Surgery of the Gastrointestinal Tract in Camelids–Part 1

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South American camelids (llamas, alpacas) may represent a significant financial investment for the owner, but they are viewed most commonly as pets, companions, or valued friends. Veterinarians should be aware of potential life-threatening lesions associated with the acute abdomen (colic). Camelids demonstrate clinical signs of abdominal pain similar to those seen in true-ruminants (depression, recumbency, abnormal posture) and horses (kicking at the abdomen, rolling). Clinicians working with camelids must become familiar with the normal activity, anatomy, physiology, and diseases common to these interesting patients.

Gastrointestinal anatomy

The esophagus enters the first forestomach compartment (C1) where digesta is fermented, eructated, re-swallowed, passed through the second compartment (C2), third compartment (C3), and pylorus into the duodenum. C1 and C2 function as fermentation chambers and absorb water and various nutrients. C1 motility waves travel from caudal to cranial (two to four per minute). The proximal 80% of C3 absorbs water and nutrients; the distal 20% of C3 is acid secretory and performs gastric digestion. The pH changes from 6.5 to 7.0 in C1, C2, and proximal C3 to 2.0 to 3.0 in the distal C3. The duodenum continues as the jejunum, and then the ileum. The ileum enters the large intestine at the cecocolic junction. The cecum is small and the proximal loop of the spiral colon (ascending colon) is long and larger in diameter than the spiral colon. The spiral colon exits into the transverse colon, descending colon, rectum, and anus.

Historical information

Although young camelids (< six months old) demonstrate clinical signs of acute abdominal pain (kicking at the abdomen, rolling, thrashing), these signs are less commonly observed in mature animals. Mature camelids demonstrate abdominal pain as restlessness, lying down and getting up frequently, vocalizing, grinding teeth, straining to urinate or defecate, flagging the tail, lying their head and neck flat against the ground or down across their back, and lying in an abnormal cush position (sternal recumbency). Changes in diet, defecation, urination, and recent activity (transportation, showing, weaning) are critical pieces of information.

Physical examination

The physical examination should be complete and thorough. Patience is the key. The clinician must differentiate abdominal diseases from those of neurologic or musculoskeletal origin. Physical examination variables in normal adult camelids include: temperature 99.5° to 102°F (37.5° to 38.8°C), heart rate 60 to 80 beats per minute, respiratory rate 10 to 30 breaths per minute, and rumination waves 2 to 4 per minute. Abdominal distention may be evaluated by palpation, simultaneous auscultation/percussion/succussion, and orogastric intubation. The animal's body condition should be evaluated for evidence of chronicity. Digital rectal examination should be done to determine if feces are present in the rectum. Rectal examination must be performed carefully. Rectal tears have been induced in camelids. The decision to perform rectal palpation may be based on the animal's size and temperament, the palpator's experience, and the expected benefit. I instill 40 mL lubricant and 20 mL 2% lidocaine into the lumen of the rectum and liberally lubricate the rectal sleeve. An epidural may be used to aid examination of anxious patients.

Laboratory data

Selection of laboratory tests is based on history and the results of physical examination. Our "colic work-up" includes a complete blood count (CBC) with differential, fibrinogen, and serum electrolytes, glucose, creatinine, BUN, SDH, GGT, and CPK. Unlike cattle, camelids do not consistently suffer hypochloremic metabolic alkalosis with intestinal obstruction. This is probably because all three forestomachs are absorptive. However, hypokalemia is commonly found.

Ancillary diagnostic tests

Ancillary diagnostic tests are chosen based on history, physical examination findings, and initial laboratory data. The common tests performed include C1 fluid analysis, abdominal ultrasound and radiographs, peritoneal fluid analysis, urinalysis, and fecal examination/flotation/occult blood analysis. Other available procedures include laparoscopy, endoscopy, and positive contrast urethrography. The urinary bladder in males cannot be routinely catheterized because of the presence of the urethral recess at the level of the ischial arch.

Indications for surgery and differential diagnoses (see Table 1)

Continuous and intractable pain is an indication for exploratory surgery. However, in my experience, C3 ulcers in crias may be exceptionally painful for up to 48 hours after initiating treatment. Persistent, low-grade discomfort despite supportive therapy is an indication for abdominal exploratory. Temperature, heart rate, or respiratory rate have not been reliable indicators of surgical lesions. Abnormal rectal palpation findings are an indication for exploratory surgery. Failure to pass feces for > 24 hours is suggestive of intestinal obstruction. Failure to urinate for > six to eight hours is suggestive of urinary tract obstruction. Ultrasound identification of intestinal or urinary bladder distention is suggestive of intestinal or urethral obstruction, respectively. Exploratory surgery should not be used as a "last resort" to establish a diagnosis. Exploratory celiotomy can be done safely and efficiently when performed early in the progression of the disease. Laparotomy performed as an emergency or in a deteriorating patient is more likely to result in complications or death.

Surgical approach

Unlike cattle, ventral midline celiotomy with the patient under general anesthesia is the approach of choice for exploratory laparotomy. Paralumbar fossa laparotomy may be useful for nephrectomy, ureteral manipulation, C1 or C3 enterotomy, or unilateral ovariectomy. Exploratory celiotomy may be performed after sedation and regional anesthesia, but this procedure is highly discouraged because of the potential for contamination of the abdomen and discomfort to the patient caused by visceral manipulation.

Surgical diagnosis and treatment

The most common reason for abdominal surgery in our practice is to perform cesarian section either because of uterine torsion with poor cervical dilation or severe fetal malposition. Intestinal obstruction is a common cause of surgical gastrointestinal lesions. We have treated digesta impaction of the proximal loop of the spiral colon, enterolith obstruction of the spiral colon, extramural obstruction of the descending colon caused by an umbilical abscess, and postoperative obstructive adhesions with small intestinal strangulation. Impaction of the proximal loop of the spiral colon may be treated by instillation of saline into the mass, massage of the impaction, and administration of IV fluids for 48 hours. Enteroliths may be removed via enterotomy. Compromised bowel (strangulation, intussusception) may be treated by resection and end-to-end anastomosis. Umbilical (and rarely inguinal) hernias are occasionally diagnosed in young camelids, but intestinal incarceration or strangulation is uncommon. We perform open herniorrhaphy with appositional closure of the abdominal wall in all patients to ensure that infected umbilical remnants do not remain in the abdomen. Urethral obstruction is an uncommon lesion in our practice, but has been seen more commonly in other geographic regions. Closure of the linea alba should be done using an appositional pattern. I prefer a cruciate suture pattern with No. 1 or No. 2 PDS, Vicryl®, or Maxon®. Simple continuous suture patterns are acceptable, but the incision should be divided into three segments with each segment closed with a separate simple continuous closure. The skin of the ventral midline in camelids is thin and pliable. Therefore, I routinely place a subcuticular suture pattern (No. 2-0 Vicryl® or Monocryl®) and do not use skin sutures. An abdominal bandage maintained for three days after surgery (changed daily) may markedly reduce postoperative incisional swelling.

Postoperative management

Camelids appear to be fairly tolerant of intestinal surgery when performed early in the progression of the disease. Ileus has not been a limiting factor in the outcome of our cases. However, ileus is a prominent feature with transmural enteritis.

Table 1. Differential diagnoses for the acute abdomen of camelids.

Surgical lesions	Medical lesions
Gastrointestinal	
perforating C3 ulcer	C1 acidosis (grain overload, C1 atony)
enterolith/fecalith/trichobezoar	C3 ulcers (intestinal/colonic ulcers)
intussusception	Enteritis (Clostridial, *E. coli*
proximal loop of spiral colon impaction	Peritonitis
complicated umbilical / inguinal hernia	Pancreatitis, hepatitis
intestinal volvulus, internal hernia	Megaesophagus
Urinary	
urolith, ruptured bladder	Cystitis, pyelonephritis
Reproductive	
uterine torsion, dystocia	Metritis

Complications of disease or treatment

Incisional infection or hernia appear to be uncommon complications of celiotomy. I routinely place crias on sucralfate (1 to 3 g, po, Q8h) as a prophylaxis for C3 ulcers. H2 blockers are ineffective in camelids; therefore, omeprazole (0.4 mg/kg, IV, Q6 to 8h) may be administered to decrease acid secretion in C3.

Overview

The decision to perform exploratory celiotomy can be frustrating. In general, medical diseases affecting the abdomen are far more common than surgical lesions. However, diagnosis of a "medical" lesion by exploratory celiotomy may be an acceptable procedure when a definitive diagnosis cannot be made based on historical, physical examination findings, laboratory data, and clinical observation. Diagnosis of a "surgical" lesion by the pathologist is undesirable!

Anesthesia and Surgical Approach for the Abdomen

Anesthesia

The minimum database required for anesthesia is the weight, packed cell volume, and total protein. In more severely compromised patients, a full biochemistry panel is required to determine electrolyte abnormalities. Exploratory laparotomy may be performed with the patient sedated and a regional anesthesia using lidocaine HCl 2%. Camelids are less accepting of this procedure compared with cattle, and therefore should be positioned and restrained in lateral recumbency for flank laparotomy. The authors perform exploratory laparotomy under sedation and local anesthesia when economic constraints or patient medical status creates a greater risk for general anesthesia.

Exploratory laparotomy may be more easily performed after induction of general anesthesia. A cuffed endotracheal tube is placed using a stylette and long laryngoscope. Anesthesia is maintained using isoflurane and a circle rebreathing system. Problems during anesthesia include excessively deep anesthesia, inadequate ventilation, low mean arterial pressures, regurgitation, hypothermia, hypoproteinemia, and post-extubation nasal edema. The ideal anesthesia depth includes the absence of limb movements and the presence of a blink reflex. The absence of this reflex is interpreted to mean the depth of anesthesia is excessive. Positive pressure mechanical ventilation is often required. Hypotension is often encountered and treated with a dopamine constant-rate infusion (CRI).

A heated water pad is used to maintain body temperature intraoperatively. At the completion of surgery, the cuffed endotracheal tube is removed fully inflated when the camelid begins chewing. Camelids tend to develop some degree of nasal edema during general anesthesia, and more severe cases may involve the entire head. Careful monitoring for nasal airflow post-extubation and intervening early using nasopharyngeal tubes and ephedrine applied topically to the nasal passages to facilitate nasal airflow likely improved anesthetic survival. Improved anesthetic recoveries have been observed recently.[4,28] By minimizing the anesthetic depth, extubation occurred much earlier in the present study and post-extubation oxygen was not required. Differences between inhalant anesthetics may account for improved survival; hepatic necrosis associated with halothane anesthesia has been reported in one alpaca.[12]

Surgical approaches and techniques

Camelids should be administered perioperative intravenous fluids, antibiotics, nonsteroidal anti-inflammatories, and possibly a gastric acid production inhibitor.[1,3,4,8,23,26,27,28] The anticipated lesion location determined the approach. Forestomach lesions were approached by the left paralumbar in cases of C1 involvement,[28] and either the right paralumbar or ventral midline for C2 and/or C3 lesions; approaches to small intestinal lesions included ventral midline[4] and right paralumbar[4,28] and; approaches to large intestinal lesions included ventral midline[2,3,4,8,27] and right paralumbar. The proximal duodenum is best approached using a right paracostal approach[28] rather than a ventral midline approach.[4] A ventral midline approach was used to perform a splenectomy.[26]

The area associated with the intended approach is clipped and surgically prepared. Surgical techniques that are commonly used in other species are adapted for use in camelids, including resection, anastomosis, and enterotomy. In the event of gross abdominal contamination, the abdomen should be lavaged using copious volumes of warm isotonic fluids.[2,3,8,26,27,28]

Gastrointestinal Anatomy and Physiology

Camelids have an unique gastrointestinal system that is similar to but distinctly different compared to traditional four-chambered ruminants.[9] Termed "pseudo" ruminants, adult camelids rely on forestomach protozoal and bacterial fermentation to break down plant material to digest nutrients, can eructate and ruminate, and have a three-chambered stomach, partitioned into anatomically separate and functionally distinct areas named C1, C2, and C3. All three compartments have the ability for secretion and absorption. C1 is largest of the three compartments and is loosely considered the equivalent of the rumen in the cow. Ideally the normal pH of C1 fluctuates between 6.5 and 7.5. Like the rumen in the ruminant, C1 can absorb water and volatile fatty acids. However, prominent papilla are lacking as compared to the ruminant. C1 contents do not stratify in the normal healthy individual, and there are rows of saccules along the caudal ventral aspect. These saccules are believed to aid in microfermentation and secrete bicarbonate directly into the C1 lumen. The role of C2 is believed to mimic the reticulum and omasum in ruminants. C3 is considered the "true" stomach since it functions similarly to monogastrics and the abomasum in ruminants by secreting H and Cl. Anatomically, C3 most closely resembles the equine stomach, since the proximal 80% is non-acid secreting and the distal 20% is acid secreting. Furthermore, the junction between these two regions is the typical location for ulcers to develop, especially along the lesser curvature. Like neonatal ruminants, the forestomachs in the neonate (cria) initially most resembles monogastrics while the cria is primarily consuming a milk-based diet. Over several months, the forestomachs gradually increase in size and change in function to more closely resemble the adult ruminant – the fermentation process is continuous and without the forestomachs truly ever emptying.

After the forestomachs, other unique characteristics of the camelid gastrointestinal tract are present. A prominent duodenal ampulla is located immediately aborad to the pylorus. Unlike ruminants, camelids do not have a gall bladder. Though camelids have a spiral colon, the proximal loop is longer when compared to ruminants. The omentum in ruminants is very prominent, whereas in camelids the omentum is much less robust and prominent. Furthermore, the omentum attaches to C1 along its transverse pillar and does not attach to the dorsal body wall.[4,9]

Clinical signs and physical examination

As with other species, signs of colic may arise from disorders from other organ systems.[9] Causes of abdominal pain include ulceration of C3, enteritis, intestinal wall perforation, intussusception, volvulus of the mesentery, meconium impaction, impaction of the cecum or ascending colon, mesenteric or umbilical abscesses, toxicities, and urinary rupture.[2,4,8,9,17,23,25] Colic signs in camelids include vocalizing (groaning), bruxism, getting up and down, refusing to stand, rolling, kicking or looking at the belly, peculiar stance, kyphosis, depression, pyrexia, anorexia, tachycardia, tachypnea, tenesmus, decreased fecal output, tense or painful abdomen, distended abdomen, pollakiuria, C1 atony, and regurgitation. Signs of colic in camelids tend to be more vague (anorexia, tachycardia, and tachypnea) and less frequent, more closely resembling cattle rather than horses; therefore, the camelid patient should be closely observed over a 15- to 60-minute period.

Forestomach lesions tended to have more vague clinical signs such as depression and anorexia, presumably because of the greater capacity of the forestomachs to sequester fluid.[4] In comparison, the severity of clinical signs associated with small intestinal obstruction is associated with their anatomical location,[28] and includes abdominal distention, abdominal pain, recumbency, pyrexia, anorexia, tachycardia, tachypnea, decreased fecal output, dehydration, and regurgitation,[4,28] and are rarely violent. In the authors' experience, the severity of clinical signs associated with lesions affecting the large intestine tend to be more subtle compared to the small intestine.

In crias, abdominal masses may be felt during deep abdominal palpation. Though rectal palpation is possible in adult camelids, the usefulness of this procedure is likely limited to lesions affecting the distal gastrointestinal tract and spleen.[26]

Since exploratory laparotomy tends to be well tolerated by camelids, early surgical intervention should be performed in a timely manner when the cause of abdominal pain is in doubt,[2,18,23] and likely improves outcome.[4,8,26] An exploratory laparotomy or laparoscopy should be considered an extension of the physical examination. The normal laparoscopic anatomy of the llama has been described,[32] and may provide a minimally invasive alternative to exploratory laparotomy for the acute abdomen of unknown etiology in selected cases when the abdomen is not markedly distended.

Ancillary diagnostic testing

Serum biochemistry–Unlike ruminants, camelids have a greater capacity to absorb water and chloride through their forestomach wall, and may be less prone in the short term for significant gastric fluid sequestration in the forestomachs causing dehydration and hypochloremic metabolic alkalosis. Gastrointestinal disorders typically cause a metabolic alkalosis in adult ruminants, and a metabolic acidosis in pre-ruminating ruminants.[21] Gastrointestinal disorders in camelids causing a metabolic alkalosis have been inconsistent,[4,28] and do not necessarily reflect the duration of clinical signs.[28]

Decreased potassium concentrations are consistent in proximal and distal obstructive lesions. Decreased serum chloride concentrations are inconsistent in proximal obstructions compared to distal obstructions and ruptured viscus. Chloride values returned to normal within 24 to 48 hours postoperatively. Though decreased serum glucose levels can differentiate between abomasal and proximal duodenal obstructions in adult ruminants, hyperglycemia was frequently observed by others and the authors in camelids presenting with proximal gastrointestinal lesions amenable to surgical intervention.[10]

C1 chloride concentration–C1 chloride analysis may help determine whether a proximal small intestinal obstruction is the underlying cause of forestomach distention. In ruminants, elevated rumen chloride levels (>30 mEq/L) suggest abomasal and proximal duodenal outflow obstructions since the chloride secreted by the abomasum becomes sequestered in the forestomachs.[22] Elevated C1 chloride values (> 40 mEq/L) have been reported previously in proximal obstructions. Normal C1 chloride values (< 40 mEq/L) were observed in distal obstructions.[2,4,28]

Peritoneal fluid analysis–Abdominocentesis is recommended in all camelids presenting with gastrointestinal disease, and may help differentiate between medical and surgical conditions.[11,13,20] Abdominocentesis may be contraindicated in camelids with distended abdomens;[8,23] however, the safety margin may be improved when combined with transabdominal ultrasonography. Furthermore, transabdominal guided abdominocentesis yielded consistently high-quality samples compared to blind, ventral, or paramedian approaches.[6] Using a 5 Mhz linear transducer, an ultrasonographic examination reveals the ideal location for sample collection: typically either lateral or medial to C3. This technique has been improved by the original authors and was recently described in the literature,[7] and provided sufficient quantities of peritoneal fluid safely without the benefit of ultrasonography. The camelid is placed in a restraint chute and sedated (butorphanol tartrate 0.04 mg/kg). The location for abdominocentesis is approximately 1 cm dorsal and 3 cm caudal to the costochondral junction of the last rib in alpacas, or 2 cm dorsal and 5 cm caudal to the costochondral junction of the last rib in llamas.[7] The adjacent area is shaved and surgically prepared, and local anesthetic using 2% lidocaine hydrochloride is infused subcutaneously and intramuscularly at the intended location for abdominocentesis. A stab incision is made through the skin, and a sterile teat cannula is advanced through the muscle and peritoneum. By gravity flow, between 1 to 10 mL of peritoneal fluid may be quickly collected using a potassium-EDTA tube for cytology and a lithium heparin tube for biochemical analyses. The teat cannula is then withdrawn, and the skin incision left to heal by second intention.

The normal reference values for peritoneal fluid have been determined.[7] In normal camelids, the peritoneal fluid typically contains low cell count and protein concentrations, and similar electrolyte levels when compared to venous blood; however, some clinically normal camelids have higher values. Therefore, any result at the higher end of the normal range must be interpreted cautiously. A large amount of cellular or proteinaceous fluid,[2,7,8,26] or a high cell count (> 3000 nucleated cells/µL) and protein concentration (> 2.5 g/dL) likely indicates the presence of gastrointestinal disease.

Abdominal radiography

The normal radiographic appearance of the neonatal gastrointestinal tract with survey and contrast radiography has been described.[30] Administering barium (11 mL/kg) by orogastric tube was of diagnostic value in crias either consuming a predominantly liquid diet or fasted 12 hours: the transit of barium from C1 into C3 was not delayed. Lateral views best delineated the morphology of C1, C2, and C3.[30] The transit time of barium to the ascending colon was a mean of 25 hours with a range of 16 to 36 hours. The timing sequence should be every 20 minutes for the first two hours, hourly for 12 hours, and every six hours for 36 hours after the spiral colon is filled with barium. Furthermore, crias must be allowed to nurse through the series to prevent hypoglycemia. A contrast study may be a useful aid in a cria that presents with either an acute abdomen or has not defecated.

In a three-month-old llama, a large, poorly circumscribed, opaque, soft tissue mass with a gas fluid interface located in the caudal ventral abdomen and extending ventrally to the umbilicus was visualized on standing lateral abdominal radiographs, consistent with a radiographic diagnosis of an abscess-causing gastrointestinal obstruction.[23] A marked reduction in the size of the abscess was observed on repeat radiographs performed 12 hours postoperatively.

Gastric distention and/or visualization of the obstruction have been observed in survey abdominal radiographs in juvenile camelids that presented with upper gastrointestinal obstructions.[28]

Transabdominal ultrasonography

The transabdominal appearance of the gastrointestinal viscera in healthy camelids has been described using a 5MHz linear transducer.[5] The left ventral abdomen contained C1; the saccules of C1 appeared hyperechoic. The right ventral abdomen contained C3, and lacked fluid and compartment wall motility. All other viscera appeared as tubular structures, with fluid and compartment wall motility. The normal wall thickness was between 2 and 4 mm; however, the caudal portion of C3 occasionally had a thicker wall. Little free abdominal fluid is observed in normal camelids. The small intestines are best viewed from either the right paralumbar fossa or paramedian areas, and demonstrated progressive motility with transient segments of fluid.

Transabdominal ultrasound has been used clinically as an aid to differentiate between medical and surgical gastrointestinal diseases, including but not limited to peritonitis, enteritis, strangulating obstructions,and intraluminal obstructions.

Peritonitis is associated with increased free abdominal fluid. Enteritis is associated with increased wall diameter, whereas focal thinning is associated with ulcerative gastroenteritis, which tends to occur along the caudal aspect of C3. Interpretation of focal thinning associated with C3 ulceration is difficult due to the variability between camelids in wall thickness of the caudal lateral portion of C3; however, higher resolution equipment may improve the sensitivity of this modality. A unique observation in camelids with intestinal obstruction or atony is the increased length and number of fluid-containing segments rather than distended lumens, a finding more typical in horses.[16] Transabdominal ultrasound has been a useful tool to identify abnormal bowel in camelids including duodenal trichophytobezoar obstruction, especially when the camelid is too small for rectal palpation.

Expectations

Timely surgical intervention in camelid colic cases early in the disease process likely contributes to improved survival, especially for small and large intestinal lesions. Forestomach lesions tend to have more vague clinical signs such as depression and anorexia. Transabdominal ultrasonography and abdominocentesis are useful ancillary tests in the work-up of acute abdominal disease in camelids. Radiographs may be useful in juvenile camelids with proximal gastrointestinal obstructions. The lower survival rate for small intestinal lesions compared to forestomach lesions is likely associated with the severity of clinical signs preoperatively. Small intestinal surgery has been prone to postoperative adhesion and stricture formation, and has been the primary reason for repeat celiotomy. The higher rate of survival for large intestinal lesions versus small is likely associated with the rectal examination findings. Unlike the small intestine, lesions affecting the large intestine tend to be palpable, therefore influencing the timing of surgical intervention. Gross abdominal contamination does not necessarily result in septic peritonitis, provided aggressive therapy is instituted, including meticulous material removal, lavage using copious volumes of warm isotonic fluids, and appropriate antimicrobial therapy.

Surgery of the Gastrointestinal Tract

Gastrointestinal diseases are reportedly considered the leading causes of camelid deaths.[4,14,15] There is increasing evidence that some of these deaths likely have surgically correctable lesions that are unresponsive to medical treatment alone.[3,4,8,18,23,29,31] As in other species, the success of gastrointestinal surgery is, in part, reliant upon early recognition and timely surgical intervention. The signs and severity of gastrointestinal disease in camelids tend to be vague and less frequent, unlike in other species such as equine. Furthermore, the opportunity and usefulness of rectal palpation is often limited by their relatively small size and lesion location. Transabdominal ultrasonography, combined with rectal examination and abdominocentesis, likely improves the early detection of surgical lesions.

Not surprisingly, the scientific literature has lagged behind the relatively rapid rise in camelid popularity. Individual case reports predominate the literature on the surgical management of gastrointestinal lesions in camelids; however, there are three reports that describe 41 acute gastrointestinal surgical cases. This paper will review the published literature on the management of camelid gastrointestinal surgery. The successful outcome of gastrointestinal surgery includes the preoperative, intraoperative, and postoperative time periods; therefore, the gastrointestinal surgical anatomy and physiology, clinical signs, clinical pathology, transabdominal ultrasonography, anesthesia, surgical approaches, surgical treatments of forestomach, small and large intestine, complications, and outcome will also be discussed.

Surgery of the Forestomach and Intestines

Surgery of the forestomachs

Specific forestomach surgical lesions include C1 trichophytobezoars, C3 gastric ulcers, and gastric puncture secondary to abdominal wall perforation. A C1 gastrotomy may be performed under local anesthetic for initial treatment and stabilization in selected proximal intestinal obstruction cases involving trichophytobezoars. Retropulsion and C3 gastrotomy were performed as an alternative to duodenotomy to relieve a trichophytobezoar obstruction from the proximal duodenum.

Surgery of the small intestines

Small intestinal surgical lesions include intraluminal obstruction, intestinal wall perforation, intussusception, torsion, epiploic foramen entrapment, adhesions from a previous surgery, and an umbilical abscess.

In one report, a three-month-old llama had a large umbilical abscess surgically drained and marsupialized under a general anesthetic; 3 liters of purulent exudate were removed from the abscess. Cultures yielded *Proteus* sp, *Steptococcus equisimilis*, and *Clostridium septicum*.[23] The llama recovered uneventfully.

Trichophytobezoars have caused complete obstructions of the proximal duodenum, 10 cm aboral to the pylorus, at the junction between the duodenal ampulla and ascending duodenum. Obstructions were relieved by either duodenotomy adjacent to the obstruction or retropulsion combined with C3 gastrotomy. Trichophytobezoars have also caused complete obstruction in the jejunum; however, postoperative complications adversely affected the outcome in both alpacas.

Jejunal enterotomy closure patterns have been evaluated in llamas. A full thickness, simple continuous suture pattern was oversewn by either a Cushing or Lembert pattern. Though there was no difference in bursting pressures, the Cushing pattern reduced luminal diameter less compared to the Lembert pattern, regardless of suture material used (polydioxanone or polyglactin 910) or size (2-0, 3-0, or 4-0). Though enterotomies closed using polydioxanone had higher bursting strengths compared to polyglactin, the mean bursting pressures of all techniques were considerably higher than expected and may not be clinically relevant. Since none of the sutures failed by breaking, the difference in bursting strength is likely associated with the differences between suture types tearing through the tissues. Based on this study, a suture size of 3-0 or 4-0 is recommended for enterotomy closures in llamas, especially when using polydioxanone.[24]

A side-to-side, hand-sewn anastomosis without resection was performed to treat an ileocecal intussusception;[4] however, postoperative complications occurred during recovery. An ileocecocolic intussusception, presumptively caused by an *Eimeria* spp infection in a four-week-old female llama, was successfully treated by intestinal resection and anastomosis.[8] The intussusception was non-reducible, and 80% of the ileum was removed along with the cecum, and the proximal ileum was anastomized with the ascending colon after reducing the lumen diameter of the ascending colon by a third. A hand-sewn anastomosis using 3-0 polycaprone 25 was performed in a single layer of three interrupted segments of a full thickness, simple continuous pattern starting at the antimesenteric border. The cria recovered uneventfully without complications.

Surgery of the Large Intestine

Large intestine surgical lesions include impactions,[31] torsion of the spiral colon,[2] adhesions from prior surgery,[4] diaphragmatic herniation,[3] and colon puncture secondary to abdominal wall perforation.[4] Impactions of the cecum or ascending colon are common.[31] The relative narrowing of the ascending colon presumably predisposes this section of the gastrointestinal tract to impactions.[31]

In a 14-year-old male alpaca, a ventral midline approach was used to exteriorize, then correct 720° torsion of the spiral colon.[2] The spiral colon appeared non-viable based on its appearance, lack of motility, and palpable blood flow; therefore, it was resected using a gastrointestinal anastomosis linear stapler device and hand suturing, and the proximal and distal segments of the ascending colon were anastomized. The anastomosis was hand sewn since the distal portion of the ascending colon was too small for the gastrointestinal linear stapler device. The alpaca recovered without complications.

A section of the proximal ascending colon was incarcerated through a 3-cm rent in the dorsal left section of the diaphragm in a seven-year-old castrated llama.[3] This hernia was presumptively a congenital defect in origin since it was located dorsally, and the edges of the rent were round and smooth. This llama had been placed in dorsal recumbency two months earlier during castration, which may have permitted a portion of the mesentery and ascending colon to become entrapped, and explains why clinical signs associated with the rent were not apparent prior to castration. The rent was enlarged to free the incarcerated bowel; unfortunately, the rent was not sufficiently accessible to be closed. The cecum and a portion of the ascending colon were resected and an ileocolic side-to-side anastomosis was performed using a gastrointestinal anastomosis staple instrument.[3] The llama recovered uneventfully from anesthesia and did well before the diaphragmatic hernia recurred.

Miscellaneous gastrointestinal surgeries

The surgical management of iatrogenic rectal tears has been reported.[27] Full-thickness tears were present in three of four llamas. Full-thickness tears proximal to the prepubic reflection (4 cm in llamas) may result in fecal contamination of the abdomen.[27] A transanal approach was used to surgically repair rectal tears located closer (6 to 9 cm) to the anus; whereas a caudal midline approach was required to surgically repair tears located further (15 to 20 cm) from the anus. A pubic symphysiotomy was required to facilitate access to the tear, located 15 cm from the anus. Complications were observed in the laparotomy approaches and were likely associated with the degree of fecal spillage into the abdomen.

A six-year-old female alpaca 280 days in gestation initially presented with a uterine torsion that was corrected under a general anesthetic by transabdominal manipulation.[26] An enlarged and caudally displaced spleen was observed during the physical examination, including rectal and transabdominal palpation, transabdominal ultrasound, and abdominocentesis. Despite correcting the uterine torsion (confirmed by rectal palpation), the alpaca's condition and abdominal discomfort continued to worsen, and a ventral midline exploratory laparotomy was performed. A 720° torsion of the spleen was revealed and corrected; however, the spleen was black, congested, and had a necrotic odor. The spleen was easily exteriorized, and a splenectomy was performed using a ligating, dividing, and stapling device. No post-operative complications were observed; the alpaca carried her cria to term, delivered a live cria, and later rebred.

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