compress the urethral orifice with his or her fingers during gentle flushing with saline to prevent the saline from leaking out of the orifice. Potential complications of catheter passage and urohydropulsion include traumatic urethritis and urethral rupture.

Passage of a urinary catheter into the bladder is difficult in ruminants and swine. These animals have a urethral recess (formerly termed *diverticulum*) (Figure 23-37) that extends from the dorsum of the urethra at the level of the ischium. During retrograde urethral catheterization, it almost invariably enters the recess and cannot be redirected into the bladder. To confirm that the catheter has reached the urethral recess, the surgeon can introduce a hand or finger into the animal's rectum and palpate the catheter tip at the caudal aspect of the pelvic urethra while the catheter is gently moved back and forth.

Urinary Acidification

Walpole's solution to dissolve uroliths in the bladder and urethra has been used in small animals, but its use in goats was recently reported by Janke et al (2009). Walpole's solution is composed of sodium acetate, glacial acetic acid, and distilled water with a pH of 4.5 so it can be useful in dissolving certain types of calculi such as struvite. It can be administered into the bladder percutaneously (50 mL) following ultrasound-guided cystocentesis. Janke et al found that urethral obstruction resolved in 80% of goats; however, a recurrence rate of 30% was observed. Urinary acidification with Walpole's solution may be a good alternative in cases where surgery is cost prohibitive. This procedure is hypothesized to be most effective in animals with struvite (magnesium ammonium phosphate) calculi, which are readily solubilized under acidic conditions.

Penectomy (Penile Amputation)

Penectomy is considered a salvage procedure for intact and castrated ruminants and swine intended for slaughter. Bulls and steers are restrained in a squeeze chute or stocks, the rectum is emptied of feces, and sacrocaudal epidural or bilateral pudendal nerve anesthesia is administered. Calves, sheep, goats, and swine are typically restrained in dorsal or lateral recumbency. Sacrocaudal or lumbosacral epidural anesthesia, local infiltration with 2% lidocaine, or general

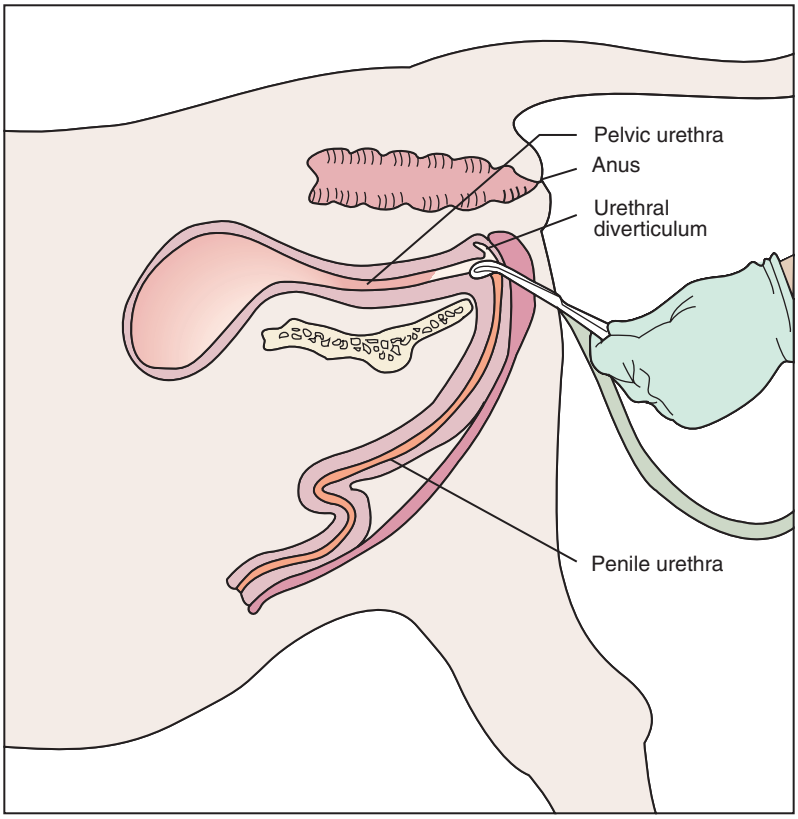


Figure 23-37 Diagram of the urethral diverticulum.

anesthesia can be administered. The tail is tied to the side. The perineum, which extends from the anus to the scrotum or castration scar, is clipped and disinfected.

The skin incision should be located in the lower half of the prepared area, where the vertical surface of the perineum begins to curve cranioventrally. Placing the surgical site here will facilitate urine egress from the transected penis and minimize urine scald. A vertical skin incision is made on the midline. The incision length should be approximately 10 to 20 cm or more in bulls and steers and 3 to 6 cm in calves, small ruminants, and swine. The subcutaneous tissue and fascia are incised to reveal the pink, paired, strap-like retractor penis muscles that extend dorsal to ventral beside the midline of the deep subcutis. The retractor penis muscles can be traced distally to identify their insertion point, which is the distal bend of the sigmoid flexure of the penis. These muscles may be ligated and excised if the surgeon desires to clear the surgical field. Alternatively, the dissection is continued between the retractor penis muscles to reveal the penis. The penis is firm and covered by the smooth, white tunica albuginea.

Blunt digital dissection is used to free the entire circumference of the penis. Blunt dissection is continued ventrally and cranially to free the distal bend of the sigmoid flexure. Traction should be applied to the penis in a caudodorsal direction to exteriorize enough of the penis so the distal sigmoid flexure is held external to the incision under minimal tension. This is relatively easy to accomplish in urethral rupture cases because the peripenile tissues and preputial attachments of the penis are necrotic from extravasated urine. If urethral rupture does not exist, sharp dissection with heavy scissors is often necessary to free the distal penis from its attachments to the prepuce.

If still present, the retractor penis muscles are ligated and excised. In bulls and steers, the transection point for the penis should be located approximately 5 to 10 cm distal to the dorsal aspect of the skin incision. In calves, small ruminants, and swine, the transection point should be located 2 to 4 cm distal to the dorsal aspect of the skin incision. The transection site should be located so that the resultant proximal penile stump can be easily oriented in a caudal and slightly ventral direction.

The surgeon should then decide if the distal penis is to be excised. Excision of the distal penis greatly facilitates drainage of urine-damaged tissues in cases of urethral rupture. If the surgeon prefers to excise the distal penis, the vessels on the dorsum of the penis should be ligated immediately proximal to the selected transection site. The penis is then transected perpendicular to its long axis and the distal penis is excised. If the distal penis is to be preserved, the vessels on the dorsum of the penis are carefully dissected free from the tunica albuginea of the penis at the level of the proposed transection site. A pair of hemostatic forceps is placed between the vessels and the dorsal surface of the tunica albuginea of the penis. These forceps are intended to protect the vessels from transection. The penis is transected at the appropriate site, leaving the dorsal vessels and distal penis intact.

Heavy monofilament suture (e.g., nylon) is preferred for suturing the proximal penile stump to the skin because monofilament suture is expected to hold less exudate, debris, and bacteria in the wound than braided suture or umbilical tape holds. The proximal stump is composed of the urethra and corpus spongiosum within the dorsal third of the stump and the corpus cavernosum located in the ventral two thirds of the stump. The stump is oriented to face caudoventrally and is fixed to the skin with a horizontal mattress suture. To create the first limb of this suture, the suture is passed through the skin at a point 1 to 3 cm lateral to the right side of the skin incision. The suture is then passed through the entire body of the penile stump, passing through the corpus cavernosum. The surgeon should take care not to incorporate the urethra into this suture. The suture is exited from the skin on the left side of the incision, equidistant from the incision edge as placed on the right side. The second limb of the horizontal mattress suture is created by returning the suture through the skin on the left side of the incision, passing through the ventral aspect of the penile stump, and exiting on the right side of the incision at a point ventral to the suture entry point (Figure 23-38). The suture is then pulled tight and tied to secure the penile stump in place. If needed, additional interrupted sutures may be placed through the ventral aspect of the tunica albuginea of the stump and the ventral apex of the skin to add security to the penile stump fixation.

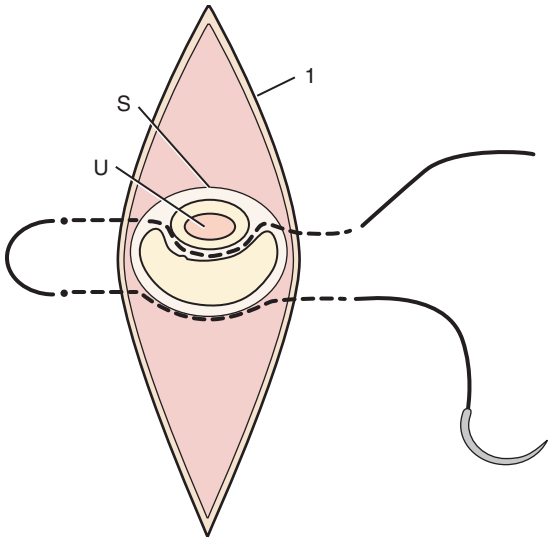


Figure 23-38 Securing the penile stump to the skin in a penectomy. U, urethra; I, skin incision; S, tunica albuginea of the penile stump.

The urethra is then incised along its long axis from the end of the stump to the dorsal aspect of the incision. The urethra is thus spatulated to provide a larger opening for urine egress. To create a secure urethral spatula, the dorsal aspect of the resulting urethral mucosal flaps may be sutured to the adjacent skin edges (i.e., left urethral flap to left skin edge) by using monofilament, nonabsorbable suture in a simple continuous pattern. The distal 1 to 2 cm of the urethral flaps, which protrude well away from the skin edge, should not be sutured to the skin. This technique has been termed *urethral fistulization*.

Hemorrhage from the corpus spongiosum penis may be heavy, particularly in larger animals. To limit hemorrhage, a short length of rubber tubing can be introduced into the urethra to exert outward pressure on the corpus spongiosum. This tube can be sutured in place at the edge of the stump. The tube is removed in 3 to 5 days. Alternatively, the corpus spongiosum can be closed by placing closely spaced, simple continuous 2-0 absorbable sutures through the edge of the urethral mucosa and corpus spongiosum penis, thereby sealing the cut edge of the spongiosum. Hemorrhage from the corpus cavernosum is usually less of a problem because of the compressive effect of the mattress fixation suture. If hemorrhage from the cavernosum of the stump is problematic, a horizontal wedge of the cavernosum can be excised from the distal aspect of the stump and the edges sutured together to seal the cavernosum shut.

Postoperative antimicrobial therapy is warranted for 5 to 7 days in cases of urethral rupture. Application of petroleum jelly to the skin ventral to the incision and on the medial surface of the hind limbs may help to limit urine scald. Myiasis may be limited through application of fly repellent around the surgical site or by taping a fly repellent ear tag to the tail. Suture removal is performed 2 weeks after surgery.

Perineal Urethrostomy

In perineal urethrostomy, the penile urethra is opened and sutured to the skin of the perineum to create a permanent stoma for urine egress. This procedure is preferred over penectomy for pet animals or animals with several more months before their slaughter weight is achieved; our experience indicates that the stoma tends to remain patent for a longer period of time than for a penectomy. Perineal urethrostomy is a valid option in cases of urethral rupture. This procedure results in loss of natural breeding ability.

Recurrent obstruction is possible if large calculi obstruct the urethra proximal to the stoma. Stricture of the stoma is a common complication following this procedure; in some studies, stricture severe enough to cause stranguria occurred within a few weeks to months after surgery. This is most likely a result of the urethra's small size, the animal's size, and how deep the urethra is located, all of which cause tension on the repair. Therefore the surgeon should place the initial urethrostomy site in the ventral half of the perineum to allow for repeat urethrostomy at a site more dorsal in the perineum. Placing the urethrostomy site in the ventral half of the perineum also minimizes urine scalding. Placing the incision at the site where the vertical surface of the perineum begins to curve cranioventrally is appropriate; this site lies immediately proximal to the scrotum or castration scar.

Anesthesia, preparation, and the approach to the penis are performed as for penectomy. Adequate blunt and sharp dissection is necessary to allow the penis to be exteriorized without excessive tension. To avoid placing the urethrostomy in tissues likely damaged by sharp calculi, the site chosen for urethrostomy should lie proximal to the distal bend of the sigmoid flexure.

In cases of urethral rupture, it may be advantageous to transect the penis distal to the urethrostomy site; this will facilitate drainage of urine from the tissues of the inguinal region and prevent infection in devitalized tissue. The dorsal penile vessels should be ligated immediately proximal to the transection site. As described for penectomy, the penis is transected and the distal segment excised, a horizontal wedge resection of the cavernosum of the stump is performed, and the cavernosum is closed to limit hemorrhage. The penis is then positioned so the stump is located at the distal apex of the skin incision. If the distal penis is not to be excised, the dorsal penile vessels should be left intact.

To hold the exteriorized segment of the penis in place, a horizontal mattress suture of monofilament, nonabsorbable material is placed through the skin and into the tunica albuginea of the penis on each side of the distal apex of the skin incision. Alternatively, the tunica albuginea can be secured with absorbable suture to the subcutis of the apex of the distal incision. The urethra is incised a vertical length of approximately 10 to 15 cm in steers and bulls and 3 to 6 cm in small ruminants and swine. With proper positioning of the penis, the urethral incision should lie immediately adjacent to the skin incision. If the skin incision is judged to be of excessive length, it can be closed to create a skin incision that more closely aligns with the edges of the incised urethra. A 0 to 3-0 monofilament, nonabsorbable suture material is used to appose the edges of the urethral mucosa to the adjacent skin edges, thus creating a spatulated urethral orifice.



Figure 23-39 Perineal urethrostomy in a wether goat. Strips of skin on each side of the urethrostomy have been resected and sutured closed to facilitate urine outflow from the stoma.

The dorsal and ventral apices of the urethral incision are sutured to the corresponding apices of the skin incision. A simple interrupted pattern, or several small sections of simple continuous pattern, can be used. Meticulous apposition of the urethral mucosa to the skin is necessary to limit hemorrhage from the corpus spongiosum, prevent urine leakage into the subcutis, and create a permanent stoma.

Stab incisions into edematous tissue will facilitate urine drainage in cases of urethral rupture. Postoperative care is similar to that for penectomy. In obese animals, excision and closure of small strips of skin lateral to each side of the stoma may help keep the stoma open and limit interference with urine egress by skinfolds (Figure 23-39). Suture removal is performed 2 weeks after surgery.

Ischial Urethrostomy

In this procedure, a proximal perineal urethrostomy is created, and an indwelling catheter is inserted into the bladder via the urethrostomy site. Ischial urethrostomy can be used in animals intended for slaughter and in cases of bladder or urethral rupture.

In larger ruminants this procedure is most easily accomplished with the animal standing, whereas small ruminants and swine can be placed in sternal recumbency with the perineum placed at the very edge of the surgical table. Epidural anesthesia is applied, the rectum is emptied of feces, and the perineum is clipped and aseptically prepared from the anus to the scrotal base. The perineal skin incision is made on the midline of the perineum at a point immediately dorsal to the level of the tubera ischiadicum. The incision is continued distally along the perineal midline for approximately 10 cm in steers and bulls and 4 to 6 cm in small ruminants and swine. A thick layer of fascia is encountered deep in the subcutis; this should be incised on the midline to reveal the retractor penis muscles. These muscles are separated bluntly and retracted laterally to reveal the slightly rounded surface of the underlying bulbospongiosus muscle. On the midline raphe of this muscle, a groove is detected by

palpation. The urethra lies within this groove. A 1- to 2-cm vertical incision is made through the raphe of the bulbospongiosus and into the urethral lumen. Hemorrhage from the corpus spongiosum is often profuse and can be limited by applying firm digital pressure dorsal to the incision. A finger or set of hemostatic forceps can be inserted into the incision to confirm that the smooth urethral lumen has been entered.

A sterile Foley catheter[1] is introduced into the urethra and passed retrograde into the bladder. The appropriate Foley catheter diameter is dictated by the size of the animal, but the largest catheter possible should be used. A well-lubricated polypropylene catheter or disinfected wire guide can serve as a stylette for guiding the catheter into the bladder. Passage may be facilitated by placing a slight curve in the stylette; the curved tip of the catheter is then maintained in a cranioventral direction during passage. Alternatively, the catheter can be grasped with curved forceps and guided into the pelvic urethra, from which point it can be advanced into the bladder. The proximal location of the incision typically allows the catheter to avoid entry into the urethral recess (diverticulum).

Once the catheter tip is in the bladder, the stylette is removed and the Foley catheter balloon is inflated with the appropriate volume of saline. The catheter should be directed ventrally from the incision and securely sutured to the perineal skin. The siphoning effect of the catheter is improved if the catheter opening is secured so it lies ventral to the catheter tip in the bladder. To improve the siphoning effect of the catheter, a small length of rubber tube can be attached to the catheter opening to extend the effective outside length of the catheter so that the external opening lies well ventral to the level of the bladder. This is particularly useful in bladder rupture cases where effective drainage is desired.

To prevent aspiration of air into the bladder, a Heimlich valve or a slit finger from a latex glove is fastened or glued to the catheter opening. A square rubber flap can be fashioned from an inner tube and sutured or glued to the perineal skin between the anus and dorsal apex of the incision. The flap covers the surgical site and Foley catheter, thereby limiting fecal contamination. The catheter is maintained in place until the time of slaughter.

Modified Proximal Perineal Urethrostomy

A modified proximal perineal urethrostomy has been described for use in goats (Tobias et al, 2013), although this technique could likely be used in sheep and larger ruminants. In this procedure, small ruminants, under general anesthesia, are placed in sternal recumbency with their rear legs hanging off the back of the surgical table. A 6- to 8-cm perineal skin incision is made on the midline extending distally from the level of the ischial tuberosities, and the penile body is dissected free from surrounding tissues. The retractor penis muscles are then transected and the dorsal artery of the penis separated from the penile body and retracted cranially. Transection of the penile body is performed at the level of the proximal sigmoid flexure or immediately proximal to the previous perineal urethrostomy site. The ventrolateral attachments of the proximal end of the penis are freed using a sharp and blunt dissection. Dissection of these attachments, which mainly consist of the ischiocavernosus muscles and connective tissue, allows caudal retraction of the penis. The urethra is then incised longitudinally and the spatulated end is sutured to perineal skin with absorbable, monofilament suture to create an ~2-cm urethral spatulation (Figure 23-40). Subcutaneous tissue and skin located dorsal and ventral to the spatulation can be closed routinely. The reported benefits of this modified technique include decreased tension on the urethrocutaneous apposition, which limits stricture formation and ease of bladder catheterization through the perineal urethrostomy site. Hemorrhage can occur postoperatively but does not appear to affect clinical outcome. The authors recommend this procedure if a perineal urethrostomy is elected.



Figure 23-40 Completed perineal urethrostomy using the modified technique.

Ischial Urethrotomy

For breeding bulls, a surgical approach identical to that for perineal urethrostomy is combined with an alternate method of catheter placement to preserve urethral patency along the entire urinary tract and maintain breeding ability. Primary closure of the urethra is performed; therefore the procedure is termed an *ischial urethrotomy*. Adaptation of this technique to breeding males of other species is possible, provided the penis can be exteriorized and catheterized during surgery. This procedure is less likely to restore breeding ability in animals affected by urethral rupture.

The approach to the urethra and urethral incision is performed as described for ischial urethrostomy. The distal penis is exteriorized from the sheath by an assistant, and a retrograde urinary catheter introduced into the urethral orifice and passed to the level of the obstruction. Retrograde urohydropulsion is performed with large volumes of sterile saline to expel the calculus or calculi from the urethral incision. Once the obstruction is dislodged and the urethra can be flushed freely, the retrograde catheter is removed.

One end of a 200-cm sterile polyethylene tube 3 mm in diameter is lubricated and inserted into the bladder from the urethral incision. The opposite end is then passed normograde (down the urethra) to exit the urethral orifice. Passage through the sigmoid flexure is facilitated by extending the penis. The catheter is then flushed with saline to set up a siphon from the urinary bladder. The catheter is held in place by friction. The urethra is closed with 2-0 or 3-0 monofilament, absorbable suture in a simple interrupted pattern. The bulbospongiosus muscle and fascia are closed

[1]Sherwood Medical, St. Louis, MO, USA.

with 0 or 2-0 absorbable suture in a simple continuous pattern. Skin closure is performed. The catheter is flushed with saline to initiate siphoning of urine from the bladder. Although the catheter typically remains in place for 4 to 5 days postoperatively, it may be allowed to remain in place for as long as 10 days.

In cases of urethral rupture, it is optimal to maintain the catheter in place for 2 to 3 weeks to provide the best chance for healing the urethral defect(s). To accomplish this, the penis is exteriorized and the distal 3 to 5 cm is inserted into the lumen of a latex rubber Penrose drain. The drain is sutured to the distal penis with 2-0 nonabsorbable monofilament suture. The distal end of the drain should extend 3 to 4 inches from the tip of the glans. The urethral catheter can be sutured to the Penrose drain to provide a flexible external fixation point for the catheter. The catheter should be cut off so it does not protrude too far out of the preputial orifice.

Completion of this procedure requires that urohydropulsion successfully relieve the obstruction. If retrograde urohydropulsion is not successful, alternate methods of calculus removal, such as basket catheters and laser lithotripsy, may be used. If these options are not available, the incision can be closed and another procedure that preserves breeding ability (e.g., tube cystostomy, urethrotomy) can be performed. Alternatively, the surgery can be completed as an ischial urethrostomy, as described earlier. In such cases, the obstruction may resolve spontaneously or may be dissolved by flushing the urinary tract with sterile, mildly acidic solutions (see tube cystostomy later in this chapter). Although a guarded prognosis for breeding should be made if an ischial urethrostomy is performed, relief of the urethral obstruction, maintenance of the urethral wall integrity, and complete second intention healing of the urethrostomy site might render the animal eventually able to breed.

Urethrotomy

In this procedure, the skin and subcutis are incised directly over the obstruction. The obstructing calculus or calculi are massaged or flushed out of the urethra, shattered or crushed by applying an instrument to the urethra, and/or removed through a urethral incision. If the urethra is incised, it may be sutured for primary closure or left open to heal by second intention. If the urethra is compromised, it may be advisable to avoid primary closure.

Identifying the urethral obstruction location is necessary to ensure proper incision placement. Palpation of the penis through the skin, ultrasonography, urethral catheterization, or positive contrast urethrography can be used to identify the obstruction location (Figure 23-41). Alternatively, in cattle the surgeon may simply orient the incision over the distal bend of the sigmoid flexure, thereby relying on the tendency for calculi to obstruct steers and bulls at this level.

Urethrotomy may allow breeding ability to be maintained. However, a guarded to poor prognosis is warranted because adhesion development at the surgical site may limit normal extension of the penis. Urethral stricture is another potential complication of this procedure. Urethrotomy is not a productive endeavor in cases of urethral rupture because the ruptured urethral wall is usually too friable for repair by primary closure. At least 60 days of sexual rest must be enforced to prevent dehiscence of the urethral repair during breeding.

The following description applies to cases in which the urethral obstruction is located at the level of the distal sigmoid flexure. In small ruminants and swine, lumbosacral (high) epidural anesthesia may be used. In steers and bulls, sacrocaudal epidural anesthesia alone is often insufficient for complete anesthesia of this region, so it is combined with

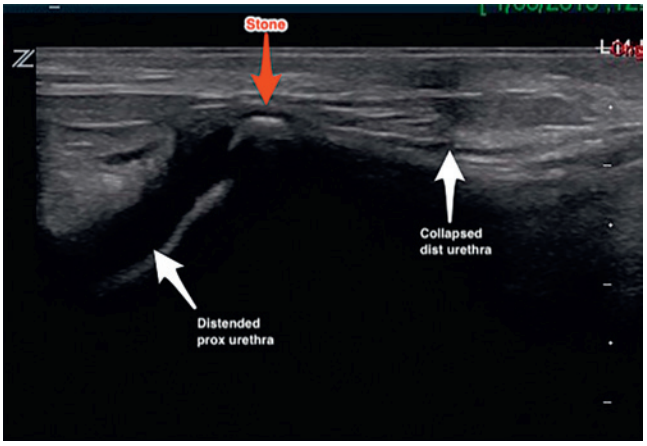


Figure 23-41 Ultrasound of the urethra of a goat showing the presence of a stone and the dilated urethra proximal to the obstruction.

lidocaine infiltration of the subcutis at the incision site. The animal is placed in dorsal or lateral recumbency with the upside hind limb abducted. The skin immediately cranial to the scrotum is clipped and prepared, and if needed local anesthetic is injected subcutaneously on the midline to create a line block.

The penis is grasped through the skin, and a 5- to 10-cm longitudinal skin incision is made over the penis on the midline. The subcutis and peripenile elastic tissue are incised. Hemostasis should be meticulous, as hematoma/seroma formation will promote infection and fibrosis. Blunt dissection in a caudal and dorsal direction is performed to free the distal sigmoid flexure of the penis, which can be identified by finding the insertion of the retractor penis muscles. Blunt dissection should be limited to the minimum necessary to exteriorize the distal bend of the sigmoid flexure of the penis. A longitudinal groove is located on the ventral penis that overlies the urethra, and the obstruction can usually be located by careful palpation along the length of this groove.

If packed, sand-like calculi comprise the obstruction, retrograde urethral catheterization and urohydropulsion can be combined with digital massage of the urethra to clear the obstruction. Large calculi may need to be crushed into smaller fragments before massage and urohydropulsion can promote their passage. A towel clamp, hemostatic forceps, or Allis tissue forceps is positioned over the calculus. Pressure applied to the calculus through the urethral wall is slowly increased to crush the calculus. Calculus fragments may be massaged to promote passage or flushed out of the urethral orifice by injecting saline through a small-gauge needle placed into the urethra proximal to the obstruction. Calculus crushing carries the potential complication of inciting urethral rupture or necrosis, and repeated attempts at crushing may damage the urethral wall.

If the calculus is not passed after two crushing attempts or the surgeon elects not to attempt crushing, a small incision is made into the urethral lumen with a No. 15 blade. The incision should be located directly over the calculus if the urethral wall at that site appears normal (Figure 23-42). If the urethral wall over the calculus is discolored or crushing attempts have traumatized the wall, the urethral incision should be placed in relatively healthy tissue adjacent to the calculus. The calculus is gently removed from the urethral lumen. A urinary catheter is introduced into the urethral lumen, and the urethra is flushed in both directions to ensure

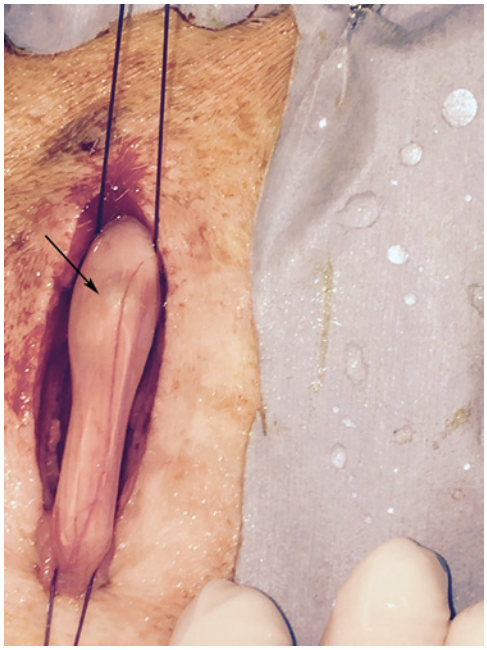


Figure 23-42 The penile urethra isolated in preparation for urethrotomy. A small urolith is present at the *black arrow*.

patency before closure. If an additional obstruction is located in the urethra distal to the incision, passage of a urinary catheter into the urethral orifice and urohydropulsion can be used to expel the calculus or calculi from the urethral incision. If additional calculi are encountered in the proximal urethra, these can be flushed retrograde into the bladder or—failing that—can be removed through a separate urethrotomy site. The urethra is closed with 3-0 monofilament, absorbable sutures in a closely spaced, simple interrupted pattern. The incision should be flushed copiously with sterile saline. The penis is returned to its normal position, and the subcutaneous tissues and skin are closed routinely.

Moderate swelling of the incision site is expected during the first few days after surgery. However, urine accumulation in the tissues surrounding the incision site manifests as severe, progressive swelling and indicates dehiscence of the urethral incision. Urethrostomy revision or an alternative procedure is to be considered in such cases, particularly if the animal is intended for breeding.

SURGERY OF THE URINARY BLADDER

General Considerations

In breeding animals with urolithiasis, surgical procedures of the bladder allow the surgeon to avoid making a urethral incision, thereby reducing the likelihood of postoperative urethral stricture and peripenile fibrosis. The surgeon is able to repair defects in the bladder wall in cases of bladder rupture, and calculi within the bladder lumen may be removed. Bladder surgery is generally more difficult to accomplish under field conditions than urethral surgery. General anesthesia greatly facilitates patient positioning and restraint for these procedures, although local anesthesia with or without concurrent epidural anesthesia can be used.

Cystotomy

Cystotomy is combined with retrograde and normograde urohydropulsion to clear the lower urinary tract of calculi. General anesthesia is usually required for this procedure. Local anesthesia of the abdominal wall combined with lumbosacral (high) epidural anesthesia will provide adequate anesthesia. However, local anesthesia of the abdominal wall alone does not provide sufficient anesthesia because the discomfort resulting from penile extension, urinary catheter passage, and repeated urohydropulsion is not eliminated. This procedure has been used most often for small ruminants and swine because it is very difficult to achieve adequate access to the bladder in large steers and bulls with this procedure.

Retrograde urohydropulsion requires exteriorization of the penis, which is difficult to do if the penile frenulum is intact. An intact frenulum may be present in prepubertal animals or, less commonly, in animals castrated at an early age. Because bidirectional urethral catheterization and flushing are required to clear the urethra, this procedure carries the risk of iatrogenic urethral rupture or stricture. An assistant is needed to perform retrograde urohydropulsion during the surgery.

The animal is placed in dorsal recumbency, and the ventral abdomen and inguinal area are clipped and prepared. The penis is exteriorized from the prepuce, the urethral process is amputated, and the penis is secured with towel clamps to one side of the abdomen. A 5 to 10 French polypropylene urinary catheter is passed into the distal urethra and left in place. The penis and urinary catheter are covered with sterile towels and a waterproof drape.

A paramedian skin incision, measuring 10 to 30 cm as dictated by the patient's size, is made in the caudal abdomen on the side opposite the exteriorized penis. The incision should be placed 1 to 3 cm lateral to the prepuce, with its caudal apex located even with the level of the rudimentary teats in small ruminants or the last row of teats in swine. The subcutis is incised to expose the external rectus sheath. At this point, the surgeon can enter the abdominal cavity by continuing the paramedian approach or can undermine the subcutis over the ventral midline and enter the abdomen through the linea alba.

Sterile laparotomy sponges are used to pack off the bladder from the surrounding viscera. Exteriorization of the bladder is facilitated by first aspirating urine from its lumen. The bladder should be inspected carefully for areas of necrosis or leakage. Stay sutures are placed and a 3- to 4-cm cystotomy incision is made in the ventral wall of the bladder. Calculi within the bladder and pelvic urethra are removed by suction with a finger and/or a bladder spoon. Samples of calculi should be submitted for mineral analysis.

A 5 to 10 French polypropylene urinary catheter is introduced into the bladder and guided through the trigone into the pelvic urethra. Multiple saline flushes through this catheter are used to dislodge calculi from the pelvic urethra and propel them back into the bladder for retrieval.

An assistant reaches underneath the drapes to attach a syringe filled with sterile saline to the retrograde catheter to perform retrograde urohydropulsion. Aseptic technique should be used for handling the saline and urinary catheter. During retrograde flushing, the assistant should squeeze the urethral orifice to prevent loss of saline to the exterior. Meanwhile, the surgeon can place a finger through the bladder trigone to digitally occlude the lumen of the pelvic urethra. As the urethra dilates, the finger is withdrawn and calculi are flushed from the urethra into the bladder lumen where they can be retrieved. Repeated flushes are usually needed to clear the urethra. Injecting saline into the retrograde catheter is difficult if the catheter has been advanced into the urethral recess, so this catheter should be kept in the distal urethra during retrograde urohydropulsion. However, it can be advanced intermittently to assess urethral clearance.

If retrograde flushing can be performed readily without evidence of saline filling the bladder, a rupture of the urethra should be suspected. In such cases, passage of a normograde urinary catheter should be attempted and left in place for 10 to 14 days, if successful, to limit urine contact with the ruptured urethra. Regardless of the success of normograde catheterization, a tube cystostomy should be performed (see the following discussion) to reduce the volume of urine passing into the ruptured urethra.

The urethra can be considered patent if saline can be flushed in the normograde and retrograde directions and be recovered at—or seen to exit readily from—the opposite end. The bladder incision is then closed with two layers of a monofilament, absorbable suture in an inverting pattern. If bladder tears or necrotic areas of bladder wall are present, they should be debrided and closed, or resected and closed, respectively. The abdomen should be lavaged with sterile saline before closure. The abdominal wall is closed routinely.

Because the animal must void urine through the traumatized urethra, postoperative dysuria may be severe. Judicious administration of antiinflammatory drugs is indicated if azotemia does not exist and hydration status is normal. Postoperative antibiotic therapy should be continued for 3 to 5 days. For valuable animals, urethroscopy and laser lithotripsy can be used to clear distal urethral stones that are refractory to urohydropulsion. Urethroscopy provides an assessment of the urethral mucosa.

Tube Cystostomy

In this procedure, a Foley catheter is placed into the bladder lumen via a laparotomy with the goal of temporarily diverting urine, decreasing urethral spasm and inflammation, and allowing spontaneous passage of calculi. Tube cystostomy is a valid option for animals intended for breeding as well as castrated males kept as pets or intended for slaughter. Because this procedure involves a laparotomy, primary repair of bladder rupture is possible. This procedure is also an option for breeding males with urethral rupture, as it allows urine to bypass the urethral defect to facilitate urethral healing (Haven et al, 1993; Rakestraw et al, 1995). General anesthesia is preferred due to the length of the procedure and desire for complete immobilization, although local or epidural anesthesia can also be used. The animal can be placed in dorsal recumbency (ventral midline/paramedian approach), lateral recumbency (low-paralumbar fossa approach), or lateral recumbency with the upside hind limb abducted (ventrolateral approach). When the animal is in lateral recumbency, ruminal gas distention may hinder bladder visualization and make closure of the body wall difficult, so repeated decompression is often necessary.

Tube cystostomy can be performed on a variety of ruminants and swine of diverse sizes. In bulls and large steers, the low-paralumbar or ventral oblique approaches are preferred, and two assistants are often needed to retract the sides of the incision for adequate visualization of the bladder. However, exposure of the bladder is limited in large bulls, even with assistants present to provide retraction.

The size of the Foley catheter needed will vary somewhat with the animal's size. The author prefers to err on the side of a larger catheter because the opening of the catheter tip is larger and less likely to become obstructed with blood or calculi. A 14 to 22 French catheter is commonly used in adult small ruminants, and a 26 to 32 French catheter is used for bulls. A 12 to 18 French catheter is usually adequate for smaller sheep, goats, and swine. A new catheter should be used for this procedure because the balloons of used, resterilized catheters appear to deflate prematurely in some cases.

If local anesthesia is used, the surgeon will need a sterile syringe filled with 5 to 10 mL of 2% lidocaine and a sterile needle added to the surgical tray to anesthetize the body wall for a stab incision for passage of the Foley catheter.

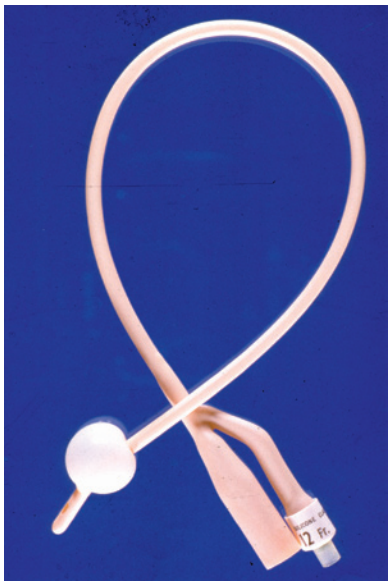


Figure 23-43 A Foley catheter shown with the balloon anchor inflated with sterile saline.

Once the surgeon is scrubbed in, he or she should fill the Foley catheter balloon with the appropriate volume of saline to test it for leaks. Usually, the maximum saline volume for the balloon is indicated on the wrapper. If not, the balloon is filled with enough saline to make it approximately 2 cm in diameter (Figure 23-43). Catheters that leak saline from the balloon or its injection port should not be used. The balloon is then deflated until the catheter has been placed into the bladder lumen.

For a paramedian approach, the animal is placed in dorsal recumbency, and the ventral abdomen and inguinal region are clipped and prepared. A paramedian skin incision of 10 to 20 cm is made in the caudal abdomen. The incision should be placed 1 to 3 cm lateral to the prepuce, with its caudal apex located even with the level of the rudimentary teats in small ruminants or the last row of teats in swine. The subcutis is incised to expose the external rectus sheath. Careful hemostasis should be practiced. The surgeon can enter the abdominal cavity by continuing the paramedian approach or can undermine the subcutis over the ventral midline and enter the abdomen through the linea alba.

For a low-paralumbar approach, the patient is restrained in lateral recumbency with the hind limbs extended and secured behind the animal. A 15- to 40-cm vertical incision is made in the caudal aspect of the paralumbar fossa, 1 to 4 cm cranial to the level of the tuber coxae, with the incision length made proportional to the animal's size. Careful hemostasis should be practiced to limit hematoma/seroma formation. The incision is continued through the muscles of the paralumbar fossa, and the abdomen is entered.

For a ventral oblique approach, the animal is placed in lateral recumbency with the upside hind limb extended behind the animal and secured in an abducted position. The caudal apex of the skin incision should lie even with the rudimentary teats. The incision is oriented on a line that lies just medial to the fold of the flank, extending from the inguinal area caudally on an oblique line toward the umbilicus cranially. A 15- to 40-cm incision is made along this line through the skin; the incision length is adjusted to the animal's size. Careful hemostasis should be practiced because

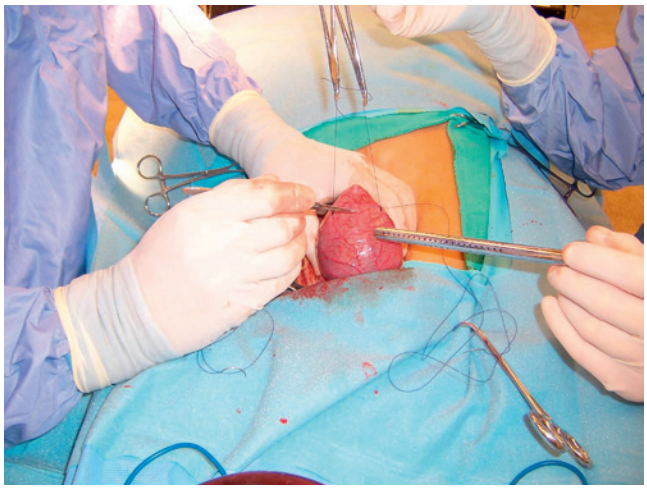


Figure 23-44 Ventral paramedian celiotomy exposing the urinary bladder, which is supported with stay sutures in preparation for cystotomy.

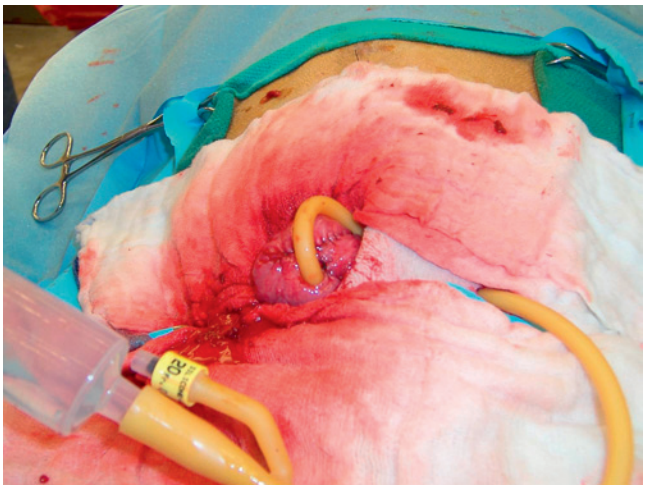


Figure 23-45 Completed tube cystostomy with Foley catheter in place.

persistent incision hemorrhage may promote hematoma/seroma development. The external rectus sheath is incised, the underlying muscle is opened with scissors, and the internal rectus sheath and peritoneum are incised.

The bladder is identified and urine can be aspirated from its lumen with a small-gauge needle to ease handling and exteriorization. The bladder is inspected for tears and areas of necrosis. Laparotomy sponges or moistened towels are used to pack off the bladder from the rest of the viscera. A pair of stay sutures are placed 3 to 5 cm apart in the ventral bladder wall immediately caudal to the apex of the bladder. A 0.5- to 1.0-cm-long incision is made into the bladder between the stay sutures (Figure 23-44). Immediate suction to limit urine contamination of the abdomen is ideal. Repeated lavage with saline and suction is used to remove calculi from the bladder lumen. A gallstone scoop is particularly useful for retrieving stones and debris from the trigone area of the bladder. Any calculi retrieved should be saved for mineral analysis. The cystotomy incision is closed using a monofilament, absorbable suture—size 0 or 2-0—in two inverting layers. Once the cystotomy incision is closed the bladder can be further evaluated, and closure of any tears or resection of necrotic areas can be performed.

A stab incision is now made in the body wall, through which the Foley catheter will be passed. For all approaches, the stab incision in the body wall should be placed even with the transverse plane of the bladder incision. The stab incision should be situated at a point so the bladder can be easily apposed to the ventral abdominal wall. For the paramedian/ventral midline approach, the author prefers to place the stab incision on the contralateral side of the paramedian incision as this maintains the tube away from the laparotomy incision during healing, although the stab incision can also be placed 2 to 4 cm lateral to the laparotomy incision. For the low-paralumbar fossa approach, the stab incision should be located immediately medial to the flank fold. For the ventral oblique approach, the stab incision is located 2 to 4 cm ventral to the incision. If local anesthesia is being used, the proposed stab incision site should be infiltrated with 2% lidocaine. The stab incision should measure approximately 1 to 2 cm in length and should be oriented in a craniocaudal direction. The stab incision is extended through the skin and muscle to the level of the peritoneum. The peritoneum should be punctured with a blunt instrument, such as hemostatic forceps. The jaws of the forceps are spread apart repeatedly to spread open the peritoneum. The surgeon should manually protect the underlying viscera during this step.

Large forceps are then introduced into the abdomen via the laparotomy incision, with the jaws extended through the stab incision. The tip of the Foley catheter is then gently placed into the forceps and pulled into the abdomen. A purse-string suture is placed in the ventral bladder using a No. 0 monofilament, absorbable suture, and then a stab incision is made into the bladder. The tip of the Foley catheter, including the deflated balloon, is placed through stab incision. The tube is secured with the purse-string suture to ensure the catheter stays in place and urine does not leak around it. The balloon is filled with the appropriate volume of saline. The balloon should be palpated through the bladder wall to ensure that it is properly filled (Figure 23-45).

The external end of the catheter is then pulled gently to appose the bladder wall to the body wall at the interior aspect of the stab incision of the body wall. Nonabsorbable suture in a Chinese fingertrap or purse-string pattern is used to secure the Foley catheter to the skin surrounding the stab incision in the body wall. Care should be taken when making both the stab incision in the abdominal wall and in the bladder so that excessive tension on the bladder is avoided when the Foley catheter is pulled tight to the body wall.

The laparotomy sponges or towels are retrieved, and the abdomen is lavaged with sterile saline. The body wall and skin incision are closed. To reduce dead space, each muscle layer can be intermittently sutured to the layer immediately interior to it. The Foley catheter should be sutured to the skin in several sites so that it lies close to the abdomen when the animal stands up (Figure 23-46). This will prevent the animal's hind feet from pulling out the catheter. A Heimlich valve can be fashioned from a finger cut from a latex glove and fastened to the catheter opening to limit aspiration of air.

The Foley catheter should be checked for patency several times per day. Urine should drip slowly but consistently from the catheter opening. If obstruction of the catheter is suspected, ultrasonography should be performed to ensure the catheter is still within the bladder lumen. Rarely, deflation of the catheter balloon results in displacement of the catheter from the bladder lumen. If the catheter is in place, the outer end of the catheter can be disinfected and sterile saline flushed into the catheter to dislodge blood clots or

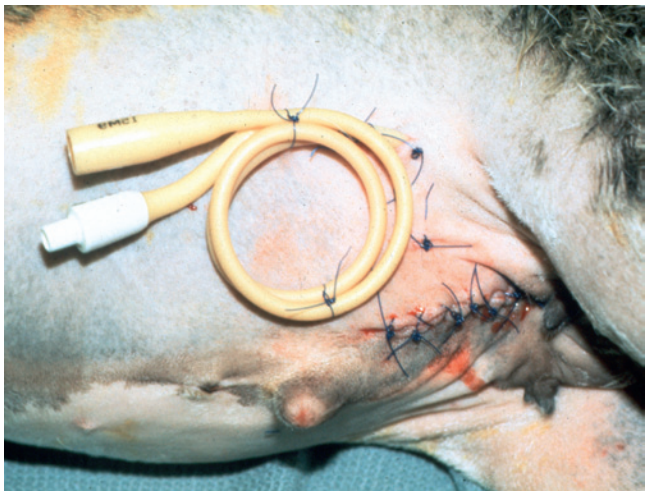


Figure 23-46 A tube cystostomy in a miniature pig. The catheter has been sutured to the abdominal skin in several sites to prevent it from being stepped on. Note the latex glove finger glued to the catheter port to serve as a Heimlich valve.

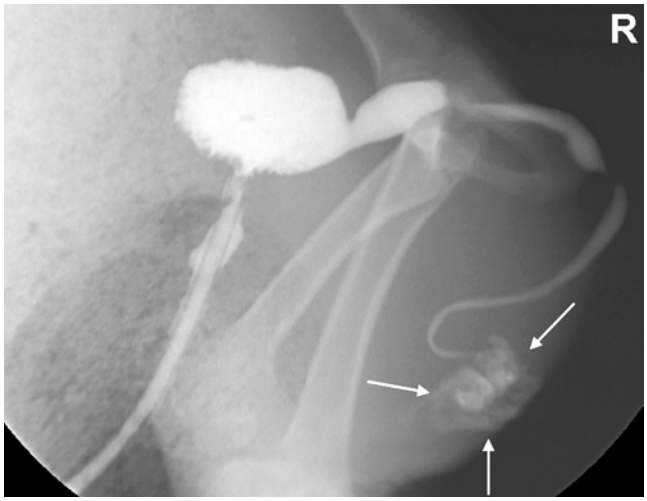


Figure 23-47 Normograde, positive-contrast cystourethrogram was performed in a goat via a cystotomy tube. Extravasation of the contrast medium is detected at the ventral aspect of the sigmoid flexure in the penile urethra, thus indicating a urethral rupture.

calculi that may occlude the catheter opening in the bladder. Fluoroscopy using radiopaque dye introduced into the urinary tract via the Foley catheter can be very useful to evaluate urethral patency and locate the level of obstruction created by calculi or urethral stricture, especially in animals that remain obstructed despite tube cystotomy treatment (Figure 23-47).

In the days to weeks after surgery, while urine is diverted from the bladder through the catheter, the calculi remaining in the urethra are most likely passed spontaneously from the urethral orifice after urethral spasm and swelling subside. Beginning 3 to 4 days after surgery, the Foley catheter can be clamped shut or plugged for 1 to 3 hours each day to determine whether the urethra has become patent. The patient should be observed closely while the catheter is occluded. If the animal shows signs of colic or stranguria, the catheter can be unclamped or unplugged to allow urine egress; the process is repeated on the following day. In 15 small ruminants treated by tube cystostomy, urine began to drip from the urethral orifice after an average of 7.5 days (range, 1 to 20 days) postoperatively (Rakestraw et al, 1995).

Once urine is seen dripping from the preputial orifice, the length of time the catheter is occluded can be gradually extended until normal micturition occurs. If the animal continues to void normally with the catheter completely occluded for 1 to 2 days, the catheter can be removed; however, catheter removal should be delayed until at least 7 days after surgery to ensure that a fibrinous or omental seal develops around the bladder incision. Catheter removal took place an average of 14 days after surgery (range, 4-36 days) in the aforementioned study (Rakestraw et al, 1995). Thus the duration of postoperative care can be considerable with this procedure.

To remove the catheter, the skin around the tube entry site is disinfected, the balloon of the catheter is deflated fully, and the catheter is gently pulled out. Urine will usually drip for 1 to 2 days from the body wall fistula created by the tube. Ultrasonography often reveals the bladder is adhered to the interior of the body wall at this site, but this adhesion appears to either break down or stretch in most cases, and no observable effects on the animal's ability to void urine usually result.

Postoperatively, antimicrobial therapy should be continued until at least 1 week *beyond* the date of catheter removal. Ascending infection of the bladder is likely with this procedure; the interior of the tip of the Foley catheter was found to culture positive upon removal in 10 of 10 animals treated with tube cystostomy (Van Metre and Gnad, 2001). However, treatment of these animals with a beta lactam as described previously resulted in no cases of persistent urinary tract infection. Phenazopyridine (4 mg/kg orally every 12 hours) can be administered as bladder analgesic and is especially useful in animals that continue to strain postoperatively due to urethral pain and inflammation. Hemiacidrin (Renacidin, Guardian Labs), a solution of citric acid, glucono delta lactone, and magnesium carbonate, can also be administered via the Foley catheter to help acidify the urine postoperatively. It is especially useful with struvite calculi. The solution (~30 mL) is instilled in the bladder, and the tube is clamped off for 30 to 60 minutes. The fluid is then drained off the bladder as the solution can be irritating to bladder mucosa. This can be performed several times a day.

Repeat tube cystotomy is possible, although prognosis seems to decrease with subsequent surgeries. During repeat cystotomy, caution should be used when entering the abdomen because the bladder is almost always adhered to the body wall. In some cases, the bladder can be freed from the body wall once it has been well identified; however, in animals with substantial adhesions it is advisable to leave the bladder in position and place a new tube in such a way that there is minimal tension on it.

Bladder Marsupialization

In this procedure, a permanent stoma is created between the bladder mucosa and the skin of the ventral abdomen, thus allowing direct urine outflow from the bladder to the exterior. Although originally described for use in goats, this procedure could be used in other animals. It is a valid option as a primary corrective procedure for urolithiasis. Bladder marsupialization is also useful as a salvage option for animals that have developed stricture of the urethra or a perineal urethrostomy. Postoperative urinary incontinence is inevitable, and urine scalding of the ventral abdomen may occur. Although uncommon, stricture of the marsupialization site and ascending urinary tract infection are potential complications (May et al, 1998).

Local, epidural, or general anesthesia can be used, although general anesthesia is preferred. The animal is placed in dorsal recumbency and the ventral abdomen and inguinal region are clipped and disinfected. A 10- to 15-cm-long skin incision is made 3 cm lateral to and parallel with the sheath. The incision is continued through the external sheath of the rectus abdominis muscle, the rectus abdominis muscle, the internal rectus sheath, and the peritoneum. The bladder is identified and urine is aspirated from the bladder to facilitate exteriorization.

Two stay sutures are placed beside the bladder apex, approximately 4 to 6 cm apart. A 3- to 4-cm longitudinal cystotomy incision is made on the ventral aspect of the bladder just caudal to the apex. Copious lavage and suction are used to clear the bladder lumen of urine and calculi.

The apex of the bladder is then positioned against the peritoneal surface on the contralateral side of the ventral abdominal wall, equidistant from midline as for the laparotomy incision. The bladder apex is positioned as far cranially as possible without producing excessive tension on the bladder. This step allows the surgeon to determine the optimal location for the marsupialization incision. At this site, a second 4-cm paramedian, longitudinal celiotomy incision is made, which is called the *marsupialization incision*. The stay sutures are used to reposition the bladder apex through the marsupialization incision. The interior of the marsupialization incision is carefully inspected to ensure that bowel is not entrapped with the bladder apex.

Four simple interrupted sutures of absorbable, 2-0 monofilament material are placed through the external rectus sheath of the marsupialization incision and into the seromuscular layer of the bladder, immediately dorsal to (deep in) the cystotomy incision. These sutures should be placed to position the edges of the cystotomy incision even with the level of the skin. These sutures are placed at 12, 3, 6, and 9 o'clock in the marsupialization incision.

Next, the entire circumference of the seromuscular layer of the bladder immediately dorsal to (deep in) the cystotomy incision is secured to the external rectus sheath with 3-0 or 2-0 monofilament, absorbable material in an interrupted horizontal mattress or simple interrupted pattern. The edges of the cystotomy incision are then sutured circumferentially to the skin with 3-0 monofilament, absorbable material in a simple continuous pattern. The abdomen is lavaged and the laparotomy incision is closed routinely.

POSTOPERATIVE CARE AND COMPLICATIONS

Fluid therapy is continued for azotemic animals or those with significant acid-base or electrolyte derangements. Periodic assessment of hydration status is necessary to maintain normal fluid balance; occasionally, postobstructive diuresis results in large-volume fluid losses that require aggressive therapy. Antibiotic treatment is generally maintained for 7 days postoperatively. The hair on the abdomen may need to be clipped and Vaseline applied periodically to limit urine scald. The marsupialization site may require periodic cleaning with saline. With the return of the patient's appetite, salt can be gradually added to the diet to promote water intake and production of dilute urine. Dietary manipulations for prevention of urolithiasis have been reviewed (Van Metre and Divers, 1996).

RECOMMENDED READINGS

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CHAPTER 24

Congenital Anomalies in the Sheep and Goat

Amanda Hartnack and Meredyth Jones

Numerous congenital abnormalities have been reported in both sheep and goats. As in other species, these abnormalities generally result from a genetic defect (spontaneous or inherited) or from an *in utero* environmental exposure of the fetus to a teratogen. Included in the list of recognized environmental causes are a number of viruses, toxic plants, and teratogenic drugs. With the exception of congenital defects involving the genital organs, very little research into the chromosomal genetics of defects has been conducted. In many cases, the genetic basis of a defect is detected as a result of the increased incidence or expression of the defect in a given family of animals. When the defect involves the genitalia (particularly the external genitalia), the alteration in the animal's ability to mature and reproduce often leads to increased recognition of the abnormality. For the purposes of this chapter, we will focus on five of the more commonly recognized congenital abnormalities of sheep and goats.

INTERSEX

As in many other species, the genotypic sex of sheep and goats is determined by the X and Y genes. The genotypic code for males is the XY karyotype, and the XX karyotype is for females. Unlike many other body systems in which genotypic and hormonal control of embryonic differentiation are independent of outside influences, the differentiation of the genital system is highly influenced by local endocrinologic events. Genital differentiation is basically controlled by the formation of gonadal and ductal tissues. Before differentiation, the gonadal tissues (gonocytes that migrate from the endoderm of the yolk sac) have the ability to form either testicular or ovarian tissue. The differentiation of the gonadal tissue is for the most part regulated by the chromosomal sex of the fetus determined at fertilization. The XY karyotype code expression of the H-Y antigen pushes differentiation of the gonadal cells to early testicular cells. Once gonadal tissue differentiation occurs, ductal formation is driven by expression of hormones in the local and systemic environment. Thus defects in hormonal expression, in receptor expression, or in the presence of exogenous hormones can all have a profound effect on ductal formation and genital development. If no H-Y antigen is expressed, as would be the case in a chromosomal XX fetus, the cells differentiate into ovarian tissue by default. Intersex goats express the H-Y antigen even in the presence of an XX karyotype, leading to development of male characteristics.

The intersex congenital abnormality involves the presence of both male and female characteristics in the same animal (Figure 24-1). A variety of presentations can be seen. When female and male gonads are both present, this intersex condition is called *hermaphroditism*. When the gonads of one sex are present with the phenotype of the opposite sex, this condition is called *pseudohermaphroditism;* a male pseudohermaphrodite has testes, whereas the female has ovaries. Although the condition of intersex is recognized in sheep and goats, the incidence appears to be highest in goats. The intersex condition has been studied extensively in goats due to its association with polled genetics. Animals that are polled (congenital absence of horns) have the dominant mutation of the polled gene coded at the horn locus. Thus the mutated gene (P) in either a homozygous (PP) or heterozygous (Pp) state codes for a polled animal, and the homozygous recessive state (pp) codes for horns. Polled animals are desirable to producers because disbudding or dehorning is not required. However, it appears that the polled locus is in close proximity to a gene that controls sexual differentiation. This autosomal gene has functions similar to a Y chromosome, thereby inducing masculinization. As such, females (XX) that are homozygous for the polled gene have the intersex condition (female pseudohermaphroditism), and the males are often infertile secondary to stenosis of the epididymis. No such association has been reported in polled sheep.

As with other species, some female small ruminants born as a twin to males may have an intersex condition termed *freemartinism*. This condition occurs as a result of the chorioallantoic circulation of the twins fusing and exchanging leukocytes and fetal hormones. These hormones presumably cause a masculinization of the female co-twin. Compared with cattle, which have a very high rate of freemartinism, small ruminants have a very low incidence. This difference in incidence is most likely attributable to a low frequency of vascular anastomoses in small ruminants. The condition is characterized by severe ovarian hypoplasia and absence or hypoplasia of the tubular genitalia of the female. External genitalia may demonstrate clitoromegaly or increased anogenital distance. The male twins are generally normal, although fertility may be subnormal and unilateral or bilateral cryptorchidism occurs.

Because of the profound effect the intersex condition has on fertility, these animals should be culled. Surgical procedures to correct these conditions are unlikely to restore normal fertility, and these techniques are not recommended due to potential transmission of some genetic component. However, it should be mentioned that some affected animals have the potential to be used as teaser animals as long as the abnormality is of sufficient severity to assure the animal is not fertile. Hormone assays should detect the presence of androgens, even in genotypic XX animals that have no external male genitalia. For animals with high emotional value, surgical correction of urethral and genital abnormalities may improve urinary function and quality of life (Figure 24-2).

CRYPTORCHIDISM

Cryptorchidism is defined as one or both testes not descending into the scrotum. Early in genital embryogenesis, the testis is located in the fetal abdomen adjacent to the caudal pole of each kidney. It migrates caudally through the inguinal canal into the scrotum, preceded by the epididymis. The migration is directed in part by the gubernaculum and vaginal process; however, defects in these tissues are not always associated with cryptorchidism. It appears that hormones,



Figure 24-1 Goat; note vestigial penis typical of a female pseudohermaphrodite. (Courtesy of Dr. Andy Niehaus.)

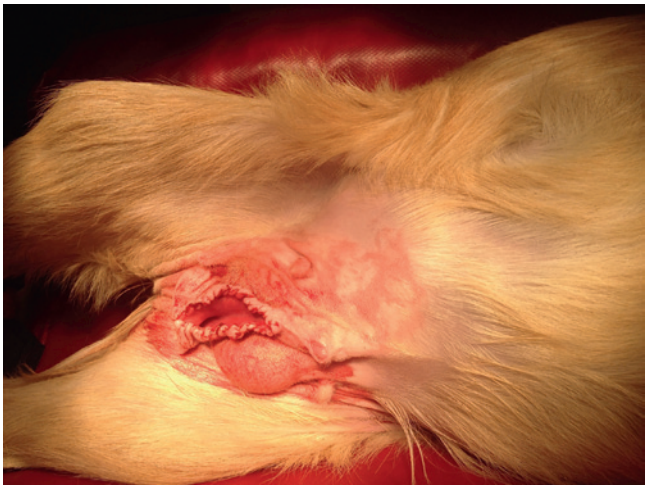


Figure 24-2 Surgical fixation of urethral abnormality. This animal presented for stranguria and a fluid-filled mass on ventral midline. A new urethral orifice has been created.

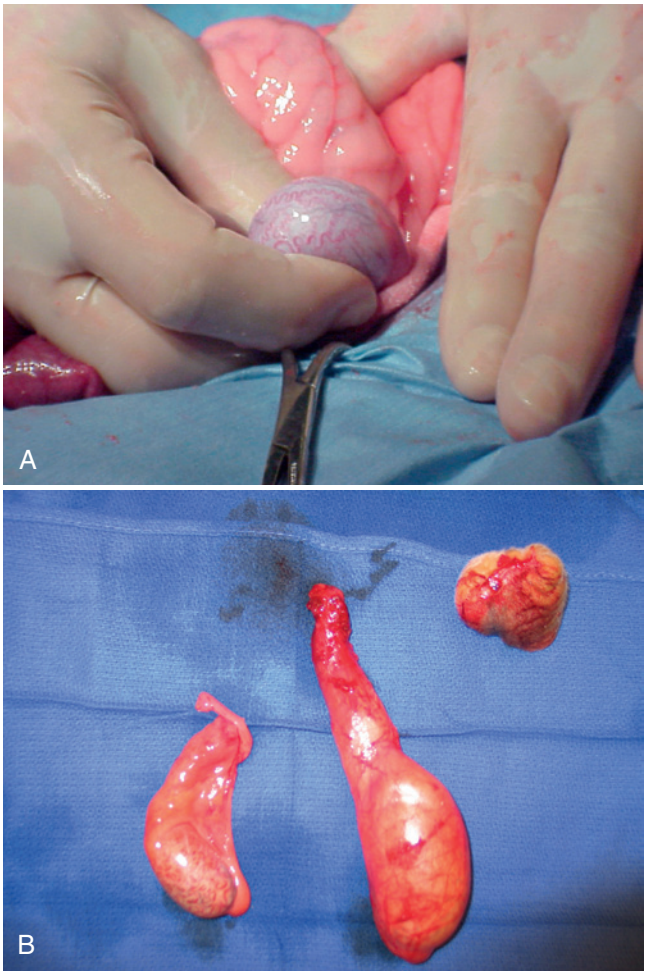


Figure 24-3 *A*, Intraoperative view of a goat in surgery for a right cryptorchid testis. The cryptorchid testis can be seen via a right paramedian celiotomy. *B*, Both testes are shown after resection. Note the normal larger left testis on the right of the figure and smaller right cryptorchid testis on the left of the figure. (Courtesy of Dr. Andy Niehaus.)

particularly mullerian inhibiting substance (MIS) and testosterone, may also play an important role in testicular descent. MIS is produced by the Sertoli cells of the fetal testis. During embryogenesis, the MIS induces a local (restricted to the side of production) regression of the paramesonephric ducts (precursors of the female genitalia) and initiates intraabdominal migration. Goats with a deficiency of MIS production by the Sertoli cells or lacking the receptor for MIS on the paramesonephric ducts develop a reproductive defect known as persistent mullerian duct syndrome (PMDS). Clinically, these bucks have a well-developed penis but are bilaterally cryptorchid. Surgery or postmortem examination demonstrates the presence of both male and female internal genitalia. These bucks have an XY karyotype and are generally considered distinct from the intersex conditions. In dogs and humans, PMDS is inherited as an autosomal recessive trait, and this may be true for goats as well.

Once the testis reaches the inguinal canal, the descent appears to be controlled by local testosterone production. The epididymis relies on testosterone for maturation, so incomplete maturation due to testosterone deficiency may impair testicular descent. In some circumstances, the epididymis may be located in the inguinal canal while the testis is still intraabdominal.

The incidence of cryptorchidism in small ruminants is estimated at 1% but may reach levels of 10% in some herds. It is likely that cryptorchidism in the sheep and goat is inherited as an autosomal sex-linked gene. It is unclear whether the gene for cryptorchidism is recessive or a dominant gene with incomplete expression. Affected testes are generally smaller and firmer than normal testes (Figure 24-3). They can be located in either the abdomen or inguinal canal or both. If they are in the abdomen, they are generally located somewhere along the path of migration from the caudal pole of the kidney to the inguinal canal. The right testis appears to be more commonly retained than the left testis in both sheep and goats. Histopathology of retained testes generally reveals marked fibrosis of the tissue. If the animal is a unilateral cryptorchid, the normal testis may be enlarged and show cellular evidence of compensatory hyperplasia. Bilateral cryptorchids are invariably sterile, whereas unilateral cryptorchids may still be fertile. Some of these animals make suitable teaser animals if their infertility is certain (i.e., after

performing an epididymectomy of the normal testis). Given the inherited nature of this congenital defect, affected animals should not be used as breeding animals. It should be noted that retained testes have been associated with an increased risk of tumor formation or torsion of the spermatic cord. For these reasons, surgical removal of the retained testis may be warranted if an animal is not being culled. Removal of the retained testis may be required for show animals.

Before starting a cryptorchid castration, the side of the retained testis should be determined. The normal testis should be removed after the retained testis to avoid confusion should attempts to remove the cryptorchid testis fail. A thorough palpation of the inguinal area and canals should be performed to determine whether the testis is intraabdominal or inguinal. Ultrasound evaluation of the inguinal region, inguinal canal, and abdominal cavity may also provide useful information about the location of the testis. Transabdominal ultrasound to evaluate an intraabdominal testis is generally performed through a right paralumbar fossa because of the difficulty of imaging the kidneys around the rumen in the left paralumbar fossa. The area between the caudal pole of the kidneys and the inguinal canals should be evaluated. It should be mentioned that many intraabdominal testes are small and structurally abnormal, thus making them difficult to identify by ultrasound. If the testis is located in the inguinal canal, a surgical approach similar to that described for horses may be used to exteriorize the testis and facilitate castration. Briefly, an incision is made over the external inguinal canal of the affected side. Digital palpation of the inguinal canal should reveal the presence of the epididymis. Once the epididymis is located, it is grasped firmly, so gentle outward pressure can be applied to exteriorize the testis. In some cases, the vaginal tunic inverted up into the inguinal canal can be used to blindly locate the testis as described in the equine. Excision of the testis is routine.

In most cases, a ventral celiotomy and exploratory are required to locate an intraabdominal testis. Laparoscopy is the least invasive method of accessing and removing the abdominal testicle(s); however, a traditional open approach is more commonly employed. A paramedian incision should be made on the side of the retained testis. Once the testis is located, excision is routine. Once the retained testis is removed, the normal testis can be removed with normal castration techniques.

CLEFT PALATE

Cleft palate in sheep and goats is commonly associated with ingestion of piperidine alkaloids during pregnancy. In these cases, cleft palate is one of many congenital abnormalities present in affected animals, and surgical fixation is not recommended (Figure 24-4). Cleft palate also occurs sporadically, either by itself or in conjunction with multiple other congenital abnormalities. Animals with cleft palate typically present for milk coming from the nose, and aspiration pneumonia is common.

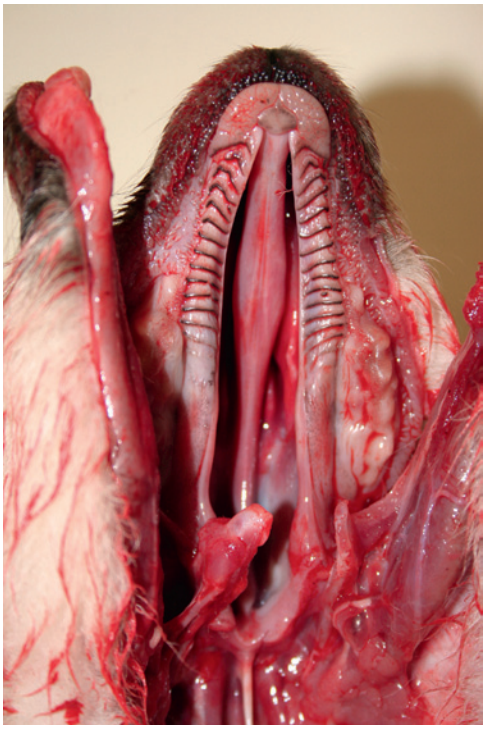


Figure 24-4 Postmortem image of severe cleft of the soft and hard palate in a goat. (Courtesy of Dr. Mary C. Smith.)

ATRESIA ANI

Atresia ani occurs sporadically in both sheep and goats, with higher incidences reported in certain breed groups of animals. The cause and heritability of atresia ani in both sheep and goats remains unclear, however. In sheep, an autosomal recessive gene has been suggested, and presence of atresia ani is often associated with other congenital abnormalities, including rectovaginal fistula. Clinical signs of atresia ani include abdominal distention, depression, anorexia, lethargy, and straining to defecate, with bulging of the anal region. Animals with atresia ani typically present at 3 to 5 days of age, and the condition is easily diagnosed on physical examination. Degree of rectal involvement can sometimes be evaluated using ultrasound in neonatal animals. Although breeding animals with atresia ani is not recommended, surgical fixation may be undertaken to salvage the animal. Surgical fixation can be achieved under sedation and local or epidural anesthesia. The perineal region is clipped and prepped in routine aseptic fashion, and a circular piece of skin is excised. In some instances, removal of the anal membrane is curative. More often, the subcutaneous tissues need to be carefully dissected and the blind end of the rectum located, grasped with tissue forceps, and exteriorized. The rectum should be fixed to the subcutaneous tissues at this point using four simple interrupted sutures at 12, 3, 6, and 9 o'clock. The imperforate end of the rectum can be incised and the rectal mucosa sutured to the skin using 4-0 monofilament suture in either a simple interrupted or simple continuous pattern. If a continuous pattern is used, it should be "broken" at least twice to prevent a purse-string effect. The surgical site should be treated daily with wound-safe fly spray, and sutures should be removed in 7 to 10 days. In animals with a large amount of absent rectum, surgery is likely to be unrewarding and should be discouraged. Breeding of these animals is not recommended.

Entropion is an inward rolling of the eyelid that results in irritation of the cornea secondary to contact with the eyelashes and periocular hair. Entropion has been reported to be the most frequent ocular disease of neonatal lambs and is considered variably heritable. Entropion also occurs in goats, particularly Boer goats. Prevalence commonly ranges from 3.7% to 10% but has been reported to be up to 80%. Entropion can be either congenital or acquired and can affect one or both eyelids, with the lower eyelid more commonly

affected. Common presenting signs include blepharospasm, epiphora, and keratoconjunctivitis.

Conservative treatment of entropion is recommended initially, with spontaneous resolution having been reported. Nonsurgical treatments include subcutaneous injection, pinching, and placement of temporary vertical mattress sutures or skin clips. The injection technique involves a subcutaneous injection of 1 cc of procaine penicillin G in a linear fashion parallel to the lid margin. Injection of the drug causes eversion of the lid initially, with irritation and fibrosis after to maintain eversion. Another simple method for producing local irritation involves pinching of the skin with a hemostat just beneath the eyelid margin. The hemostat is applied parallel to the eyelid margin for a period of 20 to 30 seconds. The final method of nonsurgical repair involves placement of two or three vertical mattress sutures of 3-0 or 4-0 nylon. These sutures are placed perpendicular to the eyelid margin and removed in 2 to 4 weeks. Most cases of entropion will adequately resolve using these methods. In refractory or particularly severe cases, surgical correction should be considered when economically viable. Surgical correction is often delayed due to the possibility of the condition changing in severity or resolving over time, which may result in overcorrection.

Surgical correction of entropion is referred to as the modified Hotz-Celsus procedure. This procedure is often performed by itself, though it has also been combined with a lateral eyelid wedge resection to treat entropion in goats. Surgical correction should be performed under general anesthesia with the animal in lateral recumbency. The surgical site should be clipped and prepped, and a No. 15 scalpel blade is used to make an elliptical incision 1 to 2 mm distal to the lid margin. A Jaeger lid plate or tongue depressor may be placed underneath the eyelid to provide support and enable the surgeon to make an accurate incision. A second elliptical incision is made below the first, with the distance between the two determining the degree of correction. This creates a crescent-shaped skin flap that is then excised. The surgeon should aim for a slight undercorrection as postoperative scar formation can increase the degree of correction and potentially lead to overcorrection. Simple interrupted sutures using 4-0 monofilament nylon are placed perpendicular to the eyelid margins in a single layer starting at the center of the incision and moving outward. Knots should be placed carefully to avoid corneal irritation. Sutures should be removed in 10 to 14 days. If corneal ulceration is present preoperatively, topical antibiotics should be continued for several days postoperatively. Swelling of the eyelids postoperatively is common, and nonsteroidal antiinflammatory drugs are recommended in the immediate postoperative period to reduce inflammation.

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PART V

SWINE

CHAPTER 25

Surgery of the Swine Digestive System

Heidi L. Reesink

GASTROINTESTINAL TRACT

Surgery of the gastrointestinal system is not commonly performed in commercial swine due to low individual economic value and difficulties in diagnosing a surgical digestive abnormality rapidly enough to allow successful surgical intervention. Nonetheless, gastrointestinal disease remains a significant cause of morbidity and mortality in commercial swine operations. In a large German breeding herd, the majority of deaths in breeding gilts was due to gastrointestinal disease, with most gilts dying from bleeding due to gastric ulcers. Gastrointestinal disease accounted for the majority of deaths in finishing pigs, with gastric ulceration, enteritis, gastrointestinal displacement, and rectal stricture accounting for 27.9% of mortality. Disorders such as these that affect a large number of animals and conditions such as atresia ani and umbilical hernia that likely have a genetic basis may warrant investigation and treatment. In purebred breeding stock, biomedical research animals, and pet swine, such as Vietnamese pot-bellied pigs, individual economic or sentimental value may warrant surgical correction of common gastrointestinal disorders or more complicated surgical conditions of the gastrointestinal tract.

Abdominal Approaches and Body Wall Closure/Abdominal Exploration

Ventral midline celiotomy under general anesthesia is the preferred surgical approach for most digestive surgery in swine as it allows the most complete abdominal exploration with potential to correct the majority of surgical conditions. The body wall of swine is distensible and easily manipulated, allowing for access to the stomach, the majority of the small intestine, cecum, spiral colon, and descending colon in most swine. The small intestine may also be approached using a right paramedian or flank incision, which may be preferable in males and may reduce the risk of incisional herniation; however, exploration is more limited. Two- or three-layer closure of ventral midline incisions in swine is recommended using synthetic absorbable suture. The external rectus sheath is closed first in a continuous pattern, followed by the subcutaneous tissues, and skin. Subcutaneous tissues are closed if there is significant dead space due to subcutaneous fat that may predispose to seroma formation. One study suggested that absorbable subcutaneous staples yielded the best healing scores for cutaneous incisions in swine, followed by 3-0 polyglactin 910, with metal staples inducing the most severe inflammatory response. Swine should be confined and separated from herdmates after ventral midline celiotomy to decrease the potential for incisional herniation.

Laparoscopic and Natural Orifice Transendoscopic Surgery (NOTES) is common in swine for biomedical research, using transgastric, transvaginal, transcolonic, or transanal approaches. However, due to the low frequency with which gastrointestinal surgical procedures are performed in swine, equipment, expense, and technical expertise will limit most NOTES approaches in veterinary medicine.

Gastric Ulcers

Gastric ulcers are seen frequently in swine. Recent studies have found small feed particle size and slatted floors as the factors most significantly associated with the development of gastric ulcers. Other findings implicated in the development of gastric ulcers are conditions that lead to stress, including intensive rearing, overcrowding, extended transport, and withholding feed. Clinical signs include pale mucous membranes and dark, tarry feces. Decreased appetite, vomiting, and weight loss may be observed. In valuable pigs, gastrostomy, partial gastrectomy, or oversew of the ulcer may be performed. The animal is positioned in dorsal recumbency, and a cranial ventral midline incision is made, starting near the xiphoid cartilage. The stomach is isolated from the rest of the abdomen using saline-soaked laparotomy sponges, and the serosal surface is evaluated for changes in color and appearance that would indicate an ulcer. Ulcers are most commonly found near the esophagus in the squamous portion of the stomach. Babcock forceps or stay sutures are placed, and a gastrostomy is performed along the greater curvature of the stomach, followed by removal of stomach contents. If a mucosal/submucosal ulcer is found, it can be surgically dissected and the edges electrocoagulated or ligated. The ulcer should be oversewn with an inverting pattern to prevent leakage. If a nearly full-thickness ulcer is found, gastrectomy is recommended. The incision in the stomach is apposed with a simple continuous pattern,

followed by an inverting pattern (e.g., Cushing or Lembert). If multiple bleeding ulcers are present, the prognosis is poor. Omeprazole may reduce recurrence of gastric ulceration and promote healing in pigs treated surgically for gastric ulcers.

Intestinal Obstruction

Intestinal obstruction may occur due to mechanical obstruction caused by feed impaction, intussusception, foreign bodies (Figure 25-1*A*), intestinal volvulus (Figure 25-1*B*), and intestinal incarceration due to inguinal or umbilical herniation. Pigs housed outdoors are at increased risk of foreign body obstruction due to stones. Intussusception is more common in postweaning and growing pigs, whereas intestinal volvulus is more often seen in adult swine. With the increase in popularity of Vietnamese pot-bellied pigs as pets, fecal impaction, obstipation, and neoplasia are increasingly recognized as causes of intestinal obstruction. Neoplasia of the gastrointestinal tract should be included as a differential diagnosis for intestinal obstruction in older swine. A case series of five Vietnamese pot-bellied pigs ranging in age from 11 to 16 years described alimentary carcinomas involving the stomach, small intestine, spiral colon, liver, and gallbladder. Three of these pigs were treated with wide-margin surgical excision of the neoplasia, with all surviving 9 months postoperatively.

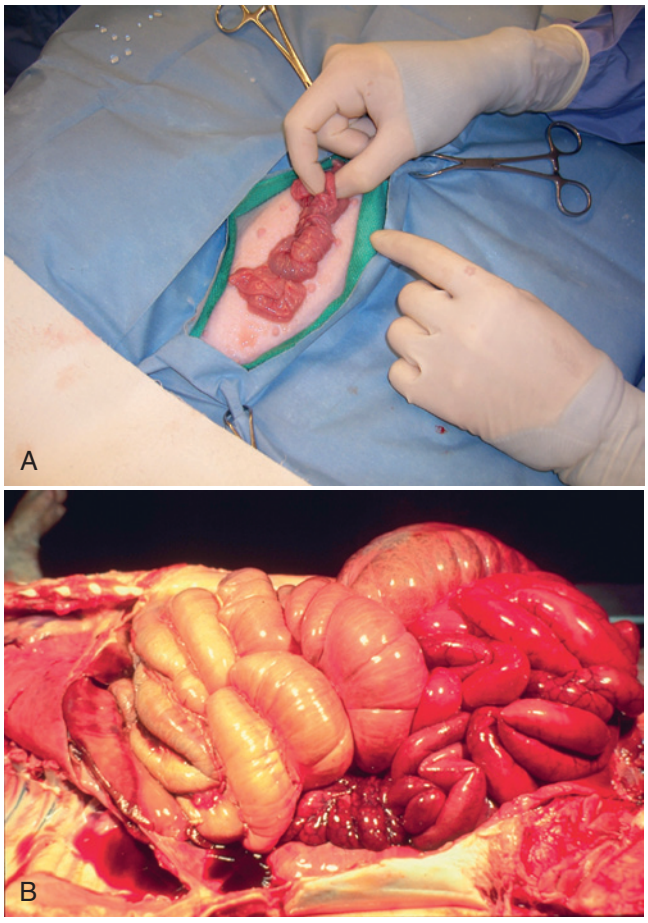


Figure 25-1 *A*, An intraoperative photograph of an 8-month-old Vietnamese pot-bellied pig with a small intestinal linear foreign body. *B*, Postmortem photograph of a finisher pig with small intestinal volvulus. Sudden death is a common clinical presentation of acute abdominal accidents in commercial swine. (Courtesy of Dr. Gerald E. Duhamel.)

Clinical signs observed with intestinal obstruction may include depression, anorexia, vomiting, abdominal distention, decreased fecal volume or defecation frequency, and the presence of blood and/or mucus in the feces. These conditions are rarely diagnosed in live commercial swine. If surgery is an option, a ventral midline celiotomy is performed. Feed impactions may be disrupted manually with massage and infusion of saline solutions or may be removed via an enterotomy. Copious lavage and lubrication of the bowel with carboxymethylcellulose is recommended to decrease bowel trauma and the risk of postoperative adhesions. An enterotomy may be performed to remove a foreign body obstruction if the bowel is viable (Figure 25-2), and an intestinal resection and anastomosis should be performed to resect ischemic bowel or an intussusception. The enterotomy should be made along the antimesenteric border of the small intestine immediately orad to the foreign body. Closure of the enterotomy may be performed using a one-layer appositional pattern in small pigs or an inverting pattern or two-layer closure in larger swine. End-to-end jejunojejunal anastomosis is most commonly performed to resect ischemic bowel or an intussusception. In small pigs, one-layer closure with simple interrupted sutures using synthetic absorbable sutures is recommended. In larger animals, a continuous suture pattern or two-layer closure with oversewing is indicated. For ileocecal intussusception, cecal bypass via side-to-side ileocolic anastomosis without ileal transection has been described using a gastrointestinal anastomosis stapling device in a Vietnamese pot-bellied pig. Spiral colon bypass has been reported for successful treatment of a stricture of the proximal centripetal loop of the spiral colon in a geriatric Vietnamese pot-bellied pig. A 5-cm, side-to-side anastomosis of the proximal centripetal loop to the distal centrifugal loop of the spiral colon after typhlotomy restored gastrointestinal function in one Vietnamese pot-bellied pig with 8 months' follow-up.

In one case series, acute abdominal accidents were characterized clinically by sudden death and were observed more commonly in dry sows. It was proposed that feeding dry sows in large breeding units once a day or every other day might be an important provoking factor. This feeding method often makes sows ingest large quantities of feed and water rapidly. Gastric torsion in swine results in death preceded by a short period of anorexia, abdominal distention, shortness of breath, cyanosis, and salivation. Clockwise torsions are more common than counterclockwise torsions and occur along the

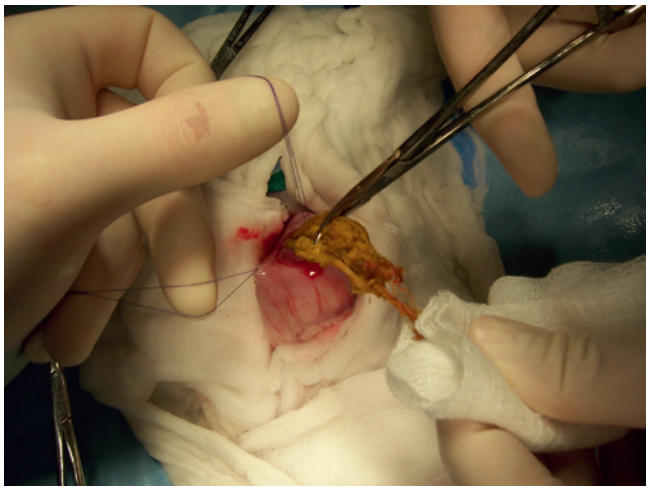


Figure 25-2 Intraoperative photograph of a small intestinal enterotomy to remove the foreign body.

longitudinal axis of the stomach. The stomach is distended with fluid, gas, and food. In some sows, the spleen rotated with the stomach; affected spleens were severely congested, and some had ruptured, resulting in hemoperitoneum. Liver torsion was also seen occasionally. For eight of the sows in that study, an intestinal volvulus diagnosis was more commonly observed in younger animals. The entire small intestine was included in the volvulus of four sows, the posterior half of the small intestine in one, the small intestine and colon in one, and the cecum and colon in another. Acute death as a result of intestinal torsion of anesthetized swine has also been reported. In this study, pigs were sedated and anesthetized using inhalant anesthesia, transported upside down, placed in dorsal recumbency for weighing and radiography, and rolled out of dorsal recumbency for recovery. Intestinal torsions only occurred in animals weighing more than 30 kg (3.2% occurrence), which led the investigators to suggest that the intestinal weight of larger animals may predispose to displacement when rotating the anesthetized patient.

Atresia Ani

Atresia ani may be the most important cause of intestinal obstruction in the pig and occurs more commonly than in any other species. This congenital defect is likely transmitted genetically and may be associated with other congenital abnormalities, particularly of the urogenital tract or large intestine. A diagnosis of atresia is made based on the following findings: absence of an anal opening, abdominal distention, slower growth rate, lack of defecation, tenesmus, and vomiting (Figure 25-3). Because pigs vomit, thus decompressing their intestinal tract, the diagnosis of atresia ani is sometimes not made until 3 to 4 weeks of age after the development of megacolon. A fistula may exist between the rectum and vagina of a female piglet, allowing feces to be voided. In male piglets, atresia ani can be rapidly fatal or may result in fistula formation between the rectum and bladder, urethra, or perianal region. Surgical treatment of atresia ani is necessary for the pig's survival, as the fistula is too small as the pig continues to grow and the feces become firmer.

After anesthesia, a circular piece of skin is excised below the tail over the bulging rectum. Ideally, the rectal pouch is identified using blunt dissection, mobilized, and tacked to the subcutaneous tissues with interrupted absorbable sutures before it is opened. Alternatively, the rectal pouch can be grasped and pulled caudally with a pair of tissue forceps. Once the pouch is opened, feces are usually discharged immediately. The area is cleaned with sterile saline, and the rectal mucosa is sutured to the skin in an interrupted pattern making an effort to create a large stoma. Pelvic dissection or flank laparotomy may be necessary to identify the descending colon and rectum if there is no rectum present at the skin opening. Atresia of the rectum and anus (atresia ani et recti) may preclude surgical correction. Surgical treatment with a celiotomy and colostomy or rectal pull-through may be necessary but is rarely economically justifiable for these severe cases. After correction of the atresia ani or recti, the pigs should be fed until they reach slaughter weight. Due to the heritable nature of atresia, pigs should not be bred after surgical correction of atresia ani.

Rectal Stricture

Pigs with rectal stricture often show clinical signs similar to pigs with atresia ani, except that they have an anus, are generally older, and often pass loose diarrhea through the rectal stricture. In one case series, pigs with rectal stricture were 16 to 18 weeks of age. These pigs suffered from weight loss in comparison to their herdmates, no feces were passed, and abdominal distention progressed. Most cases of rectal stricture result from a traumatized rectal prolapse that has constricted after repair or as a sequel to thrombosis of rectal blood vessels after ulcerative proctitis caused by *Salmonella typhimurium* enterocolitis. In the case of salmonellosis, several pigs may be affected. Other infectious agents that may be implicated in rectal stricture include *Erysipelas*, *Haemophilus parasuis*, and streptococcal infections. At necropsy, these pigs show a distended cecum and colon (Figure 25-4). The rectum is usually severely constricted by fibrous tissue. Circumferential scarring typically occurs 2.0 to 5.0 cm cranial to the anorectal junction and can be palpated digitally. The predilection for stricture at the middle third of the rectum has been associated with a propensity for ischemia due to the precarious arterial supply from the cranial hemorrhoidal artery.

Surgical treatment is similar to atresia ani. A circular incision is made around the anus, and the dissection is

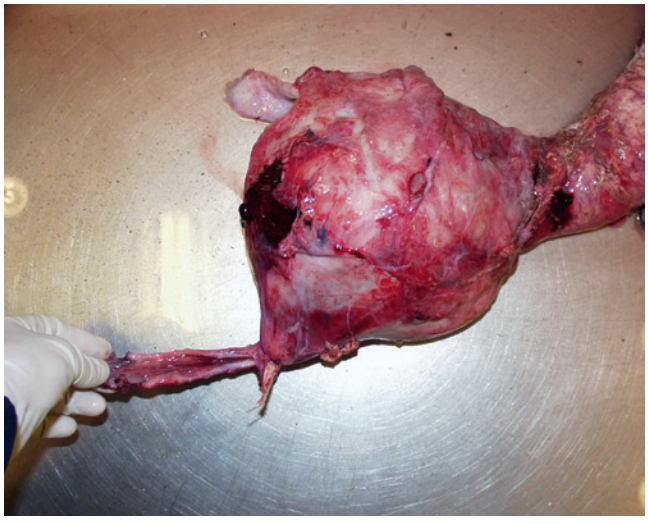


Figure 25-3 Postmortem photograph of chronic rectal stricture in a pig. Note distended descending colon proximal to the stricture area. (Courtesy of Dr. Michael Schramme.)

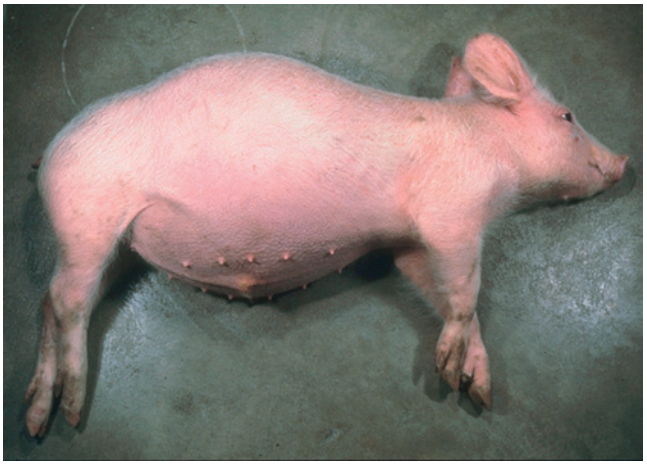


Figure 25-4 Image of a young feeder pig euthanized because of severe abdominal distention secondary to rectal stricture. Pigs with atresia ani often present similarly with severe abdominal distention. (Courtesy of Dr. Gerald E. Duhamel.)

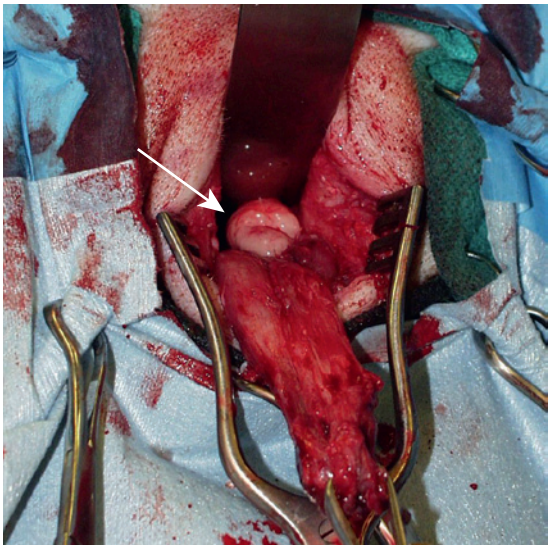


Figure 25-5 Intraoperative photograph of perirectal dissection. With the pig in dorsal recumbency, Gelpi and malleable retractors are used to provide the surgeon greater visibility. Holding the anus with Lahey thyroid forceps provides traction on the rectum and facilitates dissection. Pelvic fat is seen (*arrow*). (Courtesy of Dr. Michael Schramme.)



Figure 25-6 Intraoperative photograph of a loop colostomy to treat atresia ani with rectovaginal fistula formation in a 4-month-old gilt. The gilt presented for severe constipation and abdominal distention. (Courtesy of Dr. Rick Hackett.)

extended perirectally to the cranial aspect of the stricture (Figure 25-5). If the strictured segment is short, the narrowed portion is resected cranially, and the rectum is pulled caudally and sutured to the skin incision using size 0 or 2-0 synthetic absorbable suture. If the stricture extends more cranially, a ventral midline celiotomy can be performed to identify the cranial extent of the stricture and complete the resection. In some instances, the proximal end of the descending colon can be anastomosed to the perianal skin incision. A loop of spiral colon may need to be dissected (with its vascular supply) for use in the colonic pull-through because stretching the descending colon can interfere with its vascular supply. The pull-through is accomplished by temporarily occluding the segment of spiral colon to be anastomosed with a Penrose drain or an atraumatic intestinal forceps. The mesenteric and antimesenteric sides are tagged with stay sutures that are used to deliver the bowel through the pelvic inlet to the perianal region. The segment of bowel used in the pull-through procedure must also be sutured to the dorsal body wall to prevent volvulus of the segment. Alternatively, pigs with rectal stricture may respond to left flank celiotomy with colostomy (Figure 25-6).

Rectal Prolapse

Rectal prolapse is a common occurrence in swine, frequently as a result of conditions that cause straining to defecate (e.g., diarrhea due to salmonellosis) or violent coughing as a result of respiratory disease. The mucosa rapidly becomes edematous and hemorrhagic, and traumatization of the rectal mucosa by other pigs can be a sequela. Many factors have been associated with the development of rectal prolapse including genetics, a birth weight less than 1 kg, being male, the periparturient period in sows, diarrhea, coughing, short tails, autumn and winter piling as a consequence of chilling, chronic water shortage, certain antibiotics, zearalenone toxicosis, and a diet that contains 20% more lysine than required. Diagnosis of rectal prolapse is obvious on physical examination, but the prolapse should be carefully assessed to identify other organs that it contains, such as colon, small intestine, or bladder.

The first line of treatment, if the rectal mucosa is viable and close inspection does not reveal any lacerations, is to reduce the rectal prolapse using gentle massage and to place a purse-string retention suture around the anus. The perianal region should be anesthetized with local anesthetic, and the rectal mucosa should be cleaned and lubricated before reduction. Application of a hypertonic solution such as a sugar solution may facilitate reduction. Umbilical tape suture is passed circumferentially around the anus, in and out through the skin 1 cm adjacent to the anus. A one-finger opening should be left in growing pigs and a two-finger opening in adults when tying the purse-string suture. The suture is typically left in place for 5 to 10 days. Recurrence is likely if the underlying cause of the prolapse is not addressed. If the mucosa is too necrotic to replace, alternative methods of correction are available. See Chapter 14 for images of surgical correction of rectal prolapse. The surgical amputation of rectal prolapse requires two 18-gauge 3- or 4-inch-long needles, and a small-diameter flexible rubber tube, in addition to standard surgical instrumentation. After either epidural or general anesthesia, the rubber tube is inserted into the rectum until 2 or 3 inches protrude. To fix the rubber tube in the rectum, two needles are inserted at a 90° angle to each other, close to the anal opening and entirely through the prolapsed rectum and tubing. The exposed rectal mucosa is dissected down to the level of the inner mucosa and submucosa, and blunt dissection is used to create a submucosal plane toward the caudal aspect of the prolapse. The healthy outer segment of the prolapsed tissue adjacent to the mucocutaneous junction is pushed cranially, and the inner segment is amputated 2 to 3 cm distal to the outer segment. The inner mucosa is tacked to the outer mucosa with four interrupted cruciate sutures with size 0 absorbable suture at four equidistant sites around the circumference of the prolapse. Placing additional cruciate sutures circumferentially around the prolapse attains complete mucosal closure. Interrupted sutures and submucosal dissection to preserve additional mucosa are used to reduce the likelihood for stricture formation. After the rectum has been sutured, the needles are pulled from the tube, the tube is removed from the rectum, and the rectum is allowed to retract into place.

An alternative method of rectal amputation is to use a prolapse ring, PVC tubing, syringe case, or corrugated tube with a rubber band to cause necrosis of the prolapsed section of the rectum. The ring or tubing is placed in the rectum with the tube's halfway point inserted as far as the anal sphincter. A ligature or rubber band is applied over the prolapse as close to the anus as possible. The ligature or rubber band must be tight enough to disrupt blood supply to the prolapse. Feces may go through or may block the tube, requiring manual evacuation. Usually, the necrotic prolapse falls off in 5 to 7 days with the implant in place, and fecal production returns to normal (Figure 25-7*A* to C).

Three possible complications seen with rectal prolapse are rectal stricture, bladder retroversion, and eventration of the small intestine. In a 1-month-old castrated pig, eventration of the small bowel was seen concurrently with a rectal prolapse. The rectal prolapse was 5 cm in length, edematous, and purple-black. A small tear was found in the rectum in the pelvic area, and eventration of small intestine was observed. It was speculated that long duration of the prolapse resulted in necrosis, and the small intestine perforated this necrotic area during straining to defecate. Surgical correction of small intestinal eventration in a pig is usually not economically feasible. If treatment is requested, preoperative medical management is necessary to treat shock and dehydration. Under general anesthesia, the intestine is examined, cleansed, and resected if devitalized. A ventral midline incision is made to isolate the intestinal segment remaining within the abdominal cavity from the contaminated portion of intestine involved in the rectal laceration. The small intestine involved in the eventration is resected close to the rectum, and the remaining small intestinal segments are exteriorized through the ventral midline incision. After packing off the small intestine with moistened laparotomy sponges, an end-to-end anastomosis is performed. A single-layer, simple interrupted end-to-end anastomosis can be performed in smaller animals, and a continuous or double-layer end-to-end anastomosis can be performed in large swine. Bladder retroversion with rectal prolapse has been observed in a sow 2 days after normal farrowing. The sow had a grapefruit-sized rectal prolapse with protrusion and tension of the perineal area. The bladder was drained by passing a catheter. One week postpartum, the prolapsed rectum was amputated. The sow reared nine piglets to 6 weeks of age and was sent for slaughter 1 week after weaning the piglets.



Figure 25-7 *A*, Rectal prolapse rings. *B*, Rectal prolapse. *C*, Immediately after ring placement.



Figure 25-8 Umbilical hernia in an unthrifty feeder gilt. (Courtesy of Dr. Gerald E. Duhamel.)

Umbilical Hernia

Umbilical hernias occur commonly in swine and may be congenital or acquired. An umbilical hernia is a discontinuity of the abdominal wall at the umbilicus with a protrusion of abdominal content into a hernia sac formed by the skin and surrounding connective tissue (Figure 25-8). There is some data suggesting a hereditary basis for umbilical herniation, with susceptibility loci for umbilical hernias detected using an intercross between White Duroc and Erhualian. Umbilical hernias tend to develop commonly in piglets as a result of environmental conditions such as poor umbilical cord management, umbilical infection, or navel sucking by penmates. After birth, iodine or similar antiseptic agents are applied to the umbilicus to decrease the likelihood of infection. In swine herds, the frequency of umbilical hernias ranges from 0.4% to 1.2% and varies with breed and sex. Pigs with umbilical hernias may suffer from growth retardation, and those with smaller hernias are at risk to have intestine incarcerated in the hernial sac. In one study, pigs sired by American Spotted and Duroc boars were more likely to develop hernias than those sired by Yorkshire boars. Umbilical hernias often were detected in pigs between 9 and 14 weeks of age. It is possible that the condition was recognized at that age because the rapid growth of pigs, combined with increased weight of the abdominal organs, led to a hernia of significant size. Females had a higher risk of developing umbilical herniation. As with many other surgical conditions in swine, the cost of treatment may preclude surgical correction. In that case, pigs should be consigned to an early slaughter, usually within 1 month after hernia detection and before intestinal strangulation, evisceration, or fistula occurs. A case of intestinal umbilical fistula has been described in a 30-kg castrated pig.

The reduced growth rate in untreated pigs with umbilical hernias may encourage surgical correction of the defect. However, it is unknown if surgical correction will restore growth potential. In purebreds, show animals, and pet pigs, surgical correction is often indicated. However, it is not recommended to use a surgically corrected animal for breeding due the possible hereditary basis of umbilical hernias. Herniorrhaphy should be performed early in life. After anesthesia, the pig is restrained in dorsal recumbency in a "V"-shaped trough. The surgical area is cleaned and prepared for surgery. If surgical correction is performed on a male, the prepuce, preputial diverticulum, and penis should be reflected caudally or laterally. The hernial sac is isolated, and dissection is performed down to the hernial ring. The hernial sac and any abscesses should be removed, and the edges of the ring freshened with sharp dissection. If intestinal contents adhere to the hernial sac, the adhesions are manually separated, and bowel viability is assessed before replacing it into the abdomen if judged acceptable. If intestinal viability is compromised, resection and anastomosis of viable intestine should be performed using an end-to-end anastomosis as described earlier. Inversion of the hernial sac into the abdomen using a closed approach is not recommended due to a higher risk for recurrence postoperatively. The abdominal defect is closed in a simple continuous pattern with synthetic absorbable suture appropriate for the size of the animal. The prepuce, preputial diverticulum, and penis are repositioned and sutured to the abdominal wall with interrupted absorbable sutures. For surgical correction of umbilical hernia in the female, an elliptical incision is made around the hernial sac, and excess skin is discarded. Using a combination of sharp and blunt dissection, the hernial sac is excised, the edges of the hernial ring freshened with sharp dissection, and the abdominal wall closed as in the male. The subcutaneous tissue and skin are then closed routinely. Systemic antibiotics should be administered for 5 days, and the skin suture removed in 10 days unless subcutaneous staples or absorbable suture is used for subcuticular closure.

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CHAPTER 26

Surgery of the Swine Musculoskeletal System

Norm G. Ducharme
(The editors and the current authors acknowledge the previous edition authors Guy St. Jean and David E. Anderson.)

FOOT PROBLEMS (CLAW LESIONS)

Lameness is a common problem in commercial swine operation, affecting up to 19% of finishing pigs. Our impression is that the prevalence of hoof problems is even greater in rescue centers presumably because of the older age of their swine population and its associated greater weight. In our modest experience, lameness prevalence is less in zoo environments. Treatment of problems in a commercial environment has a different goal from the long-term quality of life of pigs in farm rescue center or zoo animals. Therefore surgical treatment must be tailored to the environment and goal.

The environment has a documented impact on prevalence of lesions. Indeed, large group housing, dirty floors, and high levels of ammonia increase the risks of lameness problems. Undoubtedly some of these leg lameness problems are heel and dewclaw lesions. The few studies on foot lesions confirms the high prevalence of foot lesions in commercial pig operations: 61.5% sole bruising and 34% sole erosion both likely to predispose to foot abscess. We have treated many pigs from rescue centers with a high incidence of hoof abscess and septic pedal osteitis extending to P2-P3 and sometimes to P1-P2 articulation. Presumably their weight and their environment predisposes to hoof abscess that extends proximally to adjacent structures.

Foot abscess result in lameness as in other farm animals. A good foot and claw examination is important to identify growth abnormalities or injuries that could predispose to foot abscess (Figure 26-1*A* and *B*). The generic treatment of foot abscess is described in Chapter 15 (Treatment of Pathologic Diseases: Foot, Including Digit Fractures). First trimming of the feet to shorten the claws to an appropriate length prevents toe-tie injury (see Figure 26-1*A*). Detached hoof material must be removed. Claw cracks must be explored because they are often the result of access to soil contaminants leading to an abscess (Figure 26-2). Partner claw disease is commonly seen. A swollen heel bulb in one claw (Figure 26-3*A*) may indicate excessive weight or stress applied because of an abscess in the partner claw (Figure 26-3*B*). After debridement, standard cleansing of the claw is done. Temporary relief of pain can be obtained as in cattle by elevating the partner claw. However, the lamina of swine feet is fairly sensitive and does not appear to sustain much stress. We have caused bleeding at the coronary band using a trimmed wooden block. Our preference is now to elevate the sound claw to a modest level using a quick-setting acrylic (see Chapter 16; Figure 26-4).

OSTEITIS AND OSTEOMYELITIS OF THE DIGIT

P3 Infection

Septic pedal bone osteitis, most commonly the result of extension of heel ulcers and hoof abscess into the third phalanx, is seen with untreated or undiagnosed abscess (Figure 26-5). Alternatively, direct trauma with a nail or other sharp object or a hematogenous spread reaching the coffin bone may also result in septic pedal osteitis and then lead to foot abscess or septic arthritis (Figure 26-6*A* and *B*). All hoof abscess that recurs should be further explored diagnostically to confirm presence or absence of pedal bone involvement. This diagnosis is best reached by imaging. A dorsopalmar (or plantar) (see Figure 26-6*A*) and a lateral view with one claw flex (see Figure 26-6*B*) allows a two-view confirmation of a lesion or abnormality.

Treatment involves proper debridement of the hoof abnormality and curettage of the coffin bone lesions. When possible, a lateral wall access (see Figure 26-6A*B*) is preferable to a solar approach (see Figure 26-4*B*) for postoperative comfort of the animal. Once adequate debridement is obtained (preferably under radiographic control), mild elevation of the partner claw is done with adhesive. A bandage is applied with local cleansing every 2 to 3 days for 7 to 14 days (until sufficient soft tissue bone coverage is obtained). Antibiotherapy (as per culture) and pain management must both be consistent with regulatory rules, which may apply differently to animals directed toward food production compared with pigs in rescue centers. In our environment, amoxicillin (40 mg/kg orally) and meloxicam (0.5 mg/kg orally), respectively, are commonly used.

Septic Interphalangeal Joints

Extension of foot abscess, infected coffin bone fracture, and direct trauma (Figure 26-7) to the joint are the most common reasons for infection into the interphalangeal joints. Most commonly the P2-P3 articulation is affected, but we have seen many cases of infection of P1 and P2 or of both interphalangeal joints. Excessive weight bearing may play a role in the pathogenesis because it is not uncommon to treat one joint successfully and months to years later see the same process affecting another interphalangeal joint.

The treatment varies whether the pig is in a commercial unit or in a rescue center. Unlike in cattle, the survival rate after a claw amputation in an adult pig is very short (i.e., only a few months) so it is only a treatment to consider in commercial operation.

DIGIT AMPUTATION

Digit amputation is indicated when severe foot abscesses or septic arthritis of the interphalangeal joints have caused unmanageable damage to a single digit (see Figure 26-7). Radiography, if elected, may show the extent of the lesion (Figure 26-8*A* and *B*). These injuries are most commonly caused by wounds from trauma on concrete flooring or metal side panels. The decision for amputation should not be delayed. Digit amputation will not be curative if the infection extends to the fetlock or more proximally on the limb. Also, the soundness of the opposite digit should be assessed to determine whether the pig will be able to ambulate on the remaining digit after amputation.



Figure 26-1 *A*, Medial claw of right front feet with broken toe tip and vertical hoof wall crack associated with suboptimal trimming. *B*, Same claw after trimming. (Courtesy of Mr. Steve Krauss, Farrier Cornell University.)



Figure 26-2 Hoof wall crack has been debrided, revealing an abscess pocket that has been enlarged to allow proper drainage. (Courtesy of Mr. Steve Krauss, Farrier Cornell University.)



Figure 26-3 *A*, Note heel bruise and widened median claw (upmost claw) indicative of excessive weight on that claw because of an abscess in the partner claw (*B*). (Courtesy of Mr. Steve Krauss, Farrier Cornell University.)



Figure 26-4 Lateral (partner) claw being elevated with acrylic. (Courtesy of Mr. Steve Krauss.)

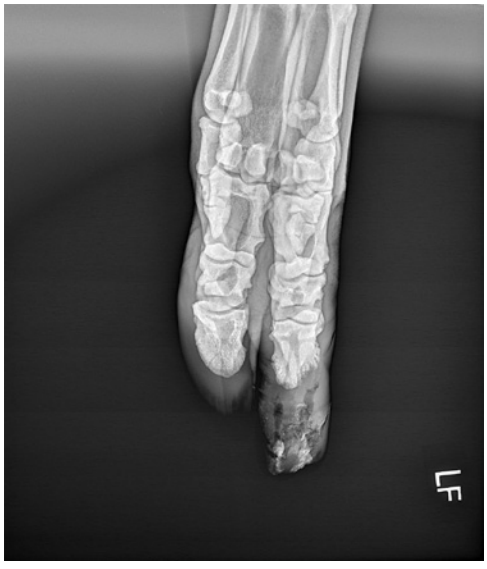


Figure 26-5 Dorsopalmar view of the left front leg of a 6-year-old pig showing a large lytic area in the lateral claw. Note that the lateral claw is much longer because of inadequate trimming. This has led to an abscess that extended to the solar margin of the coffin bone.

After induction of general anesthesia, the affected digit is cleaned and prepared for surgery. A tourniquet is placed proximal to the surgery site to prevent extensive hemorrhage during surgery. A circumferential incision is made through the skin and soft tissues at a 45-degree angle to the coronary band, starting at the axial aspect of the digit and continuing proximally to the abaxial surface. The skin is reflected proximal to the site being amputated, and a sterile obstetric wire is used to amputate the digit. The distal phalanx and a



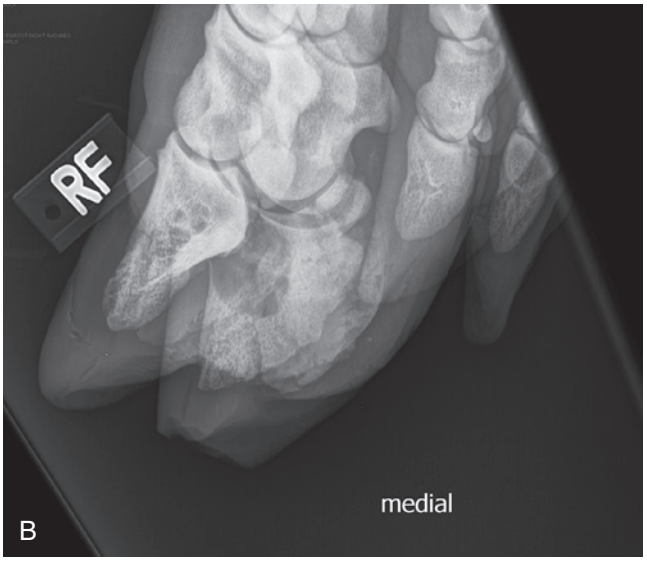


Figure 26-6 *A*, Dorsopalmar view showing a large lytic area in the medial claw. *B*, Lateral scissors view showing the same process.

portion of the middle phalanx are removed by this procedure except when infection extends to the proximal interphalangeal joint where the transection is in the distal aspect of P1. The remaining tissues are debrided and cleaned thoroughly. The foot is placed in a padded bandage for 10 to 14 days. The foot is cleaned daily with water until the wound is healed. Perioperative antibiotics and antiinflammatory drugs are indicated.

ANKYLOSIS OF THE PROXIMAL OR DISTAL INTERPHALANGEAL JOINT

Septic arthritis of the proximal or distal interphalangeal joint is an indication for digit amputation (Figures 26-9*A* and 26-10*A*). However, the lateral claw of the hind limb is important for normal ambulation and breeding activity. Salvage



Figure 26-7 A pig with severe septic arthritis of the distal interphalangeal joint. Note that the claw is sloughing. (Courtesy of Dr. Christopher Beinlich, Cornell University.)

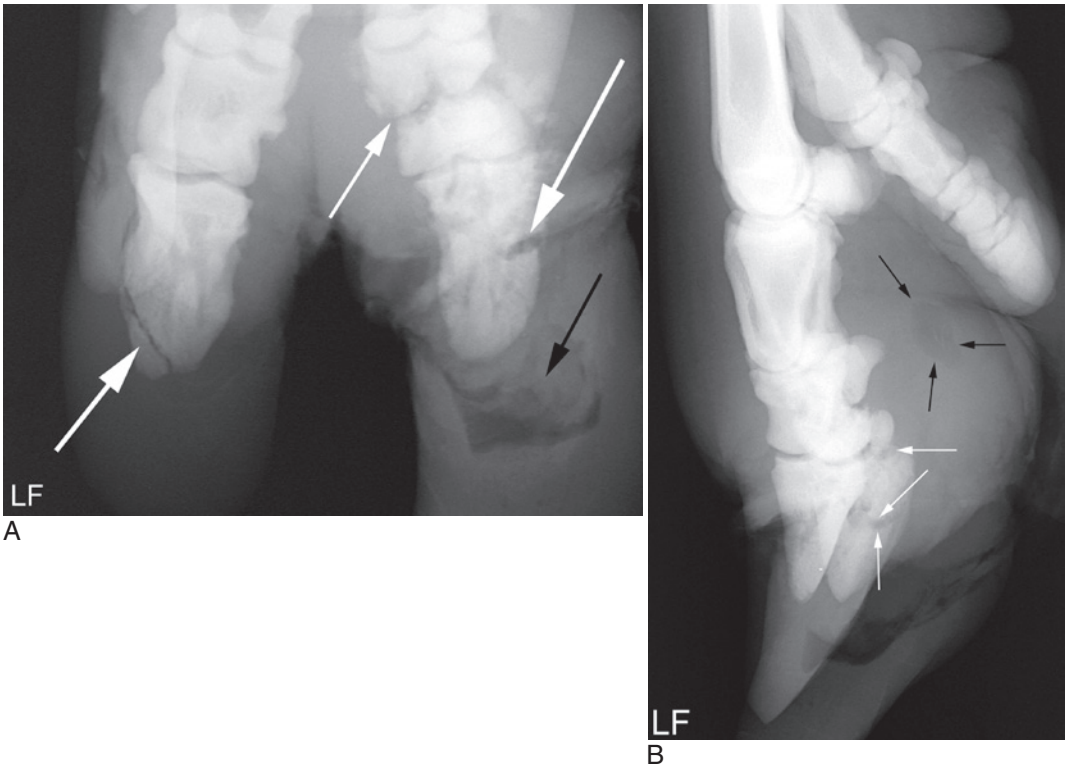


Figure 26-8 *A*, Dorsoproximal, and *B*, lateral radiographs of the left thoracic limb digit in a 2-year-old female intact porcine with left thoracic limb lameness. Note the fractures in the middle and distal phalanges of the third digit and the distal phalanx of the fourth digit (*white arrows*). Also, in the soft tissues of the claw, there are multiple gas opacities (*black arrows*). The diagnosis in this patient was chronic pathologic fractures secondary to osteomyelitis and cellulitis. (Courtesy of Dr. Anthony Pease, Cornell University.)

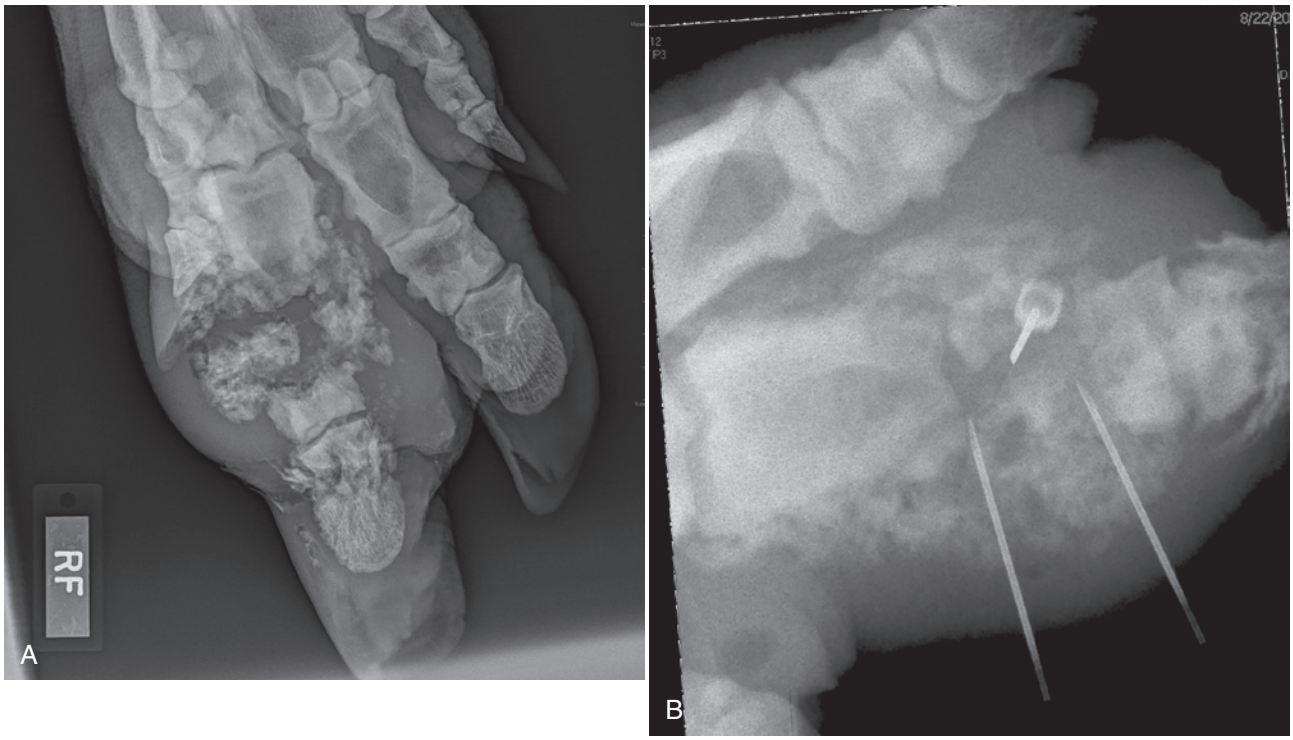


Figure 26-9 *A*, Dorsopalmar view of the right forelimb of a pig with septic arthritis of the proximal interphalangeal joint. *B*, Intraoperative fluoroscopy view outlining the debridement site.

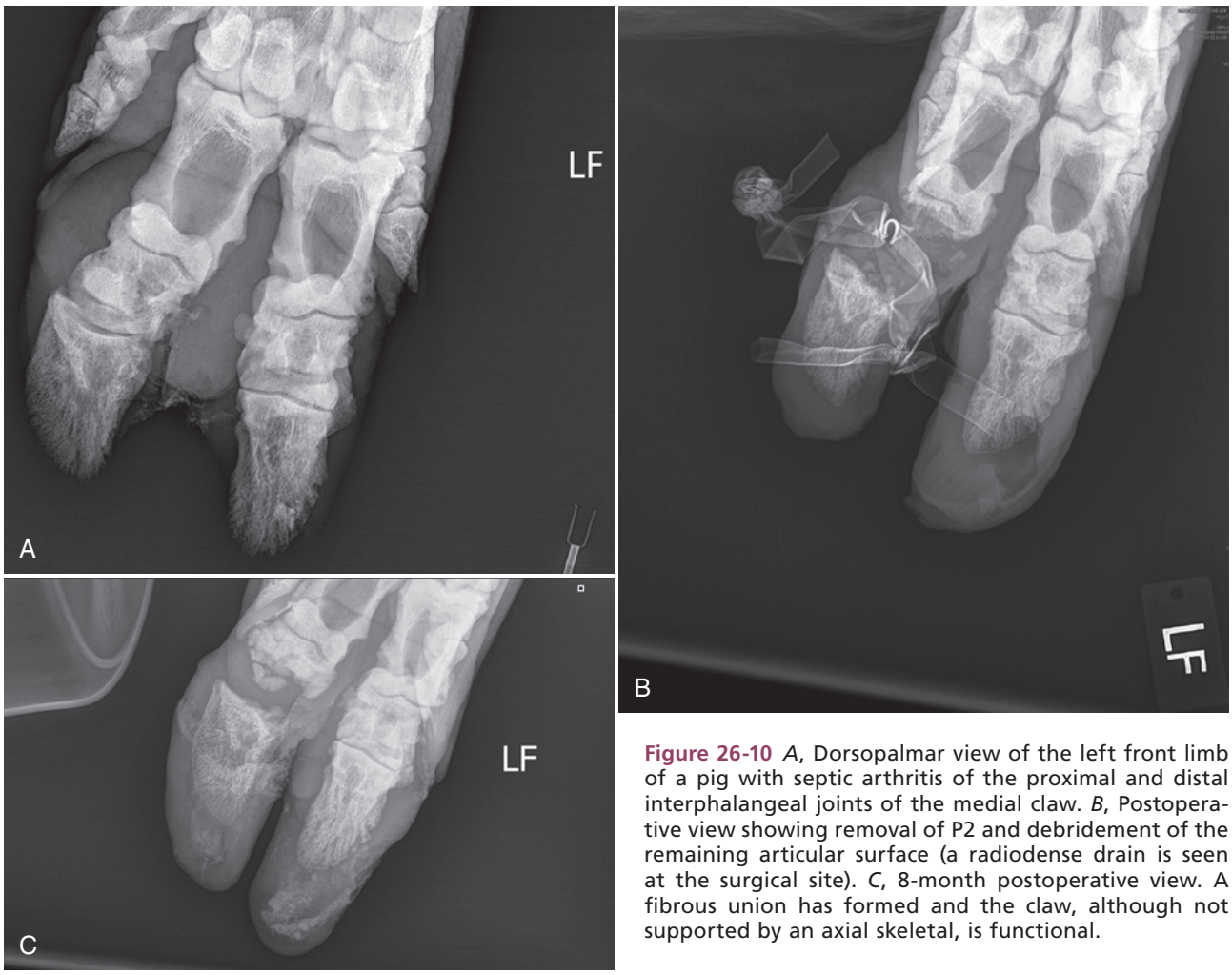


Figure 26-10 *A*, Dorsopalmar view of the left front limb of a pig with septic arthritis of the proximal and distal interphalangeal joints of the medial claw. *B*, Postoperative view showing removal of P2 and debridement of the remaining articular surface (a radiodense drain is seen at the surgical site). *C*, 8-month postoperative view. A fibrous union has formed and the claw, although not supported by an axial skeletal, is functional.



Figure 26-11 A postoperative view of the arthrodesis procedure in the interphalangeal joint of the lateral claw in a pig. Note the foot has been trimmed and a Penrose drain is in the arthrodesis site. The partner claw has been elevated with adhesive. (Courtesy of Mr. Steve Krauss, Farrier Cornell University.)

of the digit by facilitated ankylosis is an option to preserve normal ambulation. Furthermore, in rescue animals this is the only valid treatment to consider in the majority of cases. The affected pig is placed under general anesthesia and the digit prepared for surgery. A 1-cm incision is made into the affected joint. A 3.75-cm-long needle is inserted distally immediately proximal to the coronary band for an approach to the distal interphalangeal joint. The proximal interphalangeal joint may be located by palpation or inserting the needle into the midpastern region. After the arthrotomy has been made, all infected and sequestered bone fragments are removed (Figure 26-9*B*). The remaining articular surface is removed or destroyed using a 4- or 6-mm-diameter drill bit. Curettes are used to debride the joint and remove all infected subchondral bone. A distinct difference in texture and hardness will be noted between the necrotic (gritty and irregular) and healthy (smooth and hard) bone. Thorough curettage of all infected bone is critical to establishing effective joint ankylosis. The tissues are extensively lavaged with normal saline, and antibiotics are administered for 10 to 14 days. A drain is placed into the joint for 3 weeks (Figure 26-10*B* and Figure 26-11). The partner claw is elevated with acrylic. Strict confinement for 8 to 12 weeks is needed for ankylosis to occur. We have observed that ankyloses is not essential, but resolution of infection is needed to restore function (Figure 26-10C). Some authors have reported that a cast extending from the ground to the carpus or hock will hasten convalescence. However, we do not use casts in our hospital for that purpose.

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FRACTURE REPAIR

The readers are referred to Chapter 15 for principles of fracture repair and internal and external fixation. This chapter focuses on the difference pertinent to fracture management in pigs. Swine in commercial operations with fractured long bones are often salvaged because economic considerations preclude treatment. However, veterinarians may be asked to treat fractures in swine of potential value for genetic improvement and of course in rescue operations.

Treatment of fractures can be rewarding, and Vaughan reported clinical experiences with fracture fixation in commercial swine. Fracture injuries were associated with breeding (two pigs), slipping on concrete flooring (three pigs), fighting (one pig), and unknown causes (five pigs).

An important predisposing favor in fractures in pigs is nutritional deficiency, associated with inappropriate level of dietary phosphorus or calcium, an inappropriate calcium-to-phosphorus ratio (which should be 1.2 : 1), and/or vitamin D deficiency. This leads to failure of endochondral ossification in growing pigs and osteomalacia in adults. Indeed, in one report a nutritional analysis revealed inadequate calcium and phosphorus (both in absolute concentration and calcium-to-phosphorus ratio) in the feed of a herd with multiple fractures. Affected pigs were approximately 20 weeks old and weighed between 80 and 90 kg. The pigs walked with a stilted gait and arched back. Necropsy revealed slipped capital femoral physis. After correction of dietary calcium and phosphorus, clinical evidence of a femoral fracture was not observed in any additional pigs. Femoral, pelvic, and vertebral fractures have been found in pigs after accidental electrical shock. Pigs with multiple trauma injuries and fractures associated with nutritional deficiency are poor candidates for surgical repair.

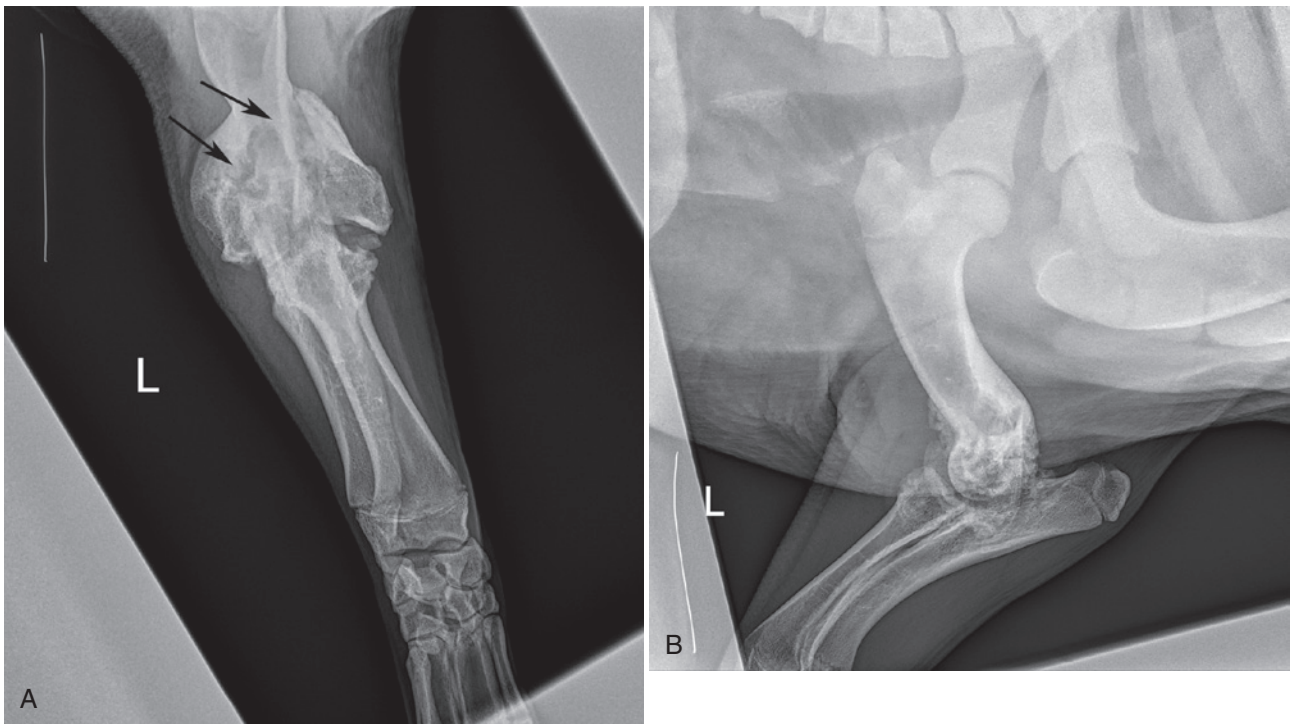


Figure 26-12 Rescued Vietnamese pot-bellied pig of unknown age presented for left front leg lameness. *A*, Dorsopalmar view revealing an old humeral condyle fracture (*arrows*) with moderate to severe elbow incongruity. *B*, Lateral view showing extensive osteoarthritis and periosteal reaction.

External fixation (i.e., a cast) is difficult to keep on pigs because of the funnel contour of their limbs and the lack of hourglass shape of their joints, so they tend to slip off. Therefore we prefer internal fixation for repair of fracture. When using internal fixation we have a strong preference for a locking plate of appropriate size in pigs. This has been supported in studies using swine as an animal model for orthopedic implants in humans, where it was shown that bicortical versus monocortical locking plate repair had a significantly different load to failure. In addition, locking plates had higher load to failure than nonlocking plates on a monocortical model.

Specific Fractures

Fractures of the Humerus

Surgical repair of an articular fracture of the humeral condyles has been reported for miniature pigs. Fractures were repaired by using lag screw and Kirschner wire fixation. Five pigs were reexamined 2 months after surgery, and all were walking soundly at that time. We have also recognized chronic fractures that presented in animals with a complaint of chronic lameness. Because clinical diagnosis/recognition of upper limb fracture is difficult in pigs. Certainly without imaging some animals undergoing natural healing develop mal-union, and if it is an articular fracture then osteoarthritis is seen (Figure 26-12*A* and *B*).

Fractures of the Tibia/Fibula

The most common fractures treated were tibia and fibula (5 pigs), femur (3 pigs), humerus (2 pigs), and tibiotarsal joint luxation with fracture of the fibula (2 pigs). Affected pigs weighed between 64 and 168 kg and were 6 months to 2 years old. Fractures of the tibia and fibula were treated by open reduction and internal fixation by using a bone plate and a full limb cast (3 pigs) or by using only a full limb cast (2 pigs). Humerus fractures were treated by confinement (1 pig) or applying a bone plate (1 pig). A tibiotarsal joint luxation—combined with a fractured fibula—was treated by applying a bone plate and using a full limb cast (2 pigs). Ten out of 12 pigs returned to normal production use, and 2 were salvaged (one pig with tibiotarsal joint luxation developed *Escherichia coli* osteomyelitis; one pig with a humeral fracture repaired by internal fixation suffered permanent radial nerve damage). Because of the substantial size of their fibulas, we have used a single plate (usually locking) on both the tibia and the fibula (Figure 26-13*A-D*).

Femoral Fractures

Slipped capital physis has been reported to be diagnosed in 20 pigs over a 6-month period and has been reported in pigs with nutritional deficiency. Therefore, although repairable using techniques described in Chapter 15, one should also identify nutritional deficiency as a cause of this fracture.

Fracture of the greater trochanter of the femur associated with nutritional deficiency has also been identified as a cause of lameness in pigs. Diaphyseal fracture has been reported to be treated by applying a single lateral bone plate in three pigs. We have used L plates for stabilization of distal physeal fractures (Figure 26-14*A-C*). As an adjunct to postoperative analgesia after repair of femoral fracture, ultrasound-guided injection of bupivacaine in the first 24 has been reported to reduce postoperative pain.

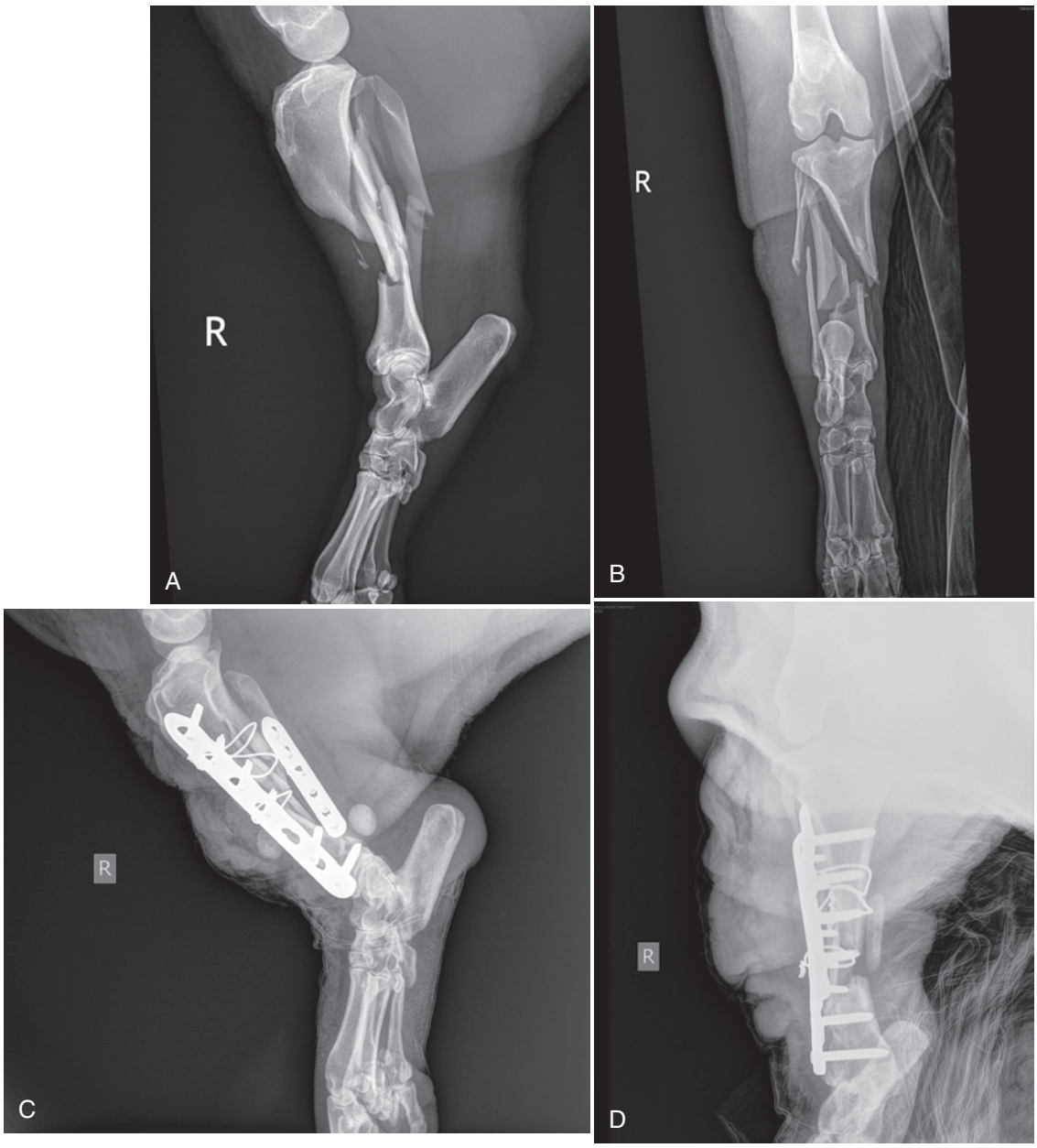


Figure 26-13 Nine-year-old Vietnamese pot-bellied pig with right comminuted middiaphysis tibial and fibula fracture repaired with two locking plates: a 7-hole broad 3.5-mm plate on the tibia and a narrow 6-hole 2.7-mm plate on the fibula. Three cerclage wires are used on the tibia. (Lateral, *A* and C; dorsoplantar view, *B* and *D*.)

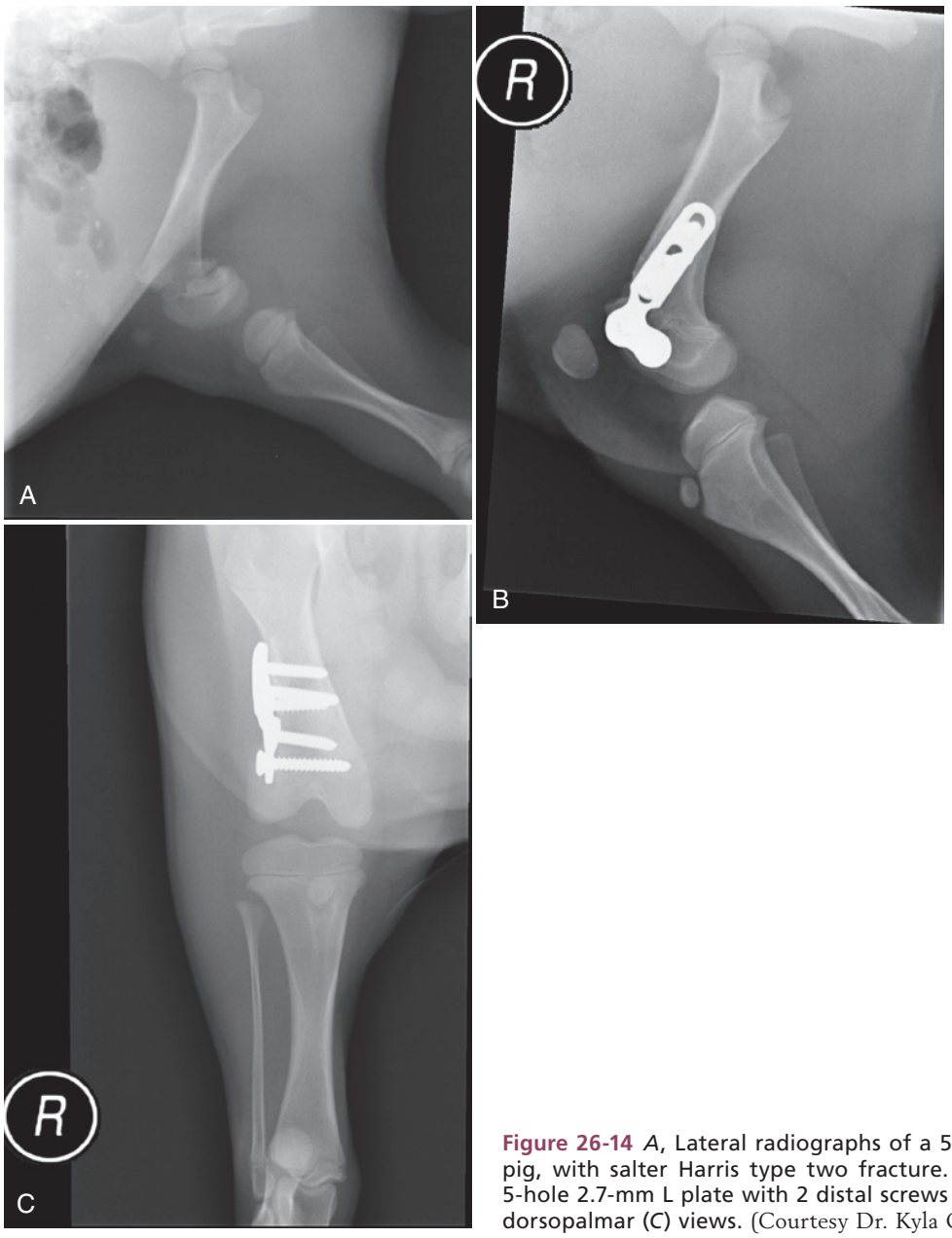


Figure 26-14 *A*, Lateral radiographs of a 5-week-old Vietnamese pot-bellied pig, with salter Harris type two fracture. This fracture was treated with a 5-hole 2.7-mm L plate with 2 distal screws into the epiphysis. Lateral (*B*) and dorsopalmar (*C*) views. (Courtesy Dr. Kyla Ortved, Cornell University.)

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CHAPTER 27

Surgery of the Swine Reproductive System and Urinary Tract

Robert J. Callan, Richard P. Hackett and Susan L. Fubini

SURGERY OF THE MALE SWINE REPRODUCTIVE SYSTEM AND URINARY TRACT

Castration

Castration of commercial pigs is routinely performed to decrease the incidence of boar taint and produce a more consistent taste and quality of meat. Boar taint is caused by the accumulation of androstenone and skatole in the muscle tissue of boars. The incidence of boar taint ranges from 10% to 75% after puberty and generally results in an unsuitable product for consumers. Other advantages of castration include decreased aggressive behavior toward humans and other pigs and decreased sexual activity. Reducing these behaviors results in less skin and carcass damage, fewer musculoskeletal injuries in comingled boars, and improved animal well-being.

Castration of pet pot-bellied pigs is primarily done to render the animal sterile and to decrease aggressiveness toward humans and other pets. Castrated pet pigs will show less sexual behavior toward owners, pets, or other household items. Another advantage is decreased development of the preputial diverticulum, resulting in less accumulation of malodorous material within the prepuce. These benefits are greatest when the boar is castrated before the onset of puberty. Puberty occurs as early as 3 months of age in male pot-bellied pigs and not until 6 to 8 months of age in commercial breeds.

The age of castration and use of perioperative analgesia are important considerations related to animal well-being and are, in part, a reflection of evolving societal expectations. In general, castration at a younger age is considered less stressful, and satisfactory analgesia is more easily and economically managed in younger pigs. Routine castration of commercial pigs is recommended between 2 days to 2 weeks of age. In pigs older than 1 month, sedation or general anesthesia (injectable or inhalation) should be considered along with local and systemic analgesia. General anesthesia should be used with caution for commercial nursing piglets because they are at greater risk of injury or smothering when returned with the dam if not fully recovered from anesthesia.

There are several studies investigating the effects of local lidocaine analgesia and systemic nonsteroidal antiinflammatory drugs (NSAIDs) alone or in combination to help mitigate pain and decrease postoperative stress in castrated pigs. These studies demonstrate that local anesthesia using lidocaine provides effective analgesia for the acute pain associated with the surgical procedure. NSAIDs decrease the demonstration of postoperative stress and pain-related behavioral signs following castration in pigs. As consumers continue to express their concerns over animal husbandry practices and the welfare of commercial livestock, local and systemic analgesia will likely become more common practice for castration procedures in commercial pigs.

Commercial piglets less than 2 weeks old can be castrated by suspending them by the hind limbs while they are laid across a smooth rail or in a tilted castration table or trough (Figure 27-1). The surgical site is prepared for aseptic surgery. Lidocaine (10-20 mg/mL) anesthetic is injected subcutaneously (0.5 mL per site) into the tissue overlying each testis and spermatic cord in the inguinal canal. Alternatively, 0.5 mL lidocaine can be injected directly into each testicle to provide analgesia to the testis, epididymis, and spermatic cord alone or in combination with the subcutaneous lidocaine. The surgeon should be cognizant of the toxic threshold of lidocaine in swine and use no more than 5 mg/kg lidocaine at a time. A 1-cm incision is made over each testis at the most cranioventral aspect of the scrotum, and the testes are steadily pulled from the scrotum until the spermatic cord separates. Hemorrhage is minimal at this age. Ligation of the spermatic cord is recommended for older pigs. Topical fly spray should be applied around the site during fly season. Systemic antibiotics are usually not required, except for castration of older pigs. Castrated piglets are placed under a heat lamp in the farrowing crate for convalescence.

Veterinarians may be asked to castrate older commercial pigs intended for show or mature boars that will no longer be used for breeding. Castration of older pigs is best performed with the pig sedated or under general anesthesia. The boar is restrained in dorsal or lateral recumbency, and the surgical site is aseptically prepared (Figure 27-2*A*). A 4- to 6-cm incision is made overlying the testis at the ventral aspect of the scrotum. The testis should be removed with the vaginal tunic intact (Figure 27-2*B*). Inguinal fat and soft tissue are stripped from the spermatic cord, and the cord is evaluated for the presence of an inguinal hernia. The vaginal tunic and spermatic cord are twisted until the cord is tightly compressed to the level of the external inguinal ring. Circumferential ligatures of synthetic absorbable suture material are placed around the vaginal tunic and spermatic cord. An emasculator can be used to complete the castration distal to the ligatures (see Figure 27-2*B*), or the spermatic cord can be clamped and cut with a scalpel distal to the clamp. Closure of the surgical wound is rarely done and should only be performed if asepsis has been maintained. Systemic antibiotic coverage should be provided for 2 to 3 days beginning the day of surgery, to reduce the incidence of postoperative infection. Fly spray should be applied around the surgical site during fly season. The animal should be kept in a clean, dry stall during the postoperative period.

Pet pot-bellied pigs are commonly castrated by the breeder before transfer to a new owner and may be done before 2 weeks of age. However, castration of pet pigs is sometimes performed at a later age by the new pet owner. Castration before 12 weeks of age will lessen the development of the preputial diverticulum and may decrease owner complaints of urine retention in the preputial diverticulum. Most pet pig owners request castration under general anesthesia. Once anesthetized, the pig is placed in dorsal recumbency, and the surgical area is clipped and prepared for aseptic surgery (Figure 27-3*A*). Local analgesia is provided with 2% lidocaine injected either into each testicle until turgid, into the

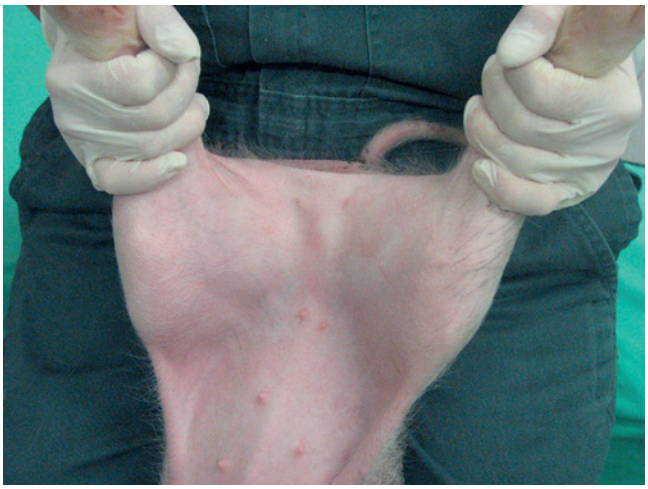


Figure 27-1 A young commercial piglet restrained by the hind legs for castration.



Figure 27-2 *A*, Boar under general anesthesia in lateral recumbency before castration. *B*, The testes removed with an emasculator placed in proper orientation. (Courtesy of Dr. Christopher Beinlich.)

spermatic cord alone, or in combination. A skin incision is made parallel to the median raphe over each testicle at the cranioventral aspect of the scrotum (Figure 27-3*B*). It is helpful to make this incision cranially and close to the inguinal ring to aid in closure of the inguinal ring for prevention of postsurgical inguinal hernia. The incision is continued through the subcutaneous tissue, tunica dartos, and spermatic fascia without incising the vaginal tunic. It is preferable to perform a closed castration to minimize the risk of herniation of abdominal contents through the inguinal ring. The testicle is bluntly dissected free from the scrotum and exteriorized. The spermatic cord is twisted to push any herniated abdominal contents back into the abdomen (Figure 27-3C). A transfixation ligature, Miller's knot, or modified Miller's knot is placed at the base of the spermatic cord near the inguinal ring using synthetic absorbable suture. This ligature can also be incorporated into partial closure of the inguinal ring. The spermatic cord is clamped and transected with a scalpel blade to remove the testicle. The inguinal ring is palpated, and one or more absorbable cruciate or horizontal mattress sutures are used to partially close the inguinal ring to help prevent inguinal hernia (Figure 27-3*D*). The subcutaneous tissue is closed with synthetic absorbable suture in a simple continuous pattern. The skin can then be closed with synthetic absorbable suture using a continuous intradermal pattern or using an external skin pattern (Figure 27-3*E*). A perioperative NSAID such as meloxicam, flunixin meglumine, or carprofen is recommended.

The most common complications after pig castration are hemorrhage, abscess, scirrhous cord, inguinal hernia, and seroma or hematoma formation. Fatal hemorrhagic shock has been reported after castration of 7-week-old pigs by a layperson. The testes had been pulled through a 10-cm incision and cut using a knife. Fatal hemorrhage occurred into the pelvic canal and abdomen; therefore the cause of death was not recognized until necropsy. This report emphasizes the need for routine necropsy to determine the cause of all nonapparent deaths. Meat inspection of 131 pigs with postcastration abscesses revealed that *Actinomyces (Trueperella) pyogenes*, β-hemolytic streptococci, *Streptococcus viridans*, *Staphylococcus aureus*, and *Pasteurella multocida* were the most common bacteria isolated. Approximately 65% of the abscesses were monomicrobial, and 35% were polymicrobial infections. Of the 131 pigs inspected, 11% were judged to be unfit for human consumption. Bilateral hydronephrosis also has been reported as a complication of castration in a Hampshire pig castrated at 8 weeks old. A ventral midline incision was used to remove both testes and tincture of iodine applied after castration. Infection of the soft tissues occurred, and the ensuing infection resulted in progressive occlusion of the urethra at the level of the sigmoid flexure. Chronic resistance to urine outflow caused hydronephrosis, and the pig died 4 weeks after castration. This case illustrates the importance of adequate ventral drainage after castration.

Immunocastration (Improvac®, Zoetis) of male pigs is an alternative to surgical castration and is available in several countries outside of the United States. The vaccine induces antibodies against gonadotropin-releasing hormone (GnRH). The product is indicated for the control of boar taint and modification of prepubertal behavior and increased finishing growth compared with noncastrated boars. Although likely rendering nearly all boars vaccinated sterile, the product is not currently licensed for that purpose.

Unilateral Castration

Indications for removing only one testis include testicular trauma, torsion (Figure 27-4), unilateral inguinal or scrotal hernia, hematoma (Figure 27-5), seroma, and orchitis or periorchitis. The damaged testis may cause enough swelling, heat, and pressure to reduce fertility. The boar is placed under general anesthesia, a 6-cm incision is made over the testis starting at the most ventral aspect of the scrotum, and the testis is removed after circumferential ligation of the spermatic cord and excision. The wound should be left open

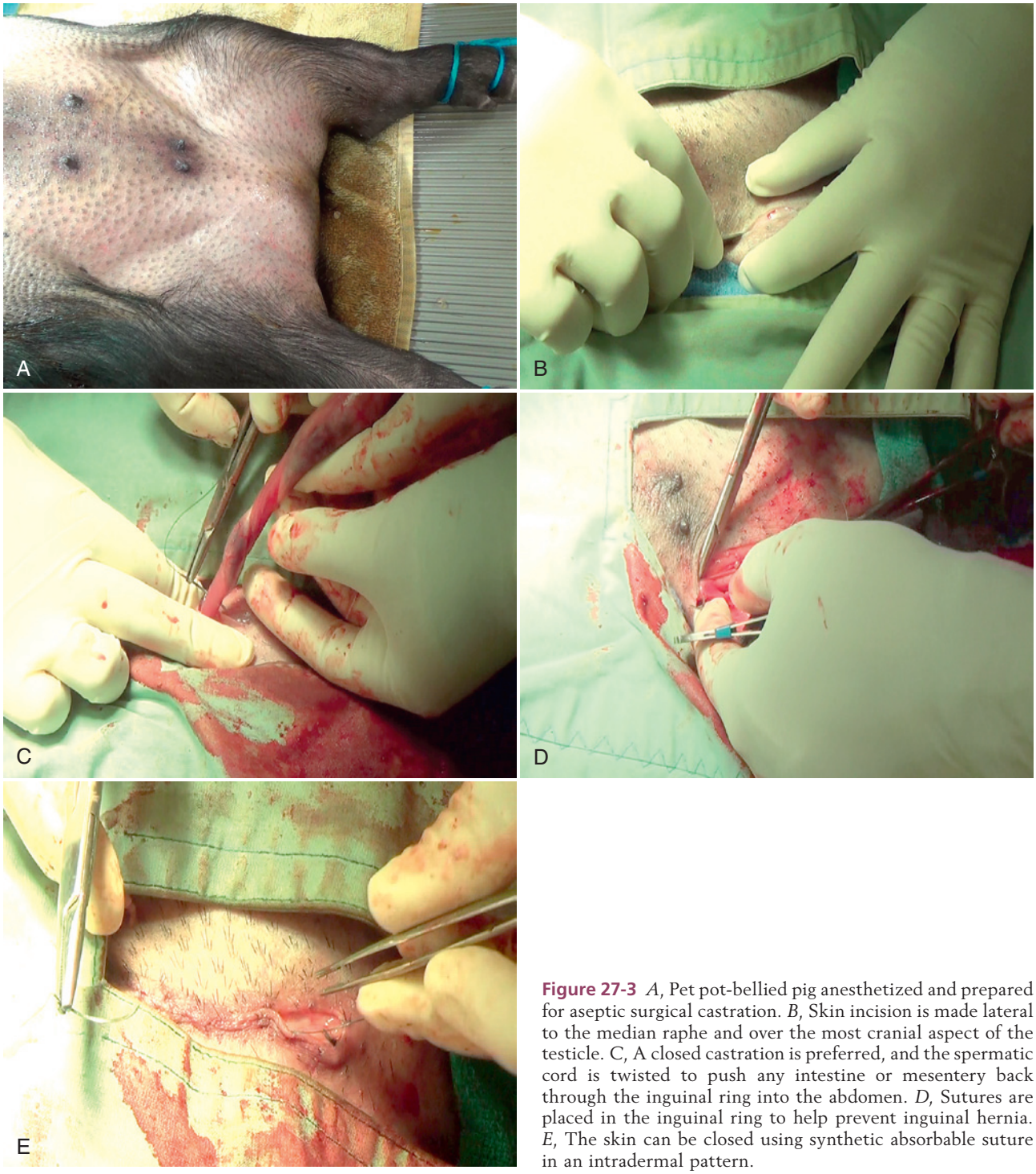


Figure 27-3 *A*, Pet pot-bellied pig anesthetized and prepared for aseptic surgical castration. *B*, Skin incision is made lateral to the median raphe and over the most cranial aspect of the testicle. *C*, A closed castration is preferred, and the spermatic cord is twisted to push any intestine or mesentery back through the inguinal ring into the abdomen. *D*, Sutures are placed in the inguinal ring to help prevent inguinal hernia. *E*, The skin can be closed using synthetic absorbable suture in an intradermal pattern.

for drainage and second intention healing. Antibiotics are administered for 5 to 7 days, and daily hydrotherapy is used to minimize postoperative swelling. Affected boars may return to productive service 30 to 60 days after surgery.

Cryptorchid Castration

Cryptorchidism is observed in commercial swine as well as miniature pot-bellied pigs. Veterinarians may be presented with boars with unilateral or bilateral retained testicles. Alternatively, veterinarians may be presented with previously castrated swine that demonstrate boar-like traits for removal of retained testicular tissues. In commercial swine, cryptorchid pigs often still have a high incidence of boar taint as well as intact boar behavior. The testes of swine descend in the last 30 days of gestation and should be palpable at birth. True cryptorchidism (testis not descended at birth) is a common congenital defect in swine. A homozygous recessive trait involving two gene loci has been postulated based on a breeding trial of cryptorchid Duroc swine. The presence of cryptorchid piglets in a litter is associated with a higher ratio of male piglets in swine litters. "Late-onset" cryptorchidism is also described in swine when male piglets are born

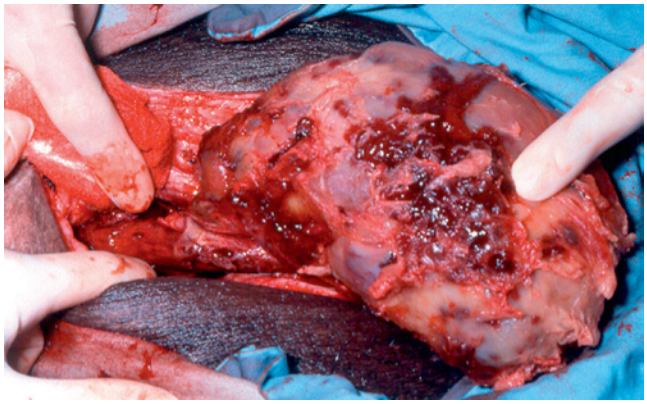


Figure 27-4 Boar with testicular torsion. Note swollen hemorrhagic testis. (Courtesy of Dr. André Desrochers.)



Figure 27-5 Boar with testicular hematoma. Note swollen scrotum. (Courtesy of Dr. André Desrochers.)

with both testicles normally descended but then only one testicle is present later in life.

Cryptorchid testes are usually intraabdominal and are found midway between the ipsilateral kidney and deep inguinal ring. However, the affected testis may be located within the inguinal canal and not readily palpable from either the inguinal region or peritoneal cavity. Previous removal of the descended testis makes surgical removal of the retained testis more difficult because the incision is best made over the affected superficial inguinal ring. Determining which testis has been removed can be difficult. Ultrasound examination of the abdomen from the inguinal ring toward the kidney can be helpful in identifying the location of a retained testicle.

Cryptorchid surgery is best performed with the pig under general anesthesia. Either a paramedian or an inguinal approach can be used. For the paramedian approach, a 4- to 8-cm incision is made approximately 2 cm lateral and parallel to the prepuce in the caudal ventral abdomen on the side of the retained testicle (Figure 27-6*A*). The external rectus sheath is incised, and the underlying muscle is separated by blunt dissection. In some pigs, there is a significant layer of fat between the rectus abdominus muscle and the peritoneum. This is bluntly separated, and the peritoneum is elevated with thumb forceps and opened with scissors. For the

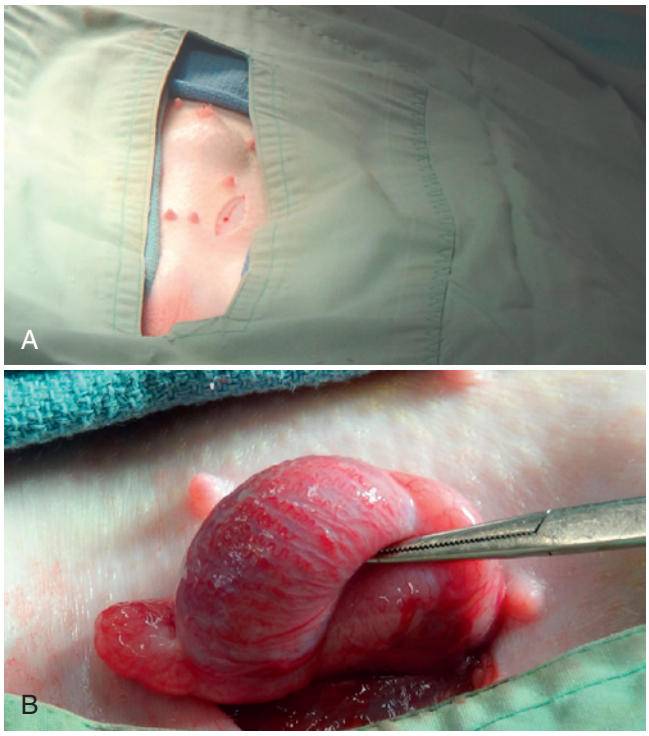


Figure 27-6 *A*, Left paramedian approach for left cryptorchid surgery in a young pig. *B*, The testicle is identified and exteriorized through the incision for ligation and removal.

inguinal approach, an incision is made over the appropriate superficial inguinal ring, extending the incision cranially. The laparotomy is performed by extending the incision from the cranial commissure of the superficial inguinal ring. In some cases, the retained testis will be immediately present upon entry into the abdomen, and visual inspection should be attempted before further digital exploration. If the testicle is not immediately identified, the abdomen is explored digitally starting at the pelvic brim and searching along the dorsal and lateral abdominal wall until the kidneys are encountered. Once the testicle is identified, it is retracted from the abdomen (Figure 27-6*B*). The abdominal attachments including the testicular artery, pampiniform plexus, and vas deferens are ligated as a single stump using synthetic absorbable suture, and the retained testicle is removed. Routine abdominal wall closure is best performed using synthetic absorbable suture. Laparoscopic exploration and removal of abdominal testes can also be performed and may attain better cosmesis, fewer incisional complications, and more rapid incisional healing.

In countries in which it is available, immunocastration is an alternative to surgical castration of cryptorchid boars and will reduce boar taint. True cryptorchidism should be differentiated from ectopic testicular tissue. Ectopic testicular tissue has been observed in numerous pigs at the time of slaughter. These tissues occur as smooth, pink, or tan nodules on the surface of the liver, spleen, mesentery, and other abdominal viscera. Initially, these masses may be interpreted as metastatic neoplasia, but histology reveals the presence of convoluted seminiferous tubules and interstitial cells. No evidence for neoplasia is seen. Ectopic testicular tissues may be found in castrated or intact male pigs.

Inguinal Hernia

Inguinal hernia results when a defect permits intestines or other abdominal organs to pass into the inguinal canal. This

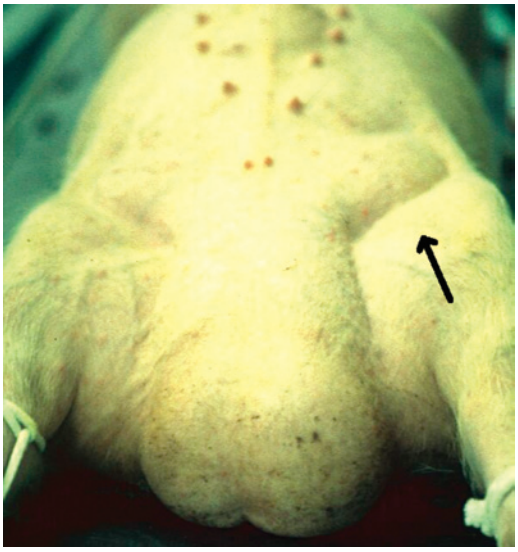


Figure 27-7 Pig with a scrotal hernia restrained in dorsal recumbency. Note swelling in left scrotum and left inguinal area (*arrow*).

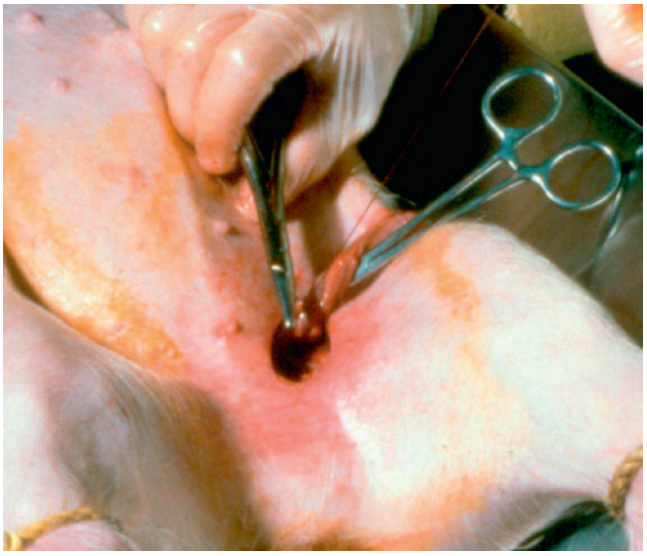


Figure 27-8 Pig restrained in dorsal recumbency; an oblique incision is made over the affected superficial inguinal ring and the vaginal tunic isolated. (Courtesy of Dr. André Desrochers.)

is a result of an abnormally large and patent vaginal ring that allows free communication between the vaginal tunic and peritoneal cavities. If the organs protrude into the scrotum it is termed a *scrotal hernia* a more exaggerated form of the defect (Figure 27-7). These hernias are common in swine. The frequency of inguinal hernia among the porcine population varied between 0% and 15.7%, with a realistic estimate of approximately 1%. The development of inguinal hernias seems to be genetically influenced. One study indicated that the variation associated with anatomic structures relevant to scrotal hernia is influenced polygenically. In that study, the heritabilities of susceptibility to scrotal hernia development were estimated to be 29%, 34%, and 34% in Duroc-, Landrance-, and Yorkshire-sired pig groups, respectively.

Inguinal and scrotal hernias (see Figure 27-7) need to be differentiated from hydrocele, scirrhous cord, and hematoma (see Figure 27-5) of the testis. Diagnosis is made by historical data (e.g., a pig that has been castrated before is more likely to have a scirrhous cord) and direct manipulation. If necessary, ultrasonography and needle aspiration can be used. Inguinal hernias often are encountered at the time of castration. Some of these hernias will reduce spontaneously but recur later. With chronic inguinal hernia, intestinal incarceration and strangulation may be observed.

Surgical repair of an inguinal or scrotal hernia in the boar is easier before the pig is castrated. With the pig restrained in dorsal recumbency and its rear quarters elevated, the inguinal and scrotal area is thoroughly cleaned and prepared for surgery. An oblique incision is made over the affected superficial inguinal ring (Figure 27-8). After sharp incision of the skin, the subcutaneous tissue is dissected bluntly. The tunica vaginalis is also isolated by blunt dissection (see Figure 27-8). The tunica vaginalis should be kept intact, because this will keep the intestine contained. While external pressure is put on the scrotum, the tunics are gently pulled free from their scrotal attachment. The tunic and testis are then twisted to force the intestines into the peritoneal cavity (Figure 27-9). The tunics and spermatic cord are transfixed as close to the superficial inguinal ring as possible. The tunic and cord are cut, and the superficial inguinal ring is closed with interrupted or horizontal mattress sutures. The herniorrhaphy site is checked by applying external

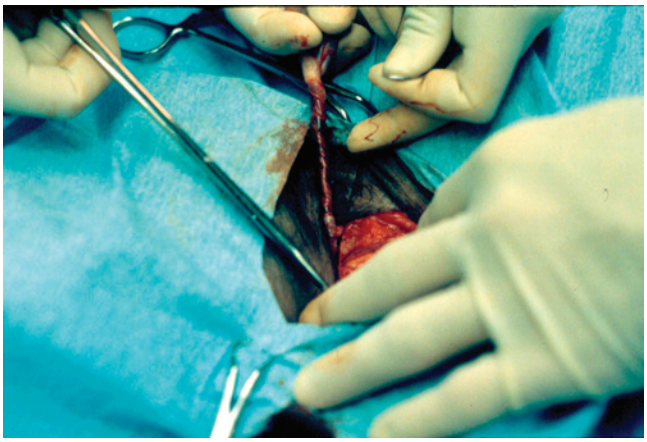


Figure 27-9 Surgical repair of an inguinal hernia showing the tunic and testis being twisted to force the intestines into the peritoneal cavity.

pressure on the abdomen. The skin is closed using absorbable sutures in an intradermal or external pattern. The opposite inguinal ring is then examined for possible bilateral herniation before performing a castration. If the surgery was done to repair a large hernia in which marked serum accumulation in the scrotum is expected, an incision in the most ventral aspect of the scrotum should be performed to provide ventral drainage. If intestinal adhesion and incarceration are observed during surgical correction, the vaginal tunic should be opened, and the intestine dissected free or an intestinal resection and end-to-end anastomosis performed. If an inguinal hernia occurs after castration, one needs to clean and lavage the herniated bowel, enlarge the vaginal and superficial inguinal ring, and replace the prolapsed intestine (if it is judged still viable) before suturing the superficial inguinal ring closed.

Castration is generally recommended in boars with inguinal hernia because of the heritable predisposition. In rare circumstances, inguinal trauma may be suspected as a cause of the hernia, and surgical correction without castration may

be requested. Inguinal hernia may also occur in previously castrated pigs or in female pigs. In such cases, the hernia can be repaired as described in other livestock species. Laparoscopic inguinal hernioplasty has been described in the ram.

Preparation of Teaser Boars

Vasectomy or epididymectomy is done to produce teaser boars that are used to detect sows in heat for artificial insemination or scheduled breeding to valuable boars. Teaser boars are also used to promote the onset of cyclicity in confined gilts (young females). For vasectomy, the boar is placed in dorsal recumbency under general anesthesia, and a 4-cm incision is made over each spermatic cord approximately 3 to 6 cm cranial to the ventral aspect of the scrotum. Each spermatic cord is elevated, the parietal vaginal tunic is incised, and the ductus deferens identified. The ductus deferens is firm and pale, and an arterial pulse is not present. The ductus deferens can be easily freed from the other tissue of the spermatic cord by grasping within two towel clamps placed close together around the ductus deferens and then separating them apart. Ligatures are placed on this section 3 to 4 cm apart, and the ductus deferens is excised. The incision through the vaginal tunic is sutured with synthetic absorbable suture material, and the skin is sutured with nonabsorbable suture material in a simple interrupted pattern or with synthetic absorbable suture in an intradermal pattern.

Epididymectomy is performed by making a 2- to 3-cm incision in the ventral scrotum overlying the tail of the epididymis. The tail and 1 cm of the body of the epididymis is isolated using sharp and blunt dissection to elevate it away from the testicle. Care must be taken not to cut into the testicle in order to avoid persistent hemorrhage. Ligatures are placed between the testis and the tail of the epididymis and around the exposed portion of the body of the epididymis. The epididymis is excised between these two ligatures. The skin is closed with nonabsorbable sutures in an interrupted pattern or with absorbable sutures in an intradermal pattern.

Prolapsed Penis

Penile and preputial prolapse may occur after administration of neuroleptic drugs or as a result of trauma to the penis. There are also anecdotal reports of paraphimosis in pet pot-bellied pigs after castration. Congenital penile prolapse in a litter of Vietnamese pot-bellied pigs has been observed in which all males in the litter were affected. When prolapsed, the penis is at risk of further injury. The penis and prepuce should be returned to their normal position as soon as possible after prolapse. Treatment of penile prolapse usually requires general anesthesia. The penis is thoroughly cleaned with cold water and a topical antiseptic ointment applied to its surface. If a penile wound is present, debridement may be performed. Penile wounds typically are not sutured closed unless they have occurred within 2 to 4 hours because of the likelihood of infection. The penis and prepuce are gently massaged until reduction into the sheath is complete. Use of hydroscopic agents (e.g., anhydrous glycerin) may help reduce the swelling by resolving edema. After the penis and prepuce have been repositioned, a purse-string suture may be used to prevent reoccurrence of the prolapse. The purse string should be removed in 5 to 7 days. If wounds or abrasions are present, daily preputial lavage or administration of systemic antibiotics and antiinflammatory drugs is indicated. Sexual rest should be enforced for at least 14 days. If wounds that require treatment are present, sexual rest should be enforced for 30 to 60 days. Reevaluation of the penile injury is advisable before use for breeding. In the case of congenital penile prolapse, penopexy was used to maintain normal penile retention, but all males were castrated and used as pets.

Persistent Frenulum

The congenital epithelial attachment of the penis and prepuce normally atrophies, and these tissues separate between 4 and 6 months of age in commercial boars and earlier in pot-bellied pigs. Sexual maturity is achieved by 7 to 8 months of age. Persistence of the frenulum attachment between the penis and prepuce beyond sexual maturity causes failure of breeding soundness. Surgical removal of the persistent frenulum is performed with the boar under general anesthesia or during a hand-mating exercise. Resection of the tissue may be performed with scissors. Ligation is not required in most cases but can be done, and minimal bleeding is observed after excision (see Chapter 16). Sexual rest should be enforced for 7 to 10 days after surgery.

Preputial Prolapse

Prolapse of the internal lamina of the prepuce may occur with penile prolapse or may result from preputial injury and swelling. If wounds to the prepuce are not present, the internal lamina may be repositioned within the sheath, as described for penile prolapse and a purse-string suture used to maintain the reduction. Careful evaluation of the preputial swelling should be done to ensure that urination is possible. Preputial edema may be reduced by application of hydroscopic agents. A preputial retaining tube, constructed from rubber or polyurethane tubing, may be placed into the preputial cavity to prevent prolapse and allow exit of urine.

Often, the prolapsed internal lamina has been traumatized, and surgical removal of the affected tissue is indicated. Preputial amputation may be performed, but the opening to the preputial diverticulum must be maintained. Alternatively, the preputial diverticulum may be removed at the time of surgery. The boar is placed under general anesthesia, the internal lamina is pulled cranially until normal preputial epithelium is exposed, and stay sutures or crossed pins (7.6-cm, 18-gauge needles) are placed through the exposed internal lamina to prevent premature retraction into the sheath. The damaged tissues are amputated, and the two layers of internal lamina are sutured closed in an interrupted suture pattern using synthetic absorbable suture. After anastomosis, antiseptic ointment is placed on the internal lamina, and it is replaced into the sheath. A purse-string suture is placed at the preputial orifice for 7 to 10 days, and sexual rest is enforced for 30 to 60 days. Systemic antibiotics should be administered perioperatively.

Resection of Preputial Diverticulum

The preputial diverticulum is a bilobed structure extending from the dorsal aspect of the anterior prepuce. This structure normally has a slightly swollen appearance near the preputial orifice that is symmetric on both sides. The diverticulum contains urine and secretions and is believed to play a role in lubrication of the penis before and during copulation. Abnormalities of the preputial diverticulum may cause reproductive unsoundness. Preputial diverticulitis (Figure 27-10), diverticular ulcers, urine retention, and penile deviation into the diverticulum may be found. Preputial diverticulectomy may restore breeding soundness to affected boars. The procedure is performed in pet pot-bellied pigs for both cosmetic and esthetic reasons. Resection of the preputial diverticulum will lessen urine retention within the prepuce and decrease the incidence and volume of the malodorous secretions in the home environment. In pet pigs, the procedure may be performed at the same time as castration. The boar is placed under general anesthesia and prepared for



Figure 27-10 Preputial diverticulitis in a boar noted by the excessive swelling at the anterior end of the prepuce. (Courtesy of Dr. André Desrochers.)

surgery (Figure 27-11*A*). Three procedures are described for diverticulectomy in boars:

1. Closed resection of the preputial diverticulum: A 4- to 6-cm parapreputial skin incision is made overlying the lateral aspect of one lobe of the preputial diverticulum. The incision is continued through the subcutaneous tissue and the cranial preputial muscle until the wall of the preputial diverticulum is identified. Both lobes of the preputial diverticulum are separated from surrounding tissue by a combination of sharp and blunt dissection. Gauze sponges are helpful in grasping the preputial mucosa and dissecting it free from the preputial muscle. After both lobes are fully free, the neck of the preputial diverticulum is identified, and a purse-string suture of synthetic absorbable material is placed, but not tightened, around the neck of the preputial diverticulum (Figure 27-11*B*). Using a finger or a blunt surgical instrument, each sac is everted through the preputial orifice and grasped with a gauze sponge. This can also be performed by reaching through the preputial opening and grasping and everting each sac with a hemostat or Allis tissue forceps (Figure 27-11C). Once both sacs are everted, the purse-string suture is tightened and tied. The subcutaneous tissue and skin of the original incision are closed. Finally, the everted diverticulum is removed (Figure 27-11*D*). The stump can remain open (Figure 27-11*E*) or be sutured with a simple continuous pattern over the clamp using synthetic absorbable suture (Figure 27-11*F*). The closed procedure reduces the risk of bacterial contamination from the preputial diverticulum contents at the surgical site both during and after surgery.
2. Open resection of the preputial diverticulum: A 4- to 6-cm incision is made as described in previous procedure. The diverticulum is dissected free from the surrounding soft tissues, excised, and sutured closed at the skin incision rather than everting through the preputial orifice. A disadvantage of this procedure compared with closed resection is that the stump is closed within the open surgical site and not externally through the preputial orifice. This may increase the risk of surgical site infection.
3. Preputial diverticulectomy via the preputial orifice: For this procedure a curved hemostatic or other forceps is passed through the preputial orifice and into one lobe of the bilobate diverticulum. The tip of the blind horn is grasped and, with gentle traction, partially everted through the preputial opening. Additional forceps are then used to evert the remainder of the lobe. Grasping the everted diverticulum mucosa with gauze may also aid in eversion of the mucosa. The procedure is repeated with the opposite lobe. In some cases, the preputial opening is too small to evert and exteriorize the diverticulum, and the preputial orifice may need to be enlarged by incising cranially along the body wall. After both lobes of the preputial diverticulum are everted, the diverticulum is excised (Figure 27-11*D* and *E*). Suturing is not required for young boars, but the opening to the diverticulum may be sutured closed in adults (Figure 27-11*F*). Tearing of the mucosa of the diverticulum during the procedure may occur and could lead to local contamination and infection.

For all three methods, care must be taken not to perforate the diverticulum before removal because contamination can result in surgical site infection. Flushing the preputial diverticulum with antiseptic solutions before surgery is recommended to reduce this possibility. Also, filling the diverticulum with antiseptic solution or gauze pads before surgery (procedures 2 and 3) makes identification of the diverticulum easier at the time of surgery.

SURGERY OF THE FEMALE SWINE REPRODUCTIVE SYSTEM AND URINARY TRACT

Vaginal Prolapse

Vaginal prolapse occurs as a prepartum event (Figure 27-12). The cause of vaginal prolapse is unknown, but straining to urinate or defecate may be involved. Sows with lateral deviation of the bladder and difficulty urinating or with inflammation associated with cystitis and urethritis may develop vaginal prolapse because of straining. When the cause can be found, treatment should be aimed at resolving the primary problem.

After appropriate anesthesia of the sow, the prolapsed vagina is cleaned with cold water or saline. Hydroscopic agents are applied, and a towel is wrapped around the prolapsed portion. Constant gentle pressure is used to reduce the edema and swelling. The prolapse can usually be reduced in 15 to 20 minutes. The vagina should be cleansed and topical antibiotic or antiseptic ointments used to reduce the secondary bacterial vaginitis that invariably occurs. Administration of antiinflammatory drugs may reduce straining and shorten convalescence. The bladder should be evaluated to ensure it is in a normal position. A Buhner suture (see Chapter 16) is placed around the vagina to prevent reoccurrence of the prolapse. The sow should be closely monitored and the Buhner suture removed at the first indication of farrowing or at 112 to 114 days of gestation. If excessive swelling of the soft tissues in the pelvic cavity has occurred, a cesarean section is indicated and should be performed early in the process of farrowing.

Bladder Displacement or Retroversion

Displacement of the bladder occurs in multiparous sows in the latter stages of gestation. The bladder is displaced laterally and occasionally may become displaced caudally. The displaced bladder results in a swollen appearance to the vagina (Figure 27-13*A* and *B*). Bladder displacement results in difficulty with urination. The displaced bladder may give the appearance of a vaginal prolapse when the sow is lying down. Affected sows may be seen straining because of the difficulty urinating, and this may lead to true vaginal

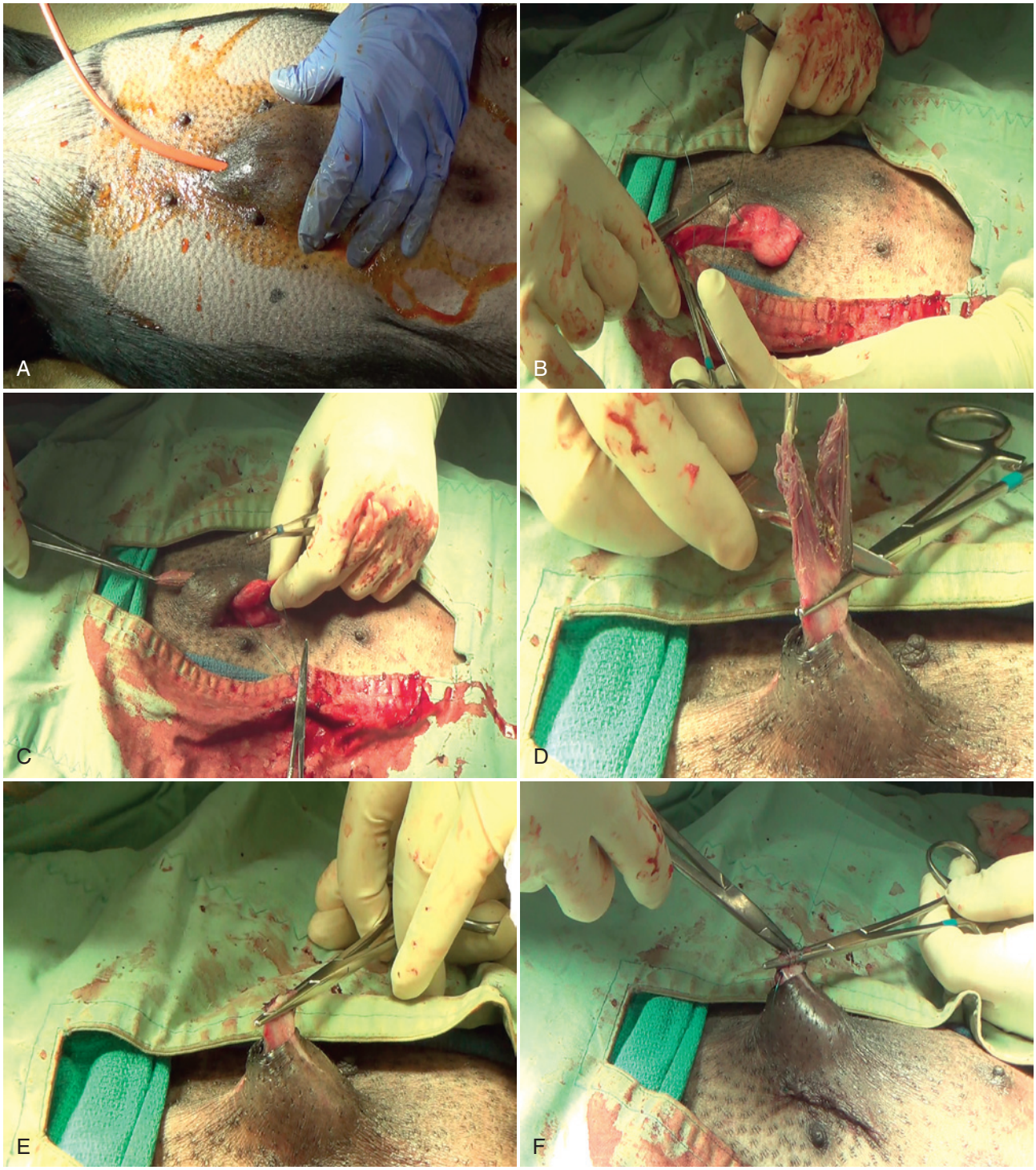


Figure 27-11 *A*, Lavage of the preputial diverticulum with disinfectant before removal. *B*, An incision lateral to the prepuce allows for access and exteriorization of both preputial diverticula. In this image, a purse-string suture is placed at the base of the preputial diverticula for a closed resection. C, Each preputial diverticulum is everted out the end of the prepuce. *D*, Both preputial diverticula are everted and ready to be excised. *E*, The diverticula are excised. *F*, After removal, the remaining stump may be released back into the prepuce or, oversewn with a simple continuous pattern.

prolapse or rectal prolapse (Figure 27-14*A* and *B*). Decompression of the urinary bladder by cystocentesis or catheterization may allow permanent replacement of the bladder. When displacement recurs, an indwelling urinary catheter may be used to allow urination until after parturition (Figure 27-13C). Ascending bacterial cystitis is a complication of the indwelling urinary catheter, and appropriate antibiotics may be necessary to prevent or treat this complication.

Ovariectomy

Removal of the ovaries (ovariectomy or oophorectomy) is rarely indicated in commercial swine. However, ovariectomy may be requested by rescue organizations, to facilitate research, or for pet pigs. Ovariectomy will render the animal sterile and eliminate cyclical estrus behavior. Ovariectomy may be performed in pet pigs that have not begun normal estrus cycles. Uterine atrophy is expected to occur after ovariectomy. Ovariectomy is reported to be easier and faster with less risk of fatal hemorrhage than ovariohysterectomy (OVH). The blood vessels of the broad ligaments of the uterus are extensive and require ligation when ovariohysterectomy is chosen. However, with ovariectomy, the uterus and cervix remain intact. Neoplasia of the reproductive tract is commonly reported in pot-bellied pigs. Neoplasia of the remaining reproductive tract in ovariectomized pet pigs has been observed (personal communication, Dr. Meera Heller) and may be a reason for pursuing full OVH in pet pigs. OVH is recommended in sexually mature pet pigs because of the potential risk for pyometra in a uterus in which the cervix has been open.

Both ovaries may be removed from a paralumbar (flank), ventrolateral, paramedian, or ventral midline incision. In large, obese pigs, ovariectomy via a left or right flank incision with general anesthesia is preferred for easier access and to minimize incisional complications. For a paralumbar approach, the incision is started ventral to the transverse processes of the lumbar vertebrae, midway between the tuber coxae and the last rib. In young pigs, the ventral midline laparotomy approach may be preferred for cosmetic concerns. Each ovary is elevated through the incision. The ovarian pedicle is identified and ligated with synthetic absorbable suture and transected from the ovary. Next, the uterine artery and vein are ligated and severed at the proper ligament near the tip of the uterine horn, and the ovary is removed. Use of electrothermal bipolar vessel sealing (EBVS)[1] to cauterize and transect the ovarian attachments has also been described. Each ovarian artery must be observed for hemorrhage before closure. The laparotomy incision is closed in a routine fashion.



Figure 27-12 Sow with vaginal and rectal prolapse.

[1]LigaSure, Valleylab Inc., Boulder, CO.

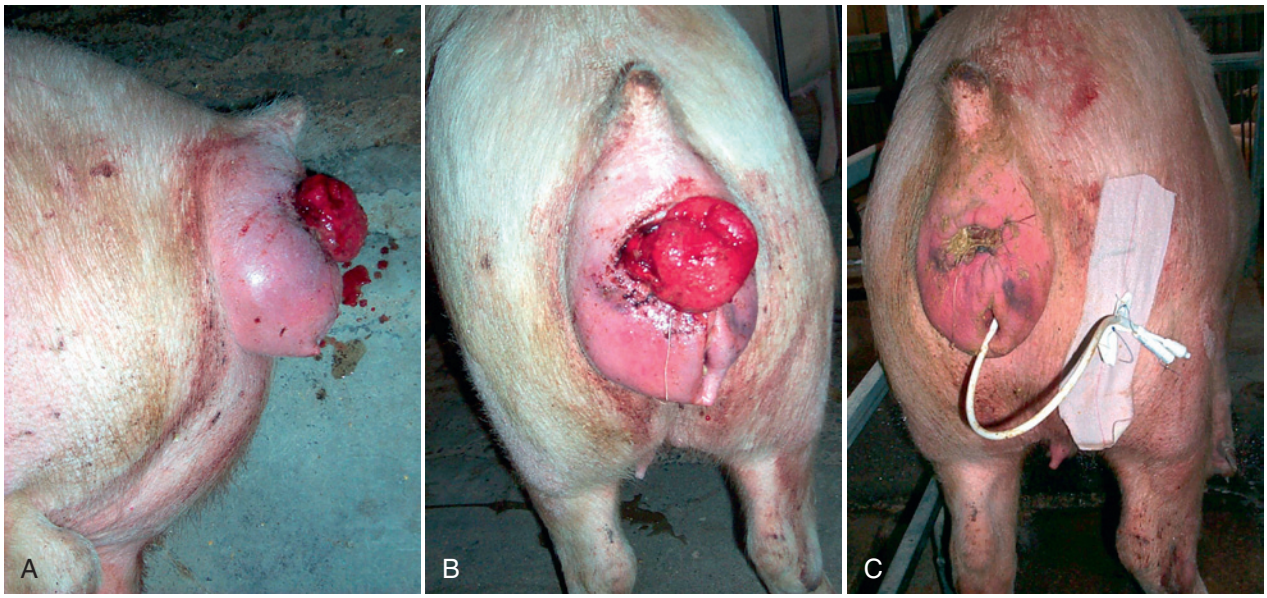


Figure 27-13 *A*, Lateral and, *B*, caudal view of a sow with bladder displacement and associated rectal prolapse. C, Treatment involves catheterization of the bladder until farrowing. (Courtesy of Dr. Mary Smith.)

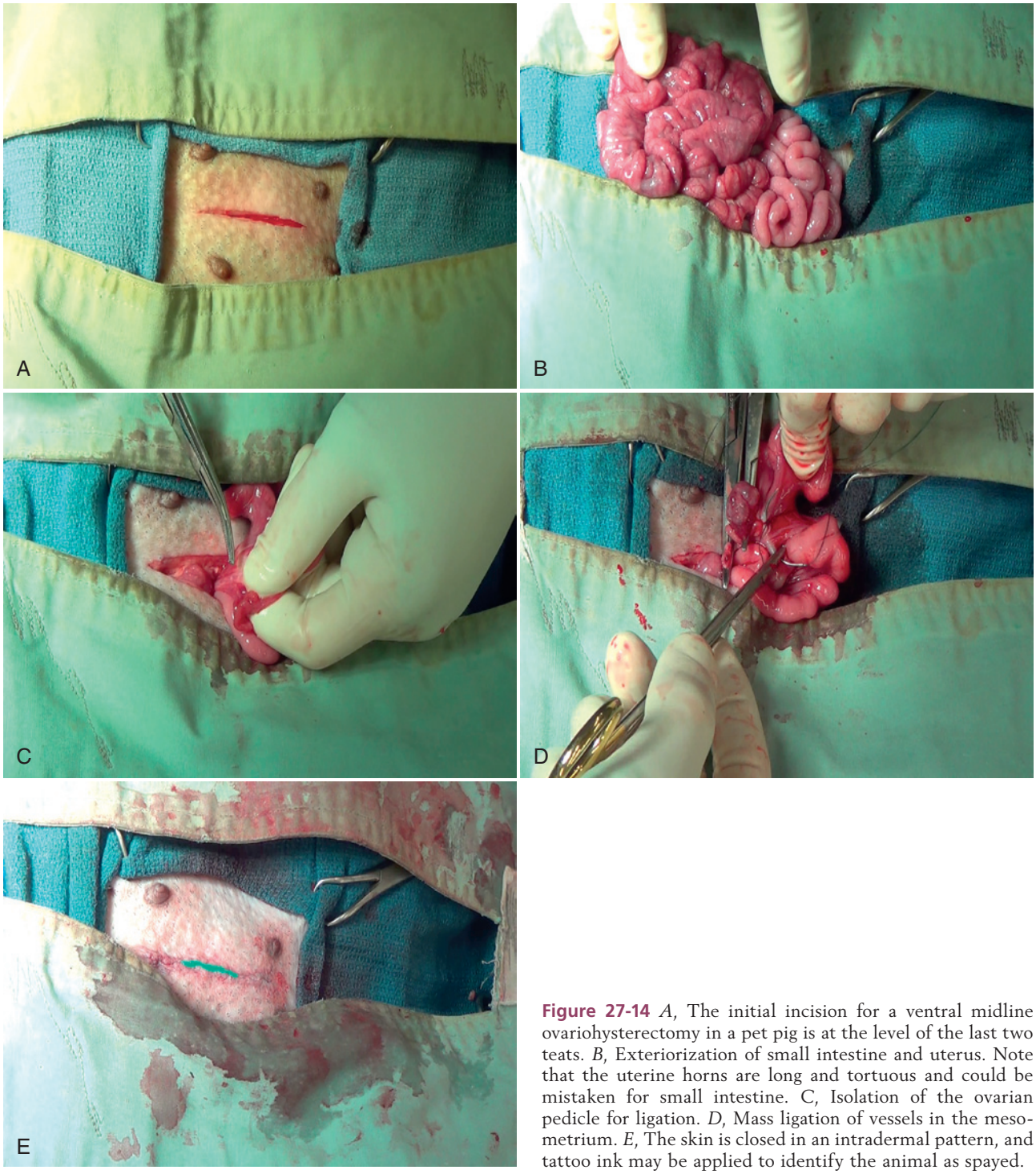


Figure 27-14 *A*, The initial incision for a ventral midline ovariohysterectomy in a pet pig is at the level of the last two teats. *B*, Exteriorization of small intestine and uterus. Note that the uterine horns are long and tortuous and could be mistaken for small intestine. *C*, Isolation of the ovarian pedicle for ligation. *D*, Mass ligation of vessels in the mesometrium. *E*, The skin is closed in an intradermal pattern, and tattoo ink may be applied to identify the animal as spayed.

Ovariohysterectomy

Elective ovariohysterectomy (OVH) is rarely done in commercial swine. OVH may be requested for research purposes or for pet pigs to render them sterile and eliminate cyclical estrus behavior, or for removal of the uterus if uterine pathology is identified such as uterine neoplasia. Elective OVH in pet pigs can be done at any time, providing that the animal is healthy enough for surgery. However, the reproductive tract may be underdeveloped in young pigs before their first estrus cycle. In pet pot-bellied pigs less than 8 weeks of age, the uterus can be very small, often less than 2-mm diameter, and may be difficult to identify. After the first estrus cycle, the uterus is larger and very apparent within the abdomen.

OVH should be performed under general anesthesia with appropriate perioperative analgesia such as nonsteroidal anti-inflammatory drugs. The uterus may be removed via a flank, ventrolateral, paramedian, or ventral midline incision. The flank approach may be preferred in commercial or large swine to minimize incisional complications such as dehiscence or infection. The ventral midline is often preferred for pet pigs for cosmetic reasons. For the ventral midline approach, the initial abdominal incision is made caudally in the abdomen at the level of the most caudal two teats (Figure 27-14*A*). Once

the abdomen is entered, initial visual inspection is performed to identify the uterus. The uterus is often visually present at the incision in a pig that has already demonstrated one heat cycle and may be mistaken for small intestine because of the long, torturous uterine horns (Figure 27-14*B*). Once identified, the uterus and ovaries are elevated through the incision. The ovarian pedicle is isolated and ligated as described for ovariectomy (Figure 28-14C). Next, the mesometrium (broad ligament of the uterus) is ligated with two to four overlapping simple interrupted sutures for mass ligation of the blood vessels (Figure 28-14*D*). Transfixation ligatures are placed in the uterine body immediately cranial to the internal os of the cervix. The uterine arteries can be included in this ligature or ligated separately. The uterus and ovaries are removed, and all sutured pedicles should be checked for adequate hemostasis before closure. The laparotomy incision is closed using synthetic absorbable suture in a simple continuous single- or double-layer closure of the abdominal wall. The subcutaneous tissue is closed with absorbable suture in a simple continuous pattern. The skin may be closed with synthetic absorbable suture using an intradermal pattern, or an external skin closure pattern can be used. In pet pigs, tattoo ink can be applied to a portion of the incision similar to dogs and cats to help identify the animal as spayed (Figure 28-14*E*).

OVARIECTOMY FOR STERILIZATION OF PET PIGS

Richard P. Hackett and Susan L. Fubini

Pet female pigs should be ovariectomized (spayed) for several reasons to improve their health and well-being. The most obvious is for population control to minimize numbers of unwanted or abandoned pigs. Unspayed pigs go through a heat cycle every month. During this time, they may be restless or even aggressive, drip blood from the vulva and scent mark by urination, clearly not desirable traits for a pet. Last, unspayed pigs are at increased risk of reproductive tract neoplasia (ovarian and uterine) and are more likely to develop mammary neoplasia or uterine infection (pyometra).

Female Vietnamese pot-bellied pigs (PBP) enter their first estrus between 3.5 and 4 months of age. Full-sized pigs will have their first heat between 4 and 9 months (average 7 months). They will have a 3- to 5-day heat cycle every month for the rest of their lives. Our practice recommends that gilts be spayed between 4 and 6 months of age. At this age, they are still small enough to handle easily and have fewer anesthetic risks. Small animal practitioners often recommend that dog bitches be allowed to go through their first estrus cycle before spaying to reduce the risk of cruciate ligament injury and urinary incontinence. Large-breed and giant-breed dogs that are spayed before 3 months of age are at higher risk of developing urinary sphincter mechanism incontinence. There is no evidence that waiting for a heat cycle is beneficial to pigs.

CHOICE OF PROCEDURE: LAPAROSCOPIC OVARIECTOMY VS. OPEN OVARIECTOMY OR OVARIOHYSTERECTOMY

Between mid-2006 and early 2015, our practice has performed elective spays on 89 pigs. These have ranged in size from a 3.6-kg PBP to a 272 kg Yorkshire sow. Thirteen of the 89 cases were PBP or PBP mixes. The rest were commercial breeds of swine, largely Yorkshire or Hampshire swine or crossbreds, presented by rescue organizations or sanctuaries. Ovariectomy without hysterectomy was performed in 78 pigs, and ovariohysterectomy was performed in 11 cases. Most (73%) of the ovariectomies were done laparoscopically, and simultaneous hysterectomy was not attempted due to additional anesthetic time and greater risk of complications. Leaving the uterus does, at least theoretically, leave the door open for pyometra or uterine neoplasia later in life, but substantial studies in dogs indicate that the risks of such problems are negligible in animals ovariectomized at a young age. Parallel studies are lacking in swine.

Laparoscopic ovariectomy was generally preferred over open ovariectomy due to reduced patient morbidity and reduced risk of incisional complications, especially herniation, after surgery. Most of the larger pigs were done laparoscopically. Pigs weighing less than 15 kg were often operated using an open procedure, depending on the surgeon's preferences. This was also influenced by the fact that our laparoscopic equipment is scaled for equine surgery (10-mm cannulas and scopes) and is awkward to use in smaller patients. The smallest pig done laparoscopically was the 5.4-kg PBP.

Ovariohysterectomy was performed in 11 cases, all as open procedures. Factors leading to ovariohysterectomy over ovariectomy alone were pregnancy, surgeon preference, and small patient size. If an open procedure was planned for ovariectomy in smaller pigs, the uterus was also sometimes removed at surgeon's preference, as doing so had appeared to have little effect on anesthesia time or risk of complications.

Technique for Laparoscopic Ovariectomy

Small pigs (less than 15 kg) are fasted for approximately 12 hours and larger pigs for 18 to 24 hours. Water is not withheld. The pig is anesthetized, placed in dorsal recumbency, and the ventral abdomen is prepared and draped for aseptic surgery. Placement of cannulas may be challenging in pigs due to substantial subcutaneous fat and a very strong peritoneum, so we use an open technique (modified Hasson) for placement of the first cannula. The first cannula (scope portal) is placed at the umbilicus. A 2- to 3-cm ventral midline skin incision is made centered on the umbilicus. Subcutaneous fat is divided using a combination of blunt and sharp dissection to expose the linea alba. Towel clamps, temporary sutures, or Allis tissue forceps are placed through or onto the external sheath of the rectus abdominus muscle, one either side of the midline. The body wall is elevated, and a 10-mm incision is made through the linea alba and peritoneum. A 10-mm laparoscopic cannula with a blunt trocar is placed, taking care to ensure that it is actually positioned within the abdomen and not between the layers of the body wall. A laparoscopic insufflator is used to achieve a pneumoperitoneum of 12 to 15 mm Hg with carbon dioxide, and a 10-mm-diameter, 30-degree laparoscope is inserted. The patient is placed into Trendelenburg position (head lower than body). Two additional 10-mm cannulas are placed as instrumental portals, one on each side approximately halfway between the umbilicus and the superficial inguinal rings just lateral to the mammary chain (Figure 27-15). These are placed under laparoscopic visualization using an incision through the skin and body wall and a sharp (pyramidal) trocar. Alternatively, at surgeon's preference, all three cannulas can be placed along the ventral midline, the scope portal at the umbilicus with an instrument portal in front and behind. If available, a 5-mm laparoscope and cannulas are preferred for smaller pigs (less than 15 kg).

The ovaries in pigs are, as in the cow, normally in the caudal abdomen near the pelvic inlet. In commercial pigs, the uterine horns are approximately 30 cm in young gilts and up to 1 m in a large sow. If a large, urine-filled bladder is

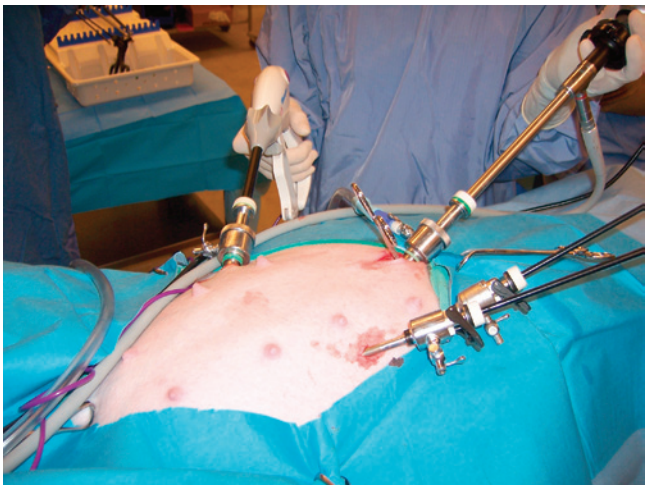


Figure 27-15 Placement of cannulas. The patient's head is to the right. The surgeon's left hand holds the laparoscope placed via an umbilical portal. The left hand holds the bipolar vessel sealing device passed through a lateral cannula.

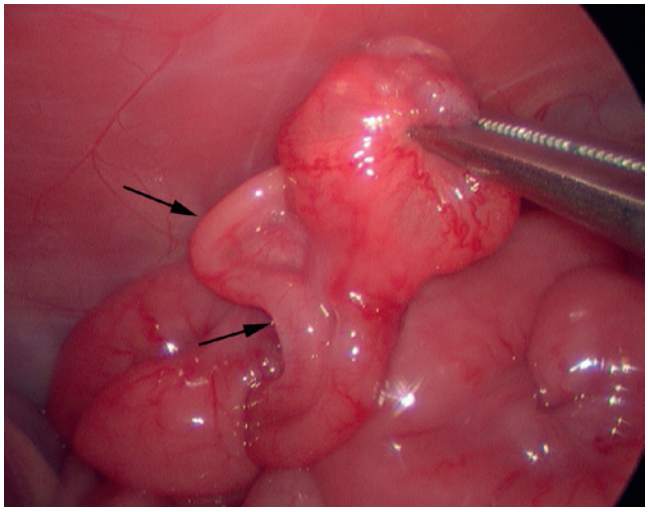


Figure 27-16 Laparoscopic view of sow's ovary. The forceps from the left is grasping the ovary. The two black arrows designate the uterine tube.

obscuring visualization of the caudal abdomen, it should be emptied by percutaneous cystocentesis using an 18-g IV catheter with applied suction before attempting manipulations. The uterus is distinguished from bowel by its pinker color and more muscular appearance. Atraumatic intestinal grasping forceps are used hand-over-hand to follow the uterine horn to the ovary. The ovary is often obscured within the ovarian bursa by an extensive mesosalpinx. It is isolated and elevated either by grasping it with a forceps or by placing the jaws of a straight forceps on each side of the proper ligament of the ovary (between the ovary and the tip of the uterine horn) (Figure 27-16). In small animals, the ovary itself is normally too friable to safely grasp with a forceps. We use a bipolar vessel sealing device to seal and divide ovarian vessels and attachments. Alternatives are monopolar laparoscopic scissors or a ligating device with a sliding knot. In a small pig, the ovary may fit into a 10-mm cannula and thus be removed. In larger pigs, the ovary is removed by enlarging the umbilical portal. The ovary is held by a grasping forceps, and the cannulas used by the scope and the other grasping forceps are exchanged. The grasping forceps (now using the umbilical portal) are used to grasp the ovary. The opening in the linea alba is enlarged slightly as necessary and the forceps, cannula, and ovary are removed together. The umbilical cannula is replaced into the abdomen, and towel clamps are placed across the linea adjacent to it as necessary to seal the abdomen so that pneumoperitoneum may be reestablished. The process is repeated on the other side. The ovaries are removed via the umbilical portal because, if enlarged, it is easier to close securely than the other two portals. The midline incision is closed in three layers—linea alba with #0 or #1 polydioxanone or polyglactin 910d, and routine subcutaneous and skin closure. The external sheath of the rectus muscle is closed for the two lateral portals.

A laparoscopic ovariectomy was attempted in 57 pigs. This procedure was completed as a laparoscopic procedure in 53 cases but was converted to an open procedure in four pigs—two due to injury to the large colon during trocar insertion, one to repair damage to the uterine horn caused by manipulation, and one due to ventilation problems (a very large sow). All of these patients survived to discharge although one of the pigs with colon injury developed an incisional infection and abscessation. There has not yet been a systematic follow-up of these cases.

Open Ovariectomy or Ovariohysterectomy

Ovariectomy or ovariohysterectomy was performed as an open procedure using standard surgical techniques. A ventral midline incision starting at the umbilicus and proceeding caudally to a length scaled to the size of the pig was used. The ovaries are sufficiently mobile that both can be removed via a single flank celiotomy as well. Procedures for removal of the ovaries or ovaries and uterus mirror those used in small animals. Based upon our experience, we do believe that pigs are at somewhat high risk of herniation of the ventral midline closure compared with other species. Whether this is due to surgical technique, porcine anatomy, or postoperative management at home is unclear. Regardless, we tend to use slightly larger suture sizes to close the ventral midline than we use in other species. Most clinicians here use polydioxanone suture in a simple continuous closure for the linea alba. Some will additionally place a few pulley mattress sutures (near-far-far-near) through muscular and facial layers of the body wall for reinforcement of the closure.

Open procedures were elected in 31 cases (21 ovariectomies and 11 ovariohysterectomies). There has not been a systematic follow-up of this group of cases, but we saw five of these sows (16%) later for treatment of incisional hernias. These ranged in size from 18 to 140 kg.

Cesarean Section

Cesarean section is required when transcervical extraction of pigs from the uterus is not possible and to obtain gnotobiotic or specific pathogen-free pigs. Cesarean section for gnotobiotic pigs is usually performed with the sow under general anesthesia. Cesarean section for dystocia is usually chosen as a last resort procedure for fetal extraction because of economic pressures. Because many producers or pet pig owners delay the decision to seek veterinary assistance in dystocia, the morbidity and mortality rate among sows and gilts that have cesarean section is often higher than desirable. Swine suffer extreme physical exhaustion, stress, and shock during prolonged labor and may be in critical condition by the time the decision for cesarean section is made. Owners and veterinarians may become reluctant to perform cesarean

section because of expense, previous experiences with fatalities, and the high rate of dead piglets delivered. Unnecessary delays in the decision for obstetric assistance and surgery are the principle cause of sow and baby pig mortality associated with cesarean section. Swine have a very narrow window of normal gestation, between 114 to 115 days. Any gestation more than 116 days should be considered a dystocia, and obstetric evaluation and intervention is indicated and should be performed immediately to maximize viability of the dam and piglets.

When the veterinarian is presented with a sow in dystocia, it should be ascertained as early as possible whether the owner is willing to incur the costs of cesarean section. Other factors that influence the decision for cesarean section include the gestation length, cause of dystocia, how long the sow has been in labor, what sorts of attempts have been made to manually extract the pigs, and how swollen or traumatized the sow's pelvic canal has become. Many owners and farmers are adept at extracting pigs, and their failure to successfully remove pigs may justify immediate cesarean section if the cause of dystocia is not apparent. Cesarean section performed at the earliest indication maximizes dam and piglet survival.

Swine that are physically exhausted, stressed, or in shock must be stabilized before cesarean section. Among sows necropsied after sudden death, retained fetuses and toxemia were found in approximately 10%. Stabilization of the sow is often simple and readily achieved with intravenous fluid resuscitation. An intravenous catheter should be placed before surgery to allow fluid support. In commercial sows and gilts, a 16- or 18-gauge, 2-inch (5.08-cm) intravenous catheter can be inserted into an ear vein (Figure 27-17). In miniature pot-bellied pigs, satisfactory venous access in the ear may not be present, and alternatives such as surgical catheterization of the lateral saphenous vein over the hock (see Chapter 1) medial saphenous vein on the inside of the thigh, cephalic vein, or ultrasound-assisted catheterization of the jugular vein may be required. Initial shock fluids (80 to 90 mL/kg) consisting of balanced electrolytes or 0.9% saline are administered rapidly as 0.25 boluses (22 mL/kg or 10 mL/lb) every 15 to 20 minutes to effect. Once the animal is more stable, fluids are continued at 4 mL/kg/hour for the duration of the surgery. Many pigs in prolonged labor are hypoglycemic and hypocalcemic. Dextrose (2.5% final solution) and calcium (23% calcium gluconate, 1 mL/kg) are added to the intravenous fluids after initial shock fluids are administered. The metabolic status of the sow may be improved further by administration of flunixin meglumine (1 mg/kg, IV). Because extensive manipulation of the intrauterine environment before cesarean section increases the risk for postoperative septic peritonitis, preoperative antibiotics should be administered.

In severely compromised sows, sedation and local or regional anesthesia may be adequate for surgery. This can be supplemented with low levels of isoflurane by mask inhalation. Supplemental oxygen (nasal insufflation or by mask) will also benefit the patient and piglets. Lumbosacral epidural anesthesia is useful to provide surgical analgesia and decrease movement of the hind legs during surgery. The location for a lumbosacral epidural in the pig is along the dorsal midline at the L6-S1 junction, just caudal to a line drawn between the tuber coxae (Figure 27-18). A 3-inch, 18- or 20-gauge spinal needle is used in smaller pigs, and a 5- to 6-inch spinal needle may be required in larger pigs. The site is aseptically prepared, and a stab incision is made using a #15 scalpel blade. The spinal needle is inserted and directed slightly cranially. Resistance is felt as the needle passes through the dorsal spinous ligament, the interspinous, and the interarcuate ligament just before entering the epidural space. Aspiration is attempted to ensure that the needle is not in the subarachnoid space containing CSF. Lidocaine (2%) is administered at a dose of 0.1 to 0.2 mL/kg, not to exceed 20 mL. Minimal resistance during injection helps confirm that the needle is in the epidural space. This placement can be confirmed by adding a small bubble of air to the syringe of lidocaine, and if it is minimally compressed during injection, then the needle is likely in the epidural space.

Multiple surgical approaches have been described for cesarean section. Selection of the surgical approach depends on the preference of the surgeon, the condition of the patient, and means of restraint and anesthesia used for surgery. The most common approaches are paralumbar fossa, ventrolateral (horizontal low flank), ventral midline, or paramedian. With a ventral or paramedian approach, movement by the sow must be prevented because of the risk for contamination of the incision from debris on the feet and legs. Also, the mammary veins must be carefully avoided or ligated to prevent excessive loss of blood during the procedure. Ventral and paramedian incisions have the highest risk for



Figure 27-17 Ear catheter being placed in a sow before cesarean section.



Figure 27-18 Lumbosacral epidural performed in a pig in lateral recumbency. Epidural anesthesia provides analgesia and restraint of hind limbs for swine cesarean section.

development of postoperative incisional infection in commercial swine.

The ventrolateral incision is made parallel and axial to the fold of the flank and lateral to the mammary chain. The sow is placed in lateral recumbency, with the uppermost hind limb tied in abduction and extension. The incision is started approximately 10 cm cranial to the inguinal region and extended cranially for 15 cm. For the paralumbar fossa incision, the sow is placed in lateral recumbency, and the incision is made in the middle of the paralumbar fossa ventral to the transverse process (Figure 27-19*A*). The incision is extended ventrally to a point just dorsal to the cranial skinfold of the flank. Ventrolateral and paralumbar incisions are relatively easy to perform, have little blood loss during surgery, and are less likely to become infected after surgery. After exteriorizing the closest uterine horn (Figure 27-19*B*), a 6- to 8-cm incision is made along the greater curvature of the uterus (Figure 27-19C) and as close to the bifurcation of the uterine horns as possible. Not all piglets may be able to be removed from a single incision in the uterus. If necessary, a second incision can be performed on the other uterine horn.

Closure of the uterine incision is done with appropriate sized synthetic absorbable suture material placed in a Cushing or Utrecht pattern. The transversus abdominis muscle and peritoneum are closed together, and the external abdominal oblique and internal abdominal oblique muscles are closed together with synthetic absorbable suture material placed in simple continuous pattern. For closure of ventral midline or paramedian incisions, simple interrupted or interrupted cruciate sutures are placed in the linea alba or external rectus sheath using synthetic absorbable suture material. The subcutaneous tissues and skin are closed in a routine fashion. The sow should remain confined in a clean dry pen for a minimum of 14 days after surgery. Antibiotics should be continued for at least 3 to 5 days and nonsteroidal antiinflammatory drugs should be administered for postoperative analgesia.

The production of gnotobiotic or specific pathogen-free pigs is an accepted model for scientific research. The selected sow should be placed under general anesthesia and the surgery site aseptically prepared. Several methods have been described for obtaining gnotobiotic pigs including hysterectomy, closed hysterotomy (using a sterile chamber attached to the side of the sow through which surgery is performed), and open hysterotomy with germicidal trap. All methods are expected to have a baby pig mortality rate of less than 15%. When a hysterectomy technique is selected, baby pig survival is better when the surgery is performed with the sow under general anesthesia rather than euthanasia of the sow before hysterectomy.

Uterine Prolapse

Prolapse of the uterus is occasionally seen in sows during or up to several days after parturition. Excessive straining (because of fetal malpositioning, fetal-maternal disproportion, or trauma with swelling and inflammation in the birth canal) is thought to cause uterine prolapse. Hypocalcemia resulting in uterine inertia may also be a predisposing factor. Prolapse of the entire uterus has the greatest potential for a life-threatening crisis because of profuse hemorrhage, but partial prolapse also may occur. The sow must be stabilized before attempts to replace the uterus into its normal position. If hemorrhage, hypovolemia, or shock is present, the sow should be placed into a warm environment, an IV catheter placed into an auricular vein, and intravenous fluids administered. Intravenous fluids may contain dextrose and calcium for metabolic support. For replacement of the prolapse, the sow may be placed on an inclined floor or platform



Figure 27-19 *A*, Sow in lateral recumbency being prepared for a cesarean section. *B*, One uterine horn is exteriorized. *C*, Longitudinal uterine incision.

in sternal recumbency with the hindquarters elevated. Lumbosacral epidural anesthesia, sedation, or general anesthesia may be required to eliminate struggling, straining, and agitation of the sow.

The prolapsed uterus is thoroughly cleaned with physiologic warm saline and assessed for the presence of lacerations and necrosis. Small lacerations may be cleaned, superficially debrided, and sutured closed. Hemorrhage may be stopped by ligating affected vessels or by performing en bloc tissue imbrication. Sutures may be placed over stents to increase the region of pressure to control hemorrhage. Hydroscopic agents may be applied to the uterus to assist in reducing edema. The uterus is wrapped in a towel and gentle pressure applied, starting from the tip of the uterine horn and working toward the body of the uterus. After approximately 15 minutes, the edema should be sufficiently reduced to allow manipulation of the uterine horns. Each horn should be inverted, starting with the tip and gradually reduced until the uterine body has been reached. The extensive edema and soft tissue swelling of the pelvic canal often impede progress. When this occurs, a left paralumbar fossa laparotomy is indicated. After appropriate preparation of the surgical site, a 10-cm, vertically oriented incision is made in the middle of the left paralumbar fossae. The clinician's left arm is passed through the peritoneal cavity and into the everted uterus. One of the uterine horns is grasped and pulled back into the peritoneal cavity. The clinician's right arm or an assistant helps by applying gentle pressure on the everted horn from the outside.

After the uterus has been repositioned, the entire uterus should be examined, and all remaining fetuses should be removed vaginally or by cesarean section depending on the size of the fetuses and the condition of the tissues. The laparotomy incision is closed in three layers (transversus abdominis muscle and peritoneum, internal and external abdominal oblique muscles, and skin). Antimicrobial and antiinflammatory medications are desirable, but strict attention should be paid to drug residues in the meat before slaughter as the sow is likely to be culled after recovery. Finally, a Buhner suture should be placed around the vulva to prevent recurrence of the prolapse. The Buhner suture (6.4-mm-wide sterile cotton tape) is deeply placed at the junction of the labia and skin of the perineum to re-create the function of the vestibular sphincter muscle. The Buhner suture may be removed in 7 to 10 days with minimal risk of prolapse. Oxytocin (20 units) is routinely administered to facilitate contraction and involution of the uterus and cervix. Sows should survive partial prolapse of the uterus (greater than 75% survival rate), but complete prolapse carries a guarded prognosis (less than 50% survival rate).

Amputation of the uterus is indicated when excessive bleeding, extensive laceration, trauma, or necrosis of a uterine prolapse is observed. Before amputation, the uterus should be closely inspected to ensure the bladder or small intestine is not entrapped within the prolapsed tissues. Hypovolemic or hemorrhagic shock may be present and should be addressed during the course of treatment. If the uterus is swollen, it should be elevated above the pig to encourage drainage of venous congestion. Towels can be placed around the uterus so that pressure may be applied without further trauma to the wall of the uterus. Hydroscopic agents may be used to help resolve edema of the uterine tissues. After venous congestion has been reduced, amputation is more easily performed. Transfixation ligatures are placed around the circumference of the uterus. Heavy suture material (0.5-cm sterile cotton tape or umbilical tape) is used because the thickness of the uterus requires extreme tension to completely occlude the uterine arteries. Stay sutures or cross pins (with 15-cm, 18-gauge needles) are placed in the vital uterus and the prolapsed portion amputated. Then any bleeders are ligated before the remaining tissues are released and placed back into the pelvic canal. A Buhner suture or purse-string suture should be placed into the labia at the level of the vestibular sphincter to prevent prolapse of the remaining tissues. Affected sows are salvaged as soon as possible or after weaning of the litter.



Figure 27-20 Mastitis-associated mass in a sow. (Courtesy of Dr. Mary Smith.)

Mastectomy

Mastitis caused by *Actinomyces suis* may cause formation of abscesses, granulomas, and mammary fistulas. The swellings may become large and problematic for the sow (Figure 27-20). Surgical removal of the mammae is indicated for the sow's return to production soundness. Sows with at least 12 intact mammary glands that are not in the first week or last 4 weeks of gestation are suitable candidates for surgery. In pet pigs, mammary adenocarcinoma has been diagnosed. These tumors are found on routine health examination, including palpation of the mammary tissue. Tissue biopsy confirms diagnosis. Treatment for mammary neoplasia may be requested for research, rescue, or pet pigs. Evaluation for metastasis is recommended before mastectomy in cases of mammary neoplasia. Partial and complete mastectomy can be performed in pigs.

The sow is placed under general anesthesia, and the affected mammary gland is prepared for aseptic surgery. An elliptical incision is made approximately 1 cm from the base of the swelling around the mammary gland so enough tissue remains to allow closure of the tissues with minimal tension. A combination of sharp and blunt dissection is used to extirpate the gland and affected tissues. The cranial superficial epigastric vein should not be compromised, but hemostasis is essential. The subcutaneous tissue and skin are closed. Administration of perioperative antibiotics as well as nonsteroidal antiinflammatory drugs is indicated.

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