Standing Diagnostic and Therapeutic Equine Abdominal Surgery

Sarah Graham, DVM[a,*], David Freeman, MVB, PhD[b]

KEYWORDS

• Standing • Abdomen • Colic • Urolith • Laparoscopy • Uterus • Rectum

KEY POINTS

- The widespread use of laparoscopy in equine surgery has increased interest in the standing approach to a wide range of procedures typically regarded as feasible only through a ventral midline incision.
- Although a commonly cited benefit of standing surgery relates to avoiding costs of general anesthesia and risks associated with it, some procedures and horses are not suitable candidates for standing abdominal procedures.
- Some procedures, such as nephrectomy, colostomy, and closure of the nephrosplenic space, are not only suitable for standing surgery but are performed more easily and more safely through this approach than with general anesthesia.

STANDING FLANK LAPAROTOMY

Indications

A surgical approach to the abdomen via flank laparotomy in the standing horse is a useful technique under specific conditions. Historically, the most common indications for a standing flank approach are ovariectomy in the mare and correction of uterine torsion. Other indications that have been described include abdominal exploration, biopsy procedures, nephrosplenic entrapment of the large colon, closure of the nephrosplenic space (NSS), colostomy procedure for treatment of a rectal tear, nephrectomy, and ureterotomy. The standing flank approach in a horse with acute onset colic or anything greater than mild colic pain is not recommended because of limited exposure of the gastrointestinal tract and increased probability that the horse will be unable to remain standing for the entire procedure. Left, right, or bilateral approaches are feasible, and choice of laterality depends on the suspected diagnosis and desired exposure.

[a] Large Animal Clinical Sciences, University of Florida, Gainesville, FL, USA; [b] Large Animal Clinical Sciences, College of Veterinary Medicine, University of Florida, Gainesville, FL, USA
* Corresponding author.
E-mail address: sarahgraham@ufl.edu

Vet Clin Equine 30 (2014) 143–168
http://dx.doi.org/10.1016/j.cveq.2013.11.010 **vetequine.theclinics.com**
0749-0739/14/$ – see front matter

Anatomy/Landmarks

The lateral wall of the abdomen is made up of the abdominal tunic (tunica flava abdominus), the external abdominal oblique muscle, the internal abdominal oblique muscle, the transverse abdominus muscle, transverse fascia, and peritoneum.[1] The paralumbar fossa in the horse is a triangular depression on the dorsolateral aspect of the abdomen. The boundaries of the fossa are the aponeurosis of the internal abdominal oblique muscle, the eighteenth rib, and the longissimus dorsi muscle. Surgical access to the abdomen though the paralumbar fossa is limited by its relatively small size (compared with cattle, which have a larger fossa and bigger space between the last rib and the tuber coxae).[2]

Patient Preparation

The horse is brought to the stocks area for surgery. The horse should be given a bath before surgery if it has a long and dirty hair coat. An intravenous (IV) catheter is placed in the jugular vein to allow rapid and easy access for administration of sedation or to allow administration of a continuous rate infusion (CRI). The stocks should be in a clean, quiet area with nonslip footing. The sides of the stocks should be removable in case the horse goes down. If possible, the sidebar that is on the side of the operator should be lowered to expose the entire flank region. A knowledgeable handler should be positioned at the head of the horse and should have access to the catheter and sedation. The flank region is clipped from the 15th rib to 10 cm caudal to the tuber coxae and from the fold of the flank to the dorsal midline. The tail is wrapped and secured so that it cannot be swished and contaminate the surgical site. A standard surgical preparation of the skin is performed. Local anesthesia is performed using sterile technique. An inverted L block may be performed; however, we find that local infiltration (superficially and deep) tends to provide more reliable anesthesia. Draping of the flank can be problematic, depending on the size of the horse and the configuration of the stocks. Generally, we place a large iodophor incise drape (Ioban, 3M) over the area of the intended incision. The iodophor drape provides a good surface for the adhesive backing on the large laparotomy drape, which is placed next. This large drape is passed over the dorsum of the horse and should cover the sidebar of the stocks. The closest vertical bar of the stocks can also be covered with a drape to prevent inadvertent contamination of the surgeon or assistant surgeon. We have found that with this draping technique, towel clamps are not generally required. If a towel clamp is needed to secure the drape, local infiltration of anesthetic should be performed before placement of the clamp.

Abdominal Exploration Through Standing Flank Approach

Exploration of the abdomen through a flank incision is performed largely through manual examination, because visibility is relatively poor. Exploration on the left side includes systematic palpation of the stomach, spleen, left kidney, nephrosplenic ligament, jejunum, left dorsal and ventral colons, mesenteric root, the pelvic flexure, small colon, rectum, uterus, bladder, and the left inguinal ring. For a right flank incision, palpation of the liver, duodenum, right kidney, jejunum, cecum, right dorsal and ventral colons, small colon, rectum, uterus, bladder, and the right inguinal ring should be performed. If the cecum is full of ingesta, exploration of the abdomen on the right side may be impossible.[2] Only a few structures may be safely brought to or exteriorized through the incision, and these include the jejunum, proximal ileum, left or right uterine horns, midsection of the small colon, pelvic flexure, and the apex of the cecum.

STANDING FLANK INCISION

A flank laparotomy is performed through a 12-cm to 15-cm vertical skin incision between the last rib and tuber coxae, below the tuber coxae at the dorsal border of the internal abdominal oblique muscle (Fig. 1). The incision should start 3 to 6 cm higher if the retroperitoneal space is to be opened. The external abdominal oblique muscle and fascia are incised sharply along the direction of the skin incision and the internal abdominal oblique is bluntly divided along its muscle fibers. In this way, a modified grid incision is made. The transversus abdominis muscle is divided bluntly along its muscle fibers, and the retroperitoneal space and peritoneal cavity are opened by blunt dissection, usually with the tips of Mayo scissors. It can be completely opened by digital separation of the tissues from dorsal to ventral. All layers of the incision can be opened as needed to allow insertion of the surgeon's hand, and the fibers of the internal abdominal oblique can be incised vertically for 2 to 3 cm for additional space.

The peritoneum and transversus abdominis muscle are closed as 1 layer with size 0 or 1 polyglactin 910 in a simple continuous pattern, and size 2 polyglactin 910 is used in a simple continuous pattern in the internal abdominal oblique muscle. The same suture material can be used in a simple continuous pattern to close the external abdominal oblique muscle, and the subcutaneous layer is closed in simple continuous fashion with size 2-0 polyglactin 910. Skin is closed with size 2-0 poliglecaprone 25 in simple continuous fashion or with a Ford interlocking pattern. The last 5 cm or so can be closed with 3 or 4 simple interrupted sutures, which can be removed as needed to facilitate drainage of a seroma or abscess, leaving the more dorsal suture line intact.

Flank incisions in horses are more prone to forming seromas or becoming infected than most incisions in this species, although this is not common enough to discourage use of this abdominal approach. This complication can probably be attributed to the

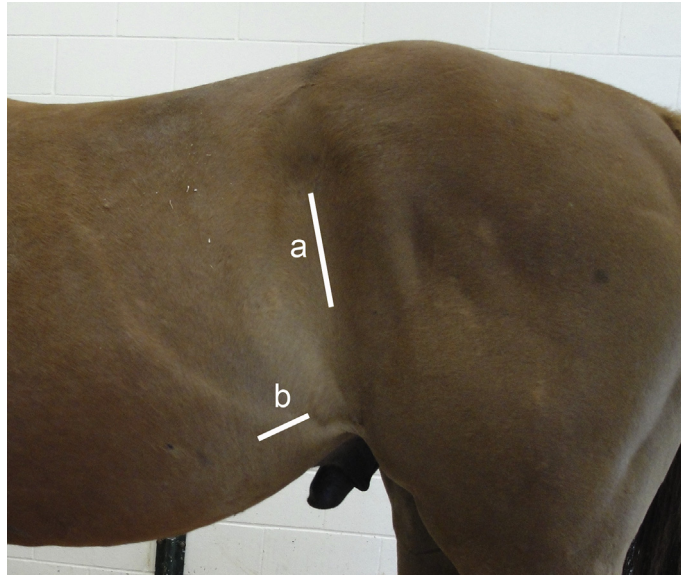

Fig. 1. Placement of incision for a typical flank laparotomy (a). The lower incision (b) is the site for placement of the stoma for a loop colostomy created with the double-incision technique.

muscle and tissue trauma associated with the incision and the depth of layers penetrated to enter the abdomen. In addition, the tight space in the horse's flank can contribute to the incisional trauma as the surgeon's hand and arm are repeatedly inserted and withdrawn.

STANDING FLANK LAPAROSCOPY

Indications

Laparoscopic evaluation of the abdomen in a standing horse is less commonly used than exploratory celiotomy under general anesthesia. The requirements for successful evaluation of a horse with colic signs are similar to those of standing laparotomy, the most important factor is that the horse is comfortable and healthy enough to remain standing for the procedure. Additionally, horses with acute onset or severe colic signs are poor candidates for laparoscopic exploration, because of increased likelihood of distended viscera, and therefore have an increased risk of iatrogenic injury. Conversely, some horses may be better suited for standing laparoscopic exploration, because of weakness from chronic disease, old age, or concomitant lameness, because the risks of anesthesia and recovery are mitigated. In some cases, laparoscopic evaluation may be used to confirm a diagnosis that indicates immediate surgical intervention (under general anesthesia) or euthanasia. However, the benefits of having a definitive diagnosis must be weighed against the cost of lost time and increased expense to the owner. Laparoscopic evaluation of the abdomen is therefore most commonly used for cases with chronic or recurrent colic after routine diagnostics have failed to result in a diagnosis. It can also be used to diagnose periparturient problems, such as postfoaling trauma to the uterus[3] or small colon,[4] hemorrhage into the broad ligament,[5] splenic trauma,[6] neoplasia, diaphragmatic hernia, abdominal abscesses,[5] and intestinal rupture.[5]

Patient Preparation

Whenever reasonable, horses are held off feed for 24 hours before surgery to reduce the bulk of ingesta within the large colon. Although not universally advocated, withholding feed can facilitate exploration of the abdomen. As in standing laparotomy, the horse is first restrained in standing stocks and the tail wrapped and secured. The preferred sedation protocol is generally initiated at this time. Left and right flank regions should be clipped, aseptically prepared, and draped to expose the paralumbar fossae. It is recommended that introduction of instruments is first performed on the left side of the horse to avoid unintended puncture of the cecum.[7] Use of disposable, guarded trocar and cannula[8] or use of an optical trocar (Covidian Medical) may also reduce the risk of organ penetration.

The laparoscope is introduced into the abdomen at a point that is halfway between the tuber coxae and the last rib, just dorsal to the crus of the internal abdominal oblique muscle. That site is blocked using infiltration of local anesthetic. A 1.5-cm-long skin incision is made with a number 10 scalpel blade. The laparoscopic trocar and cannula are then introduced through the muscle and into the abdomen by aiming toward the opposite coxofemoral joint. The trocar is removed and replaced with the laparoscope once a loss of resistance is perceived. Confirmation that the abdominal cavity has been entered is important before beginning insufflation; the abdomen is insufflated to a pressure of 10 to 15 mm Hg. Alternatively, some surgeons elect to insufflate the abdomen before introduction of the laparoscope to further reduce the potential for inadvertent puncture of bowel. A long teat cannula or Veress needle is inserted through the musculature and into the peritoneal cavity. Kolata and colleagues[9] described several ways to ensure that the Veress needle or cannula has

penetrated the peritoneum: (1) a small hissing noise may be heard on penetration of the abdomen; (2) if the insufflation tubing is connected to the needle on penetration, a negative pressure may read on the insufflator; (3) aspirate from the needle to ensure no intestinal contents or blood from splenic puncture before injecting saline (no resistance should be appreciated on injection, and no saline recovered after injection); (4) when insufflating, the pressure within the abdomen should increase slowly and should not increase higher than 5 to 8 mm Hg within the first liter; (5) observation and ballottement of the abdominal cavity as it is filling may confirm insufflation. If asymmetric swelling, crepitus, or emphysema is noted near the cannula, or the horse becomes uncomfortable soon after insufflation has started, then the cannula is not within the abdomen. Alternatively, if a hand-assisted procedure is to be performed, the flank incision is made first (as described earlier). The surgeon's hand is then introduced into the abdomen and used to protect the viscera as the trocar and cannula are inserted into the abdomen.

The laparoscopic anatomy of the abdomen in the standing horse has been well described.[7] Evaluation of the left side is performed first, followed by the right. The laparoscope is passed up the left body wall, dorsal to the spleen to reach the left cranial abdomen. From the dorsal aspect, the diaphragm, left lobe of the liver, greater curvature and fundus of the stomach, gastrophrenic, phrenicosplenic, gastrosplenic, and nephrosplenic ligaments, the left kidney, and the spleen can be seen.[7] Ventrally, the spleen, stomach, and the left lateral lobe of the liver can be seen. The jejunum, small colon, left dorsal colon and pelvic flexure can be observed by directing the laparoscope more caudally.[7] The urinary bladder, left ovary and uterine horn or mesorchium and ductus deferens (depending on the sex of the patient) can be identified in the left pelvic region.[7] The laparoscope must be removed and inserted on the right side for evaluation of that portion of the abdomen. On the right side, left lateral, right lateral, caudate and quadrate lobes of the liver, pylorus, diaphragmatic flexure of the colons, hepatoduodenal and hepatorenal ligaments, descending and ascending duodenum, epiploic foramen, right lobe of the pancreas, right dorsal colon, transverse colon, base of the cecum, jejunum, small colon, rectum, right ovary and uterine horn or mesorchium and ductus deferens, and urinary bladder can be observed.[7] Other structures of lesser clinical importance may also be identified.[7]

BIOPSY TECHNIQUES

Intestinal biopsy may be indicated in cases of chronic weight loss or colic in order to diagnose neoplasia, eosinophilic or lymphocytic-plasmocytic enteritis, and primarily in Europe, grass sickness. If the affected bowel is exteriorizable, such as jejunum or pelvic flexure, then standard surgical biopsy techniques may be used. Often, the affected bowel cannot be accessed or exteriorized through a standard flank incision, and therefore, the surgeon must consider midline celiotomy or standing laparoscopic techniques. A full-thickness laparoscopic biopsy technique used in standing, experimental horses has been described.[10] This technique, although elegant, is technically challenging and requires good intracorporeal suturing skills.[10] Alternatively, another technique using an endoscopic linear stapler for obtaining small intestinal biopsies has been developed.[11] Use of either of these techniques in clinical cases has not yet been reported.

RECTAL TEARS

Rectal tears are usually caused by palpation per rectum. Noniatrogenic tears have been reported but are extremely rare.[12] Once a rectal tear is suspected, it should

be evaluated for severity, the owner informed about the nature of the problem, first aid given if possible,[13] and the horse should then be referred to a veterinary hospital. Rectal tears are graded by severity of the tear and associated risk of peritonitis from I to IV.[13] Grade I (torn mucosa) and grade II (torn muscle layers) have the best prognosis, and grade III (torn mucosa and muscle layers) and grade IV (full thickness) have the poorest prognosis and require the most aggressive treatment.[13] Most tears are dorsolateral and a forearm's length from the anus, and the true extent and depth can be assessed by careful digital palpation after epidural anesthesia.[13–15]

All affected horses receive flunixin meglumine (1.1 mg/kg every 24 hours IV) and broad-spectrum antibiotics, such as sodium or potassium penicillin (22,000 IU/kg of body weight every 6 hours IV), gentamicin (6.6 mg/kg every 24 hours IV), and metronidazole (15 mg/kg every 6 hours or 20 mg/kg every 12 hours by mouth) until signs of peritonitis have resolved. IV fluids are required to treat shock initially. Antibiotics and laxatives are usually sufficient treatment of grade I, II, and some grade III tears, combined with daily inspection and careful manual removal of feces.

Colostomy

The preferred method for surgical treatment is loop colostomy, occasionally for grade III tears and mostly grade IV, with the goal of diverting feces away from these injuries so they do not become contaminated and impacted, enlarged, or in the case of grade III tears, converted to grade IV tears.[16] Colostomy can be combined with direct suture repair,[17] because it protects the suture line during healing. The loop colostomy technique is preferred over others, because it is easier and quicker to establish and to reverse later.[16] Concerns about incomplete diversion of feces do not apply to a loop colostomy in horse, because gravity, combined with correct construction of the stoma, prevents feces from entering the distal small colon and rectum.[16]

A double-incision colostomy involves a standard incision in the left flank below the tuber coxae and a separate lower flank incision for the stoma (see **Fig. 1**). The principle behind this approach is that it allows creation of a snug fit for the colon in the body wall in the lower incision, where the colon can empty readily and feces can fall away from the stoma with minimal contact with the skin.[16] Alternatively, a single incision can be placed low in the left flank for the stoma, but this is difficult as a standing procedure, because the incision must be large enough to correctly locate and place the colon.[16] Because this procedure involves a large flank incision, the body wall must be closed around the colon, and this creates a weaker body wall repair and makes the ventrally placed stoma prone to prolapse and herniation. With the double-incision technique, the stoma is placed in a low and snug flank incision, so that it is surrounded by intact body wall, and the risks of prolapse and herniation are reduced.

A standing approach is ideal for colostomy because: (1) muscle layers and landmarks are not distorted as they would be in the recumbent horse, so the colon can be placed more accurately through all layers; (2) the cost of general anesthesia is eliminated; and (3) dehiscence of the stoma during a rough anesthetic recovery is avoided. With the double-incision technique, a standard flank incision is used to prepare the distal loop of small colon and guide it into a separate low flank incision, midway between the fold of the stifle and the costal arch. Draping is optional for this procedure, because it can interfere with accurate location of landmarks, but a large iodophor adhesive drape should be used to protect the upper incision. The distal incision is approximately 8 cm long and is almost parallel with the flank fold, angled upwards at its caudal end by 20° to 30°. Deep dissection is guided by a hand through the flank incision. Small transverse incisions are made in muscles and fascia as needed to create an even and continuous opening through all layers, without bands that could

obstruct fecal passage. The stoma should not be large but should fit snugly in the body wall. These guidelines should reduce the risk of stomal obstruction, prolapse, and herniation.[16]

The stoma is made in the small colon at least 1 m from the rectum, so that the small colon can be easily exteriorized for colostomy reversal.[16] The selected segment of small colon is folded to form a loop, and the 2 arms of the loop are sutured together side to side for 8 to 10 cm. For this, an absorbable material such as 2-0 polydioxanone is used in a continuous Lembert pattern that runs longitudinally midway between the mesentery and the antimesenteric band of each segment.[16] This suture line approaches the mesentery at the folded end to turn the antimesenteric tenia outward. The adhesion along this suture line creates a complete mucosal separation between the proximal and distal segments of small colon to ensure complete fecal diversion. The adhesion can also stabilize the loop and reduce the risk of prolapse. The loop of small colon is then inserted into the flank incision so that the proximal part is in the cranial end of the incision, the distal part is in the caudal end, and the antimesenteric tenia projects 3 to 4 cm beyond the skin.

The seromuscular layer of the colon is sutured to the abdominal muscles, fascia, and subcutaneous tissues using several interrupted sutures of 0 or 2-0 absorbable material, taking care not to penetrate the lumen or occlude or puncture mesenteric vessels.[16] To form the stoma, an 8-cm incision is made along the exposed antimesenteric tenia of the colon, and the cut edges are folded back and sutured to skin with simple interrupted sutures of 2-0 polydioxanone. The resulting stoma is approximately the same size as the small colon lumen. Because fecal balls are eliminated individually through the small colon, without accumulating as in the rectum, the risk of obstruction is low.

In the first 5 to 7 days after surgery, the mucosal protrusion of the stoma becomes markedly congested and slowly sloughs, to be replaced with healthy tissue.[16] The associated peristomal swelling resolves with time. Antibiotics and laxatives are continued for 3 to 5 days, and horses are fed hay at half the usual amounts for the first 2 to 3 days after surgery. A petrolatum-based ointment is applied to the skin around the stoma to protect it from scalding and a cradle is applied to prevent the horse from rubbing the colostomy.

When the rectal tear has started to granulate, usually after 5 to 7 days, the bypassed small colon and rectum are flushed daily in normograde fashion with approximately 20 L of warm water through a garden hose to exercise these segments. This procedure keeps the lumen as large as possible to facilitate end-to-end anastomosis at reversal.[16] For colostomy reversal, usually after 6 weeks or more, the horse is anesthetized in right lateral recumbency, the stoma is resected en bloc, and an end-to-end colocolostomy is performed through the resulting flank incision. This procedure could also be performed with the horse standing, but closure of the body wall defect created by removal of the stoma is difficult and must be secure. However, a standing closure is not jeopardized by a rough anesthetic recovery.

The most common complications of colostomy are dehiscence, abscessation, peristomal herniation, prolapse, and stomal obstruction before reversal, and anastomotic impaction and flank incisional dehiscence after reversal.

RECTAL PROLAPSE

Surgical treatment of rectal prolapse is a standing surgery on an abdominal organ that is performed with the organ in the prolapsed state. Causes of rectal prolapse are straining from diarrhea, dystocia, intestinal parasitism, colic, and rectal tumors.[18,19]

In many cases, a cause cannot be identified. Types of rectal prolapse are I to IV, with the first 3 types involving progressively greater amounts of rectal mucosa and submucosa projecting through the anus and including a variable amount of small colon in type III.[19] In a type IV prolapse, the peritoneal rectum and a variable length of the small colon form an intussusception through the rectum and anus.[19] This type of prolapse occurs during dystocia in mares and is evident as a tubular projection of a mucosa-lined organ, even reaching the point of the hock in severe cases.

Surgery

Most early type I and II prolapses respond to reduction and treatment of the primary problem. A submucosal resection may be indicated for type III and IV prolapses if the prolapsed tissues are devitalized or the prolapse recurs after conservative treatment.[18] After epidural anesthesia and gentle cleaning of the prolapsed tissues, 2 14-gauge, 13-cm-long (5.25 in) catheters with the stylet in place are inserted at right angles to each other through the external anal sphincter and healthy mucosa to maintain the prolapse during dissection.[18] Starting at the 12 o'clock position, circumferential incisions are made in healthy tissue for one-third of the prolapse circumference, combined with deep dissection to elevate a strip of edematous and necrotic mucosa and submucosa.[18] Remaining healthy proximal and distal edges of the mucosa and submucosa are apposed with size 1 polydioxanone in an interrupted, horizontal mattress pattern.[18] These steps are repeated for each of the remaining thirds of the circumference until all necrotic tissue has been removed.[18] Mucosal edges are subsequently apposed with 2-0 polydioxanone in a simple continuous pattern interrupted at 3 equidistant points around the circumference.[18] The retaining catheters are removed and the tissues allowed to return to their normal positions. Postoperative management includes laxatives, a laxative diet, and, if necessary, careful digital removal of impacted feces from the rectum.

Resection and anastomosis may be indicated for type IV prolapse if the prolapsed tissues are devitalized or too much is involved to allow reduction.[18] The procedure can be performed as for submucosal resection, except that full-thickness circumferential incisions are made in healthy tissue through the inner and outer walls of the intussusceptum.[18] The concentric edges thus created are apposed with size 1 polydioxanone in an interrupted, full-thickness, horizontal mattress pattern. These steps are repeated for each of the remaining thirds of the circumference until all necrotic tissue has been removed. Care must be taken during resection to identify and ligate any mesenteric vessels in the prolapse. Mucosal edges are then apposed in a simple continuous pattern with 2-0 polydioxanone, interrupted at 3 equidistant points around the circumference. The transfixing cross-needles and the weight of the necrotic tissue maintain the line of anastomosis outside the rectum during surgery, and removal of the needles allows it to return to the abdomen afterward. Postoperative management is the same as for submucosal resection.[18] The prognosis is favorable if there is no associated vascular damage or mesenteric disruption. However, such changes are unlikely if viable and healthy margins are evident along the line of resection.

UTERINE TORSION

Uterine torsion causes low-grade abdominal pain in mares during late pregnancy and can account for 5% to 10% of total dystocias in mares.[20,21] In 1 study of 26 cases, torsion occurred at a mean of 9.6 months (288 days) of gestation, and in a study of 103 mares, stage of pregnancy at presentation was 236 to 368 days, with 4 mares (3.9%) presenting at parturition.[22] The direction of rotation is almost equally

distributed between counterclockwise and clockwise,[22–24] and the degree of torsion ranges from 180° to 540°.[20,21] The uterus can rupture secondary to torsion, but this is uncommon. Diagnosis is not always straightforward, although it can be made if the twist in the uterus can be palpated per rectum, cranial to the cervix, and 1 or both broad ligaments can be felt following the direction of rotation.

Treatment

The choice of treatment is determined largely by the condition of the mare and fetus, the stage of gestation, and expense. Correction through a flank approach with the mare standing is a widely used and successful method. In 1 multicenter study, foal survival was significantly better if uterine torsion was corrected by standing flank laparotomy than by ventral midline celiotomy.[24] No reason for this finding was apparent except that maybe general anesthesia itself was harmful to these foals.[24] Also, large mares in advanced pregnancy are an anesthetic challenge[25] and are at increased risk of long bone fracture and incisional dehiscence during recovery. Therefore, the midline approach should be reserved for those mares that are unsuitable for other methods or have a concurrent gastrointestinal tract disease. Rolling is a cost-saving option, but not always successful, especially in late pregnancy.[24] It is imperative that the direction of rotation is accurately diagnosed for rolling to be successful.

Flank Approach

Flank laparotomy is used on the standing mare with local anesthetic infiltrated along the proposed incision site, and with a CRI of detomidine to keep the mare sedated and comfortable. Although epidural anesthesia may be used in conjunction with a local anesthetic, this is unnecessary and might be contraindicated, because it could induce hindlimb weakness, frequent weight shifting, and recumbency.

Vandeplassche and colleagues[20,21] recommended that the abdomen be entered from the side to which the torsion is directed (eg, left flank if the torsion is counterclockwise, right if it is clockwise as viewed from behind the mare). A 15-cm to 20-cm incision is placed high on the flank, with the top of the incision at the level of the ventral aspect of the tuber coxae. A vertical incision is made through all layers except the internal abdominal oblique muscle, which is divided along its fibers. The direction of torsion is confirmed. Generally, the uterus is not compromised, and some discoloration and edema do not signify a poor prognosis for continued pregnancy. If working from the side to which the rotation is directed (eg, right flank if the torsion is clockwise, left flank if counterclockwise), the uterus overlying a prominent part of the foal is gently rocked up and down through short arcs (25–30 cm) to gain some momentum. The rotation is then completed by lifting and pushing the uterus to its correct position. Care must be used to avoid tension on the wall, which could rupture the uterus, especially if it is edematous and friable. This procedure can be facilitated by alternating between pulling up on the uterus and pushing against its dorsal edge.

If the abdomen is entered on the side opposite that to which the torsion is directed (eg, left flank if the torsion is clockwise, right flank if counterclockwise), the hand is passed dorsally above the uterus to find a prominent part of the foal, which is then pulled toward the operator. Once rotation is started, the weight of the fetus and uterus may help to draw them around completely to a normal position. An alternative is to push the ventral aspect of the uterus from the operator, instead of pulling on the dorsal aspect of the uterus. Both methods can be alternated as needed to correct the torsion.

Correction of a uterine torsion close to term is difficult through a flank approach, because of the weight and size of the foal and uterus. Torsions of 240° or less are easiest to correct and are associated with less uterine edema than more severe

torsions. If it proves impossible to correct the torsion through a flank approach, the incision can be closed, and the mare is then anesthetized for a ventral midline celiotomy. In some cases, 2 surgeons might have to work simultaneously through right and left flank incisions to correct the torsion.[22]

The main concern after successful correction of uterine torsion is abortion, and progesterone therapy (respositol progesterone, 1000 mg intramuscularly every 4 days, or progesterone in oil, 300 mg daily) is considered by some to be of value. Preoperative treatment is the same as for an adult horse with colic, but might need to be more aggressive after surgery when complicated by shock, uterine congestion, or rupture. Mares should be confined to a stall for 3 weeks to reduce stress on the suture line.

Prognosis

In a recent retrospective study that combined cases from 4 equine referral hospitals,[24] the stage of gestation at which uterine torsion developed was a risk factor for survival of mare and foal. Although overall mare survival was 53 of 63 (84%), survival was 97% when uterine torsion developed at less than 320 days' gestation, compared with 65% survival rate when uterine torsion developed at 320 days' gestation or more.[24] Although overall foal survival was 54% (29/54) in the same study, it was 72% when uterine torsion developed at less than 320 days' gestation, compared with 32% when uterine torsion developed at 320 days' gestation or more.[24] The prognosis for delivery of a live foal was good if the mares were discharged from the hospital with a viable fetus, with 25 of 30 mares (83%) in this group delivering live foals that survived beyond the neonatal period.

The prospects for subsequent fertility seem to be good in mares that have had a uterine torsion.[22] A chronic form of uterine torsion has been described as a result of failure to diagnose the disease in its early stages, and can cause weight loss, anemia, fever, and mild colic.[26] This condition be treated only by ovariohysterectomy, which can save the mare, but obviously terminates her reproductive career.[26]

NSS CLOSURE

Ablation or closure of the NSS is a commonly performed laparoscopic surgery intended to reduce recurrent entrapment of the left dorsal and ventral colons over the nephrosplenic ligament (left dorsal displacement of the large colon [LDDLC]).[27–30] In a report of 44 horses with laparoscopic surgery and of 4852 horses treated for colic over 16 years,[27] 6% had LDDLC, and 21% of this group of horses had recurrence of the displacement. Hand-assisted laparoscopic ablation of the NSS is the technique with which we are most familiar and is described in some detail, and other methods are described briefly.

Case Selection

In our hospital, horses that are typical candidates for hand-assisted laparoscopic closure of the NSS fall into 3 main categories: (1) horses in which recurrent LDDLC has been confirmed at a surgery after a previous surgical treatment of LDDLC; (2) horses in which recurrent LDDLC is strongly suspected based on a favorable response to nonsurgical treatment (phenylephrine, rolling) at a subsequent admission after a previous successful treatment of LDDLC (surgical or nonsurgical); and (3) horses that have recurrent episodes of colic attributed on clinical examination to recurrent colonic displacement, but without confirmation of LDDLC as the cause.

Many horses with recurrent LDDLC in the first category would be candidates for a colopexy or large colon resection at the same surgery that confirmed recurrence, if

planned in advance by the owner and surgeon and depending on surgeon preference. Although ultrasonography can be used to confirm or refute recurrence in the third group, it has limitations, and colic can resolve in some horses with this disease before they arrive at a hospital where ultrasonography can be performed. In such cases, the owner is informed that other problems could cause recurrent colic, and closure of the space prevents only one of them, which may not be the cause. Once recurrent LDDLC is diagnosed at surgery or suspected based on response to nonsurgical treatment, and a decision is made to close the NSS, the surgery should be performed as soon as the horse is stabilized after correction of LDDLC and within the same hospitalization period.

Surgical Preparation

NSS ablation can be performed standing through the left paralumbar fossa using a traditional surgical flank incision combined with laparoscopy. Feed is withheld for 12 to 24 hours preoperatively to reduce intestinal contents and thereby improve access and laparoscopic view of the NSS. The horse is sedated with detomidine hydrochloride CRI in stocks and the left flank is prepared for sterile surgery. Local anesthesia of the skin and body wall can be accomplished with an inverted L in the paralumbar fossa, a paravertebral block, or by direct injection along each proposed incision.[31] A 20-gauge or 18-gauge 3.81-cm (1.5-in) needle is used to inject 2% lidocaine or 2% mepivacaine at each site, making sure that the skin blebs are visible. Large volumes of local anesthetic are required, including additional intraoperative injections if needed, but usually less than 200 mL per 500 kg horse.[31] Separate sites for towel clamps are injected with local anesthetic through 20-gauge needles and marked by leaving the needles in place until clamps are applied. Drapes are applied to cover the dorsum and left side of the horse.

Surgery

After a 12-cm to 15-cm flank incision is made below the tuber coxae and behind the last rib, the laparoscope is inserted dorsocranial to it through a 2-cm to 2.5-cm incision, with abdominal insertion guided by a hand in the abdomen (**Fig. 2**). Abdominal insufflation is not possible nor necessary for this procedure. The spleen, NSS, and stomach should be visible cranial to the incision, and some intestine, small or large, might need to be swept manually from the NSS. Needle holders for this surgery should be robust enough to handle the large needle that is required, and 2 are optimal, so the needle can be passed through the tissue by one and then retrieved as it exits by the other. The preferred needle holders have a 40-cm working length (Surgical Direct, Deland, FL). The preferred suture is size 2 Vicryl (Polyglactin 910, Ethicon, Summerville, NJ), which provides an ideal length of 135 cm (54 in) and has a large taper point needle, which can span 2 to 4 cm of tissue.

The needle is first passed through 2 to 4 cm of the most cranial aspect of the perirenal fascia in a dorsal to ventral direction, with the point of insertion level with or slightly below the dorsal edge of the spleen. This placement ensures that the line of traction on the dorsal rim of the spleen is horizontal from lateral to medial and not dorsomedial to ventrolateral, which could impose too much upward traction on the spleen and cause the suture to pull through the capsule. The next bite is in a ventral to dorsal direction from the medial side of the splenic rim to emerge through the dorsal edge. The needle is then exteriorized and passed through a small loop at the end of the suture or through a modified Roeder knot (more secure), and this is tightened by using a laparoscopic Babcock forceps to push the knot (**Fig 3**A). This procedure

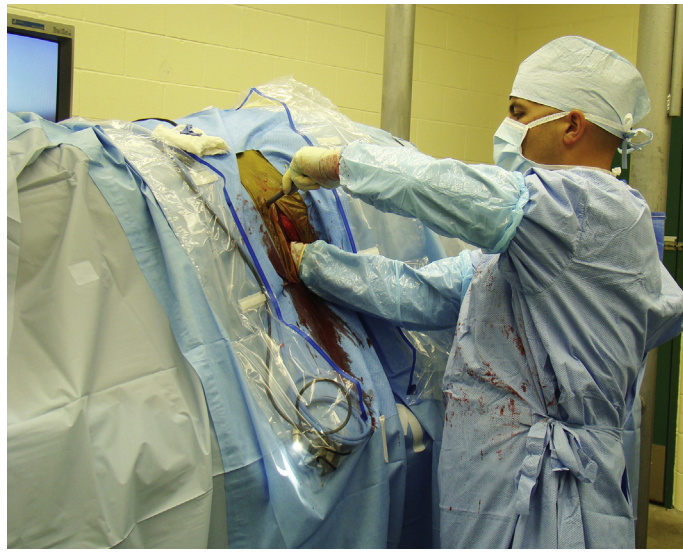

Fig. 2. Laparoscope inserted dorsocranial to flank incision for NSS closure with hand in the abdominal incision to guide safe cannula insertion.

should roll the dorsal edge of the spleen medially to contact the perirenal fascia (see Fig 3B).

Subsequent bites continue in the same fashion, using hand assistance as needed, to create a continuous suture line from cranial to caudal, with each successive set of bites at 1 to 2 cm apart (Fig. 4). As each bite through spleen and capsule is completed, it is manually drawn, so as to maintain snug apposition between spleen and perirenal fascia. As the line of closure continues, the space between the kidney and spleen becomes progressively narrower, which can impede needle placement. Some hemorrhage is inevitable and can be removed with a laparotomy sponge introduced with a grasping forceps and then rotated as it is drawn from cranial to caudal along the trough between the spleen and kidney. The NSS is closed entirely when the caudal extent of the nephrosplenic ligament is reached, and a hand tie is then used to secure the needle end of the suture to the last loop on the suture line. The flank incision and laparoscopy portal are closed routinely.

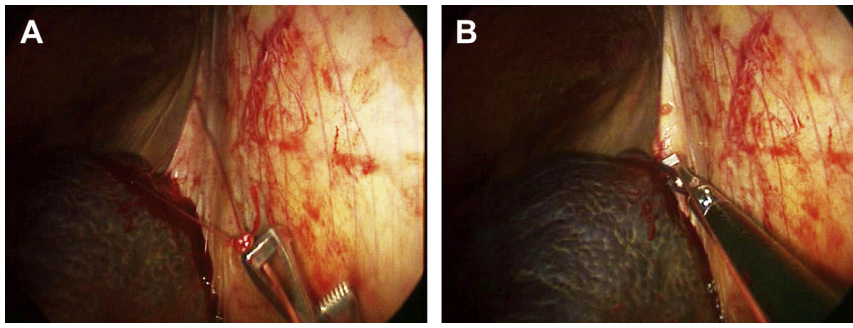

Fig. 3. Intraoperative view of the use of the modified Roeder knot. Using laparoscopic Babcock forceps to tighten the knot (*A*). The dorsal edge of the spleen moves medially to contact the perirenal fascia, once the knot once is tightened (*B*).

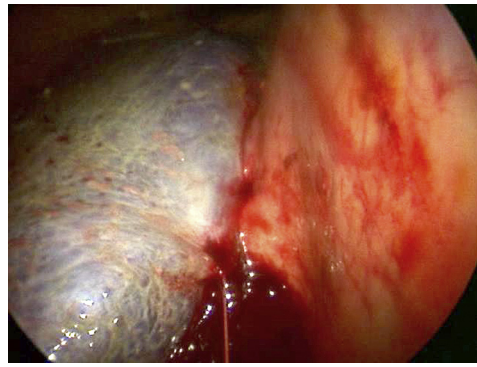

Fig. 4. Intraoperative view of continuous suture line from cranial to caudal for NSS closure.

Outcomes and Comments

The advantages of hand-assisted laparoscopic ablation of the NSS include an easier procedure than surgery performed completely by laparoscopy, avoidance of general anesthesia and associated expense, and manual suture tightening, which allows the appropriate degree of tension to be applied without risk of a loose attachment or cutting through the splenic capsule. The same approach can also be used to correct entrapment if present at the time of surgery and then close the NSS by laparoscopy.[32]

With all methods designed to close the NSS, horses can develop other forms of colic not prevented by this procedure.[28] Nonetheless, laparoscopic NSS closure can decrease the overall prevalence of colic and need for colic surgery.[28] Although recurrence of LDDLC after any method of NSS closure is rare, it has been reported at 6.5 years after laparoscopic space ablation in 1 horse.[33] This finding was attributed to the horse's young age at the time of surgery or inadequate suture bites or spacing in the perirenal fascia and splenic capsule.[33] Complications of laparoscopic closure of the NSS are rare, but a delayed bout of intra-abdominal hemorrhage was tentatively attributed to this procedure in 1 horse, presumably because the suture tore through part of the splenic capsule. Therefore, these horses should be kept quiet in a stall during the first 3 weeks after surgery. The line of closure of the NSS usually heals completely and is free of adhesions to other abdominal structures.

Other Methods for NSS Closure

A laparoscopic method to close the NSS, which requires laparoscopic instruments only (not hand assisted) and uses a custom cannula, was shown to prevent LDDLC over a 22-month follow-up period.[28] A method of laparoscopic closure with mesh was evaluated in 5 healthy mature horses.[29] A polypropylene mesh measured to fit the NSS was inserted and attached to the dorsolateral splenic capsule and perirenal fascia with helical titanium coils.[29] This method requires 1 laparoscopic and 2 instrument portals in the left flank.[29] At repeat laparoscopy 4 weeks later and necropsy at intervals of 4 to 14 weeks after surgery, all mesh implants were covered by fibrous tissue, and the mesh adhered to itself and drew the splenic capsule and perirenal fascia into apposition.[29] Each mesh implant was firmly adhered to the spleen, nephrosplenic ligament, and perirenal fascia, but 1 horse had an adhesion from the mesh to the small colon mesentery.[29] No horse developed colic.[29] In another laparoscopic method, etilefrin-induced splenic contraction facilitated suture placement and closure of the NSS.[27] LDDLC did not recur, although 5 horses had subsequent episodes of colic; 4 horses

had displacement of the ascending colon between the spleen and body wall.[27] Others have also reported displacement of the colon between the spleen and body wall.[32]

STANDING LAPAROSCOPIC NEPHRECTOMY

In the horse, nephrectomy by a hand-assisted laparoscopic approach on the standing horse seems to be considerably safer and easier than the open approach on an anesthetized horse.[34–39] The procedure can avoid the long and expensive anesthesia associated with the open method. Rib resections are not necessary, and therefore, the risk of pneumothorax is avoided.[34] The most common indications for nephrectomy in the horse include unilateral diseases, such as hydronephrosis, nephrolithiasis, pyelonephritis, abscessation, neoplasia, and ectopic ureter.[34–39]

The horse is fasted for 12 to 24 hours before surgery to reduce the volume of ingesta within the digestive tract and is then prepared for a standing surgery as described earlier for closure of the NSS.[34] A 10-cm to 12-cm vertical skin incision is made in the middle of the paralumbar fossa, beginning at the dorsal border of the internal abdominal oblique muscle, and a modified grid technique is used to expose the peritoneum. The peritoneum is then bluntly penetrated and the peritoneal opening is enlarged. A hand in the abdomen guards against trauma to adjacent viscera (see **Fig. 2**) as a trocar-cannula unit is inserted through the flank musculature just dorsal to the most dorsal margin of the skin incision (**Fig. 5**).[34] The trocar is removed and a 320-mm, 0° laparoscope is inserted through the cannula. An instrument portal is made 4 to 6 cm cranial to and 2 to 3 cm dorsal to the laparoscope portal (see **Fig. 5**). The left and right kidneys can be located but cannot be seen behind the perirenal fat and fascia that encloses them in the retroperitoneal space.

A laparoscopic injection needle is inserted through the flank incision to infiltrate the retroperitoneal space between the kidney and peritoneum with 20 to 50 mL of 2% mepivacaine. The perirenal peritoneum is lacerated with the tip of the needle

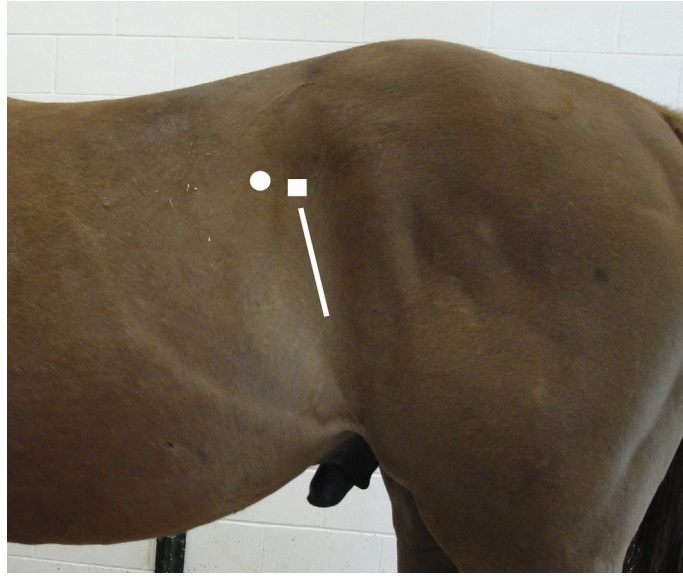

Fig. 5. Sites for flank incision (*straight line*), laparoscope (*square*), and instrument portals (*circle*) for left standing laparoscopic nephrectomy.

before removal.[34] The peritoneum around the kidney is massaged to distribute the local anesthetic throughout the retroperitoneal space. The peritoneal laceration is digitally enlarged and the kidney is dissected free from surrounding retroperitoneal fat to expose the ureter and renal vein and artery.

Careful digital dissection is used to expose the renal pedicle and ureter so that they can be viewed through the endoscope. The artery is identified and separated by careful digital dissection and a loop of size 2 polyglactin 910, 135 cm (54 in) long, is placed around it by digital insertion and retrieved with a laparoscopic instrument. Alternatively, a Deschamps needle is used to place the suture around the artery so that it can be digitally retrieved. Alternatively, the suture can be passed from a laparoscopic needle holder around the cranial edge of the artery to be retrieved by another needle holder passed dorsal to the vessel. The tips of the needle holders are angled slightly (Surgical Direct, Deland, FL), and this feature can be used to direct the suture end around the cranioventral edge of the vessel so it comes into view dorsal to the vessel. The suture is then tied through the flank incision with a sliding half hitch or Roeder knot, and the knot is digitally tightened until the surgeon is satisfied that it is secure. At least 2 more ligatures are applied in the same manner, so the artery is occluded distal to the line of transection with 1 ligature and about 1 cm proximal to it by 2 ligatures. The artery is then transected between the distal 2 ligatures. The artery is ligated before the vein, because venous occlusion as the first step would cause blood to pool in the kidney and possibly enlarge it.

These steps are repeated for the vein, and then the ureter is freed up by blunt dissection, and the kidney is drawn through the flank incision (**Fig. 6**). The ureter is double-ligated distal to the proposed line of transection and is then cut with laparoscopic scissors. Transecting the ureter before the vessels is another option that allows easy identification of both the renal artery and vein.[34] Also, care should be taken to ensure there are no accessory arterial branches to the kidney that require ligation.[34] If the kidney has an abscess or is enlarged with pyelonephritis, special care must be taken to ensure that septic contents are not released into the abdomen or into the incision. Placement of the kidney in a sterile plastic bag within the abdomen before it is drawn through the incision might be indicated in these cases.[34] The incisions are closed in a routine manner.

Outcomes and Comments

Although the preceding description applies to left-sided nephrectomy, a similar method can be used for the right kidney.[35] Intraoperative hemorrhage has been

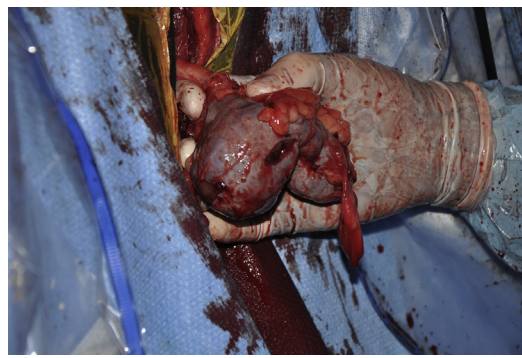

Fig. 6. After the ureter is freed up by blunt dissection, the kidney can be drawn through the flank incision, with the ureter as the only remaining attachment.

reported during this procedure,[35] but it can be controlled with Carmalt or Rochester Pean forceps. Back bleeding from the kidney can be substantial if the vein is cut before adequately ligated and before the artery is ligated. Some horses might be mildly uncomfortable after surgery, but this is manageable.[35] Obviously, health of the remaining kidney is critical to outcome, and some diseases, such as nephrolithiasis, are bilateral to some degree.[40–42] Therefore, function of the remaining kidney needs to be monitored frequently, and phenylbutazone, other nonsteroidal antiinflammatory drugs, and potentially nephrotoxic drugs should be avoided or used with care. Although a recent report described nephrectomy through a ventral midline approach in equids,[43] this method was not tested on large adult horses, which is the group most suited to a standing nephrectomy. However, the ventral midline approach allows excellent access for nephrectomy in foals and is the method of choice for foals with ureteral defects and ectopia that are unresponsive to other surgical treatments.

OTHER STANDING LAPAROSCOPIC PROCEDURES

Standing laparoscopy has also been used to investigate causes of colic in horses,[6] but it is most suitable for diseases without abdominal distention or pain at the time of surgery. Suitable candidates are horses with a history of chronic, recurrent colic with mild or no pain at surgery, or horses with weight loss. In some cases, standing laparoscopy is useful to confirm or refute a tentative diagnosis that has evolved from other diagnostic procedures, such as abdominal radiographs, abdominal ultrasonographic examination, gastroscopy, rectal examination, and peritoneal fluid analysis. It might be an easier and less expensive alternative to a ventral midline celiotomy for horses suspected of having untreatable lesions, such as ruptured viscus or neoplasia, when the owner wants absolute confirmation before granting permission for euthanasia. It can also be used for intestinal biopsy (see earlier discussion).

Laparoscopic adhesiolysis (**Fig. 7**) has been described in the horse,[44–47] and a standing approach could be used when the adhesions are strongly suspected to be in the dorsal abdomen. Adhesion prevention after adhesiolysis is improved by the addition of 0.5% ferric hyaluronate gel to the affected serosal surfaces.[44] An intraabdominal abscess and cyst can also be evaluated and drained by standing laparoscopic surgery.[48,49] Experimentally induced rectal tears have been successfully repaired by standing laparoscopy.[50] In a broodmare that underwent a ventral midline

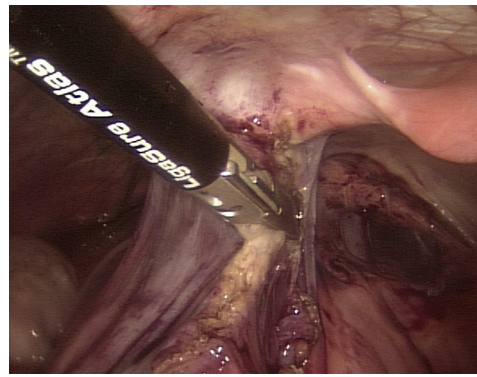

Fig. 7. Adhesiolysis using the Ligasure. (*Courtesy of* Dean Hendrickson, DVM, Fort Collins, CO.)

correction of a small intestinal strangulation in a rent in the mesenteric duodenum, the most dorsal aspect of the rent was inaccessible at surgery.[51] Subsequently, a standing right flank laparoscopic approach allowed excellent access and complete closure of the defect.[51]

A method for inguinal hernioplasty has been described as a standing laparoscopic procedure on stallions that were previously treated for strangulating inguinal herniation without castration.[52] Three portals in the flank were used to approach the vaginal rings.[52] A large inverted U-shaped peritoneal flap was then dissected and elevated proximal and cranial to the vaginal ring, and was reflected caudally over it.[52] The flap was secured to the abdominal wall with laparoscopic staples.[52] Inguinal herniation recurred in a few horses if only the cranial and middle thirds of the vaginal ring were covered but was completely prevented if the flap sealed the entire vaginal ring.[52] Major complications were not encountered, and all stallions were successfully used for breeding after surgery.[52] Although standing laparoscopy seems well suited for repair of dorsal diaphragmatic hernia in horses, access can be restricted by curvature of the diaphragm away from the surgeon and by viscera overlying the defect.[53] Instead, thoracoscopy and intrathoracic suture can be used in the standing sedated horse.[53]

STANDING FLANK APPROACH TO REMOVE URETEROLITHS

Nephroliths and ureteroliths are well-recognized causes of proximal urinary tract obstruction in horses, and induce an insidious and progressive disease, which can be characterized by varying severities of lethargy, depression, anorexia, and weight loss.[40–42] By the time diagnosis is usually made, renal disease from the obstruction has progressed to the point that renal damage is irreversible, and residual function in the affected kidney is minimal. Also, proximal urinary tract obstruction from uroliths or nephroliths can be bilateral, which reduces the chances for complete recovery.[40,41] Ureteral calculi can also be rare incidental findings on palpation per rectum for other reasons,[42] and nephroliths can be incidental findings at necropsy (**Fig. 8**). In these cases, a functional contralateral kidney is presumed to be responsible for the lack of clinical signs and absence of azotemia.[42] In all horses in which a urolith is found in any part of the urinary tract, other segments should be examined for involvement.[54]

Laboratory evidence of upper urinary tract obstruction is reflected in serum biochemical changes, such as elevated blood urea nitrogen, creatinine, and

Fig. 8. Nephroliths as incidental findings at necropsy in a horse without renal disease. Note several small stones in the renal pelvis after the 1 large stone was removed.

potassium levels. On examination per rectum, when the hand is swept dorsally for a short distance from the brim of the pelvis, a ureteral stone can usually be found approximately 10 cm from the neck of the bladder. The distended and thickened ureter can be palpated in the retroperitoneal space cranial to that point. Both sides of the abdomen should be checked.

An ultrasonographic examination of both kidneys and ureters is usually diagnostic. Transrectal ultrasonographic examination with a 7.5-mHz linear array transducer can show a distended ureter proximal to a variable-sized ureteral calculus, which shadows as a mineral opacity.[42] The kidneys are closely examined by transabdominal ultrasonographic examination with a 3.5-mHz curved array transducer, and obstructed kidneys can range in size from smaller to larger than normal and have abnormal renal architecture and cystic cavities, which indicates some degree of hydronephrosis. A careful search for shadows from mineral opacities is needed to find nephroliths, which could be obstructing outflow from the pelvis in the absence of any evidence of ureteral obstruction. Cystoscopy can be used to subjectively compare and assess urine flow from the ureteral openings into the bladder and can show a large mucous plug in the opening on the obstructed side.[42]

A renal biopsy can be taken to assess renal damage, if it would contribute meaningfully to available information, but this procedure carries risks.[40]

Surgery

Obstructive ureteroliths approximately 10 cm from the bladder were removed from 2 mature geldings through a standing flank approach, which allowed simultaneous access to the peritoneal cavity and the retroperitoneal space (**Fig. 9**).[42] Goals of the surgery were to allow excretion of urine and mucus from the affected kidney so that it might regain some function and not undergo further deterioration or develop pyelonephritis.

The obstructed ureter is usually thick walled, dilated to approximately 2.5 cm in diameter, and tortuous, all of which makes it more amenable to surgical access and ureterotomy closure through this approach.[42] The added length gained through distention and associated tortuosity allows approximately 10 to 12 cm of ureter to be freed up in proximal and distal directions so that a 6-cm segment can be elevated to the level of the skin (see **Fig. 9**). A hand inserted into the peritoneal cavity can palpate a ureterolith distal to the isolated segment but cannot massage it away from there in either direction, because of the degree of ureteral constriction around the calculus and the adhesion of ureteral lining to its rough surface. Removal by manual massage toward the ureterotomy might be easier for a recent obstruction, but most are likely to be long-standing by the time of surgery.

Two 2.54-cm-wide (1 in) Penrose drains are used to retain the ureter at skin level, so it can be incised longitudinally for 3 cm (see **Fig. 9**). Some mucus can drain through the incision, and this can be removed by suction and submitted for culture. A 56.5-cm-long uterine biopsy forceps (Eppendorfer Uterine Biopsy Forceps, Miltex, Bethpage, NY) is introduced through the ureterotomy, approximately 25 cm proximal to the calculus (**Fig. 10**). When it reaches the calculus, the jaws of the instrument are opened, and a hand in the abdomen manipulates the calculus into the jaws to be crushed into fragments, which can be removed in piecemeal fashion (**Fig. 11**).

After the stone is removed, a 6.6-mm $\times$ 137-cm stallion catheter (Jorgensen Laboratories, Loveland, CO) is inserted distally into the ureter, and sterile saline is injected through this to assess patency and flush any loose fragments into the bladder. A urethrostomy can be made beforehand in geldings to create an egress for the lavage fluid and to place an indwelling urinary catheter as a stent to maintain patency if the ureter

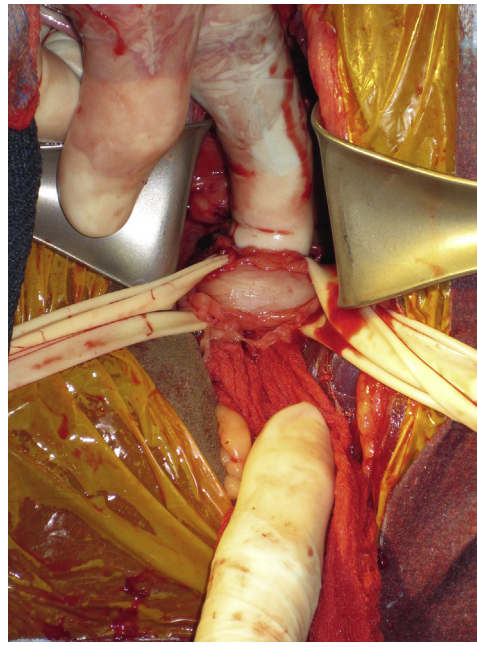

Fig. 9. Flank approach that allows simultaneous access to the peritoneal cavity and the retroperitoneal space so the ureter can be exposed. Two 2.54-cm-wide (1-in) Penrose drains are used to retain the ureter at skin level so it can be incised. Note the sponge in the incision to catch any fragments that could drop off the instrument as it is removed.

Fig. 10. Insertion of a long uterine biopsy forceps (Eppendorfer Uterine Biopsy Forceps, Miltex, Bethpage, NY) through the ureterotomy, proximal to the calculus and directed distally toward it.

Fig. 11. Jaws of the uterine biopsy forceps containing part of ureterolith removed and showing the shape of the jaws, which allows them to elevate the fragment from the mucosa (*bottom jaw*) and crush it (*upper jaw*).

swells.[42] However, the latter is not essential and can cause an ascending pyelonephritis if left in for long periods.[42] The ureterotomy is then closed in a simple continuous pattern with size 2-0 polydioxanone, taking care to avoid mucosal penetration, and the flank incision is closed in routine manner.

Aftercare

Perioperative care involves IV polyionic fluids at maintenance rates until biochemical measures of renal function return to normal (**Fig. 12**). Preoperative antibiotics such as potassium penicillin (22,000 U/kg [10,000 U/lb], IV, every 6 hours) are given and need be continued in the postoperative period only if an indwelling stent is left in

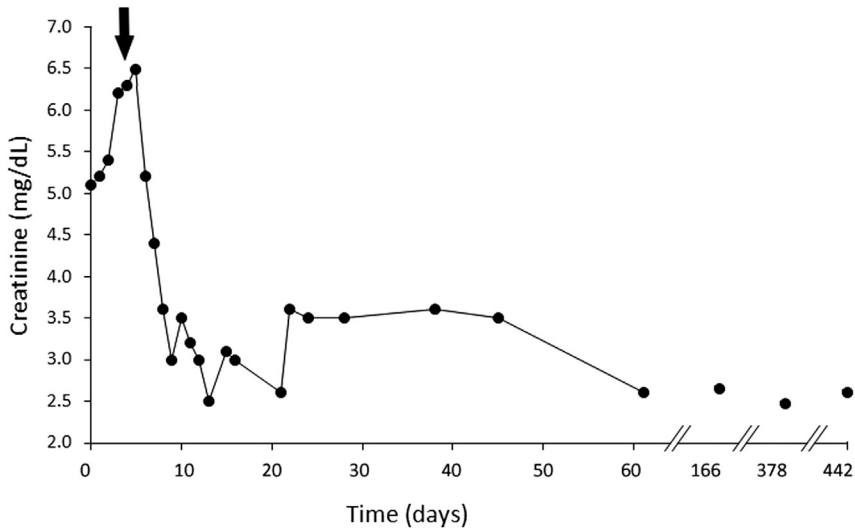

Fig. 12. Graph of serum creatinine in a horse before and after surgery (*arrow*). Note the marked improvement after the left kidney was unobstructed, but failure to regain normal values (reference range, 0.8–2.2 mg/dL), because this horse had bilateral renal disease. It was subsequently killed because of bilateral obstructive renal disease.

the ureter. Such tubes and contents as well as any fluid removed from the ureter at surgery should be cultured and sensitivity tested in case the horse subsequently develops an ascending urinary tract infection.[42] Flunixin meglumine can be given for pain control, if IV fluids are given concurrently. Cecal impaction can develop in hospitalized horses that have undergone a variety of surgical procedures, including surgery for ureteral obstructions,[42,54,55] and therefore motility modifying drugs, such as butorphanol, should be used sparingly if at all.

Urine acidifiers such as ammonium chloride and ascorbic acid are recommended but have not proved to prevent recurrence of calculi in horses.[56,57] Ascorbic acid must be given daily by stomach tube, because it is not consumed willingly in the dose required.[56,58] Ammonium chloride (Ammonium chloride USP granular, Fisher Scientific, Pittsburgh, PA) can be given by dose syringe in syrup at 28.3 g (1 oz) by mouth every 12 hours to acidify the urine and prevent recurrence, but can fail in this purpose and also cause inappetance.[42] It can increase urinary fractional excretion of calcium in goats and thereby increase the risk of calcium-based uroliths.[59] Dietary measures to consider are diets low in cation-anion balance to decrease urinary pH,[60] grass hay to reduce urinary calcium excretion, and a concentrate diet to lower urinary pH.[40,56]

Outcomes and Comments

The technique used for ureterolith removal was successful in both horses in which it was reported, and did not require sophisticated equipment. The uterine biopsy forceps is superior to shorter grasping instruments, such as arthroscopic forceps, because of its length and robust design.[42] Despite successful removal of the urolith, 1 horse developed pyelonephritis in the affected kidney and died of complications from subsequent nephrectomy. The other horse was killed, because it developed obstructive nephroliths in the contralateral kidney. These deaths underscore the importance of bilateral renal involvement in such cases, the need for early intervention whenever possible, the need for continued monitoring of renal function (see **Fig. 12**), and the importance of nephrectomy as first-line of treatment in horses with advanced renal disease[40] (see earlier discussion for description). Therefore, owners should be advised that removal of a ureterolith might not resolve renal failure, even if it does resolve hydronephrosis on the affected side.[42]

Other methods for urolith removal require retrieval baskets (Segura Basket, Cook Urological, Spencer, IN), laser technology (see later discussion), or various instruments for lithotripsy that cannot be easily inserted into the ureter of geldings.[58,61–67] Although ureteral entry with such instruments is possible in mares,[40,68] a perineal urethrostomy in male horses would not provide the same degree of access without a rigid endoscope.[58] A ventral midline celiotomy in the anesthetized horse might not allow adequate access for ureterotomy closure[68] and might necessitate an additional paralumbar incision and exteriorization of much of the large and small intestines to improve access.[55]

SURGICAL REMOVAL OF CYSTIC CALCULI

Horses with cystic calculi usually have a history of dysuria, hematuria, frequent urination, low-grade colic, urine scalding of the hind legs, stilted hind leg gait, prolonged penile protrusion, and passage of dark, cloudy urine. Geldings seem to be affected more so than mares, possibly because mares can pass the calculus before they reach a certain size. Although cystic calculi can be removed through a caudal ventral midline celiotomy, access to them in the caudal abdomen can be gained through a standing

perineal urethrostomy[69] or through a standing pararectal cystotomy (Gokel procedure).[70] Uroliths can range in size from 3 to 10 cm, with mean and median diameters of 6.37 and 6 cm, respectively.[70] Usually, these uroliths are solitary, but multiple calculi have been reported.[70] Most are formed from calcium carbonate and have a rough, spiculated surface.

Surgery

For the pararectal approach, the neck of the bladder is approached through a vertical incision lateral to the rectum, followed by blunt dissection.[70] The bladder is entered through a retroperitoneal cystotomy, and the calculus is removed intact. A perineal urethrostomy is performed through a 6-cm vertical skin incision, which starts proximally 10 cm ventral to the anus and extends distally to the ischial arch.[69] A stay suture is placed on both sides of the urethrostomy through the urethral mucosa, corpus spongiosum penis, bulbospongiosus muscle, and retractor penis muscle, and then sutured to the adjacent skin to retract the urethrostomy edges. Before removal through a perineal urethrostomy, the typical cystic calculus in a horse must be broken into several small fragments by lithotripsy, which can be time consuming.

For lithotripsy, the calculus is stabilized in the neck of the bladder by a hand in the rectum. An osteotome or a long screwdriver with a wide slotted head is placed against the calculus and is rotated into the center of it with some force until the surface starts to crumble. The process is repeated at different sites on the calculus until more fragments progressively break off around the edges. A lithotrite can be used instead for lithotripsy, but these are not readily available (**Fig. 13**). A uterine biopsy forceps or a sponge forceps is used to grasp and remove fragments, and most of the remaining sediment is syphoned from the bladder through a sterile stomach tube.

The perineal urethrostomy is left open to heal by second intention (**Fig. 14**). Within a few days after surgery, the bladder should be free of any sediment and the mucosal inflammation should be reduced. Other instruments developed specifically for lithotripsy can also be used, such as electrohydraulic,[61,62] ballistic shock wave,[63] radial extracorporeal shock wave,[64] pulsed dye laser,[65,66] and holmium:yttrium aluminum garnet laser.[67] These lasers require specialized and expensive equipment and expertise with their use.[58]

Perioperative treatment involves antibiotics (optional; see earlier discussion for ureterotomy) and flunixin meglumine for pain control (1.1 mg/kg [0.5 mg/lb], IV, every 12 hours). Urinary tract acidifiers are also recommended, although these have some limitations that influence efficacy (see earlier discussion for ureterotomy). In general, urethrostomy has a low complication rate, and usually the incision is fully healed within 3 weeks in horses.[54,69]

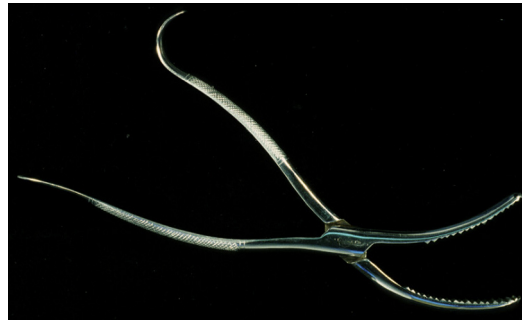

Fig. 13. Lithotrite for crushing cystic calculi in horses.

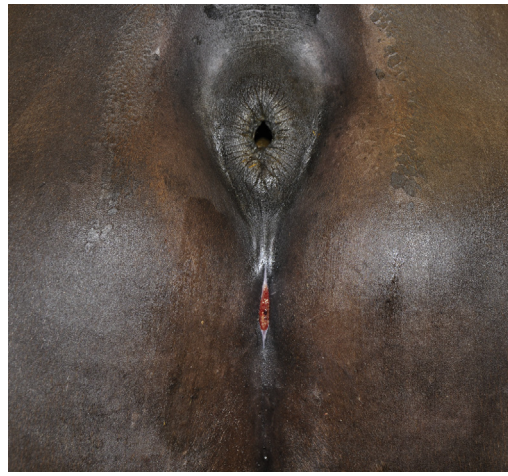

Fig. 14. Healing perineal urethrostomy at 10 days after surgery.

REFERENCES

1. Sisson S. Equine myology. In: Getty R, editor. Sisson and Grossman's the anatomy of domestic animals. 5th edition. Philadelphia: WB Saunders; 1975. p. 407–12.
2. Ross MW. Standing abdominal surgery. Vet Clin North Am Equine Pract 1991; 7(3):627–39.
3. Hassel DM, Ragle CA. Laparoscopic diagnosis and conservative treatment of uterine tear in a mare. J Am Vet Med Assoc 1994;205:1531.
4. Ragle CA, Southwood LL, Galuppo LD, et al. Laparoscopic diagnosis of ischemic necrosis of the descending colon after rectal prolapse and rupture of the mesocolon in two post-partum mares. J Am Vet Med Assoc 1997;210:1646.
5. Fischer AT. Laparoscopic evaluation of horses with acute and chronic colic. In: Fischer AT, editor. Equine diagnostic and surgical laparoscopy. Philadelphia: WB Saunders; 2002. p. 131–42.
6. Mehl ML, Ragle CA, Mealey RH, et al. Laparoscopic diagnosis of subcapsular splenic hematoma in a horse. J Am Vet Med Assoc 1998;213(8):1171–3.
7. Galuppo L. Laparoscopic anatomy. In: Fischer AT, editor. Equine diagnostic and surgical laparoscopy. Philadelphia: WB Saunders; 2002. p. 7–28.
8. Walmsley JP. Review of equine laparoscopy and an analysis of 156 laparoscopies in the horse. Equine Vet J 1999;31:456.
9. Kolata RJ, Freeman LJ. Access, port placement and basic endoscopic skills. In: Freeman LJ, editor. Veterinary endosurgery. St Louis (MO): Mosby; 1999.
10. Schambourg MM, Marcoux M. Laparoscopic intestinal exploration and full-thickness biopsy in standing horses: a pilot study. Vet Surg 2006;35:689–96.
11. Bracamonte JL, Bouré LP, Geor RJ, et al. Evaluation of laparoscopic technique for collection of serial full-thickness small intestinal biopsy specimens in standing sedated horses. Am J Vet Res 2008;69(3):431–9.
12. Slone DE, Humburg JM, Jagar JE, et al. Noniatrogenic rectal tears in three horses. J Am Vet Med Assoc 1982;180(7):750–1.
13. Baird AN, Taylor TS, Watkins JP. Rectal packing as initial management of grade 3 rectal tears. Equine Vet J Suppl 1989;7:121–3.

14. Arnold S, Meagher D, Lohse C. Rectal tears in the horse. J Equine Med Surg 1978;2:55–63.
15. Arnold J, Meagher D. Management of rectal tears in the horse. J Equine Med Surg 1978;2:64.
16. Freeman DE, Richardson DW, Tulleners EP, et al. Loop colostomy for management of rectal tears and small colon injuries in horses: 10 cases (1976–1989). J Am Vet Med Assoc 1992;200(9):1365–71.
17. Eastman TG, Taylor TS, Hooper RN, et al. Treatment of grade 3 rectal tears in horses by direct suturing per rectum. Equine Vet Educ 2000;63.
18. Turner TA, Fessler JF. Rectal prolapse in the horse. J Am Vet Med Assoc 1980; 177(10):1028–32.
19. Turner TA. Rectal prolapse. In: Robinson NE, editor. Current therapy in equine medicine. 2nd edition. Philadelphia: WB Saunders; 1987.
20. Vandeplassche M. Obstetrician's view of the physiology of equine parturition and dystocia. Equine Vet J 1980;12:45–9.
21. Vandeplassche M, Spincemaille L, Bouters R, et al. Some aspects of equine obstetrics. Equine Vet J 1972;4:105–13.
22. van der Weijden B. Proceedings of foal and fertility congress, Zwolle International, Zwolle, Netherlands, 2007. p. 1–10.
23. Pascoe JR, Meagher OM, Wheat JD. Surgical management of uterine torsion in the mare: a review of 26 cases. J Am Vet Med Assoc 1981;179:351–4.
24. Chaney KP, Holcombe SJ, LeBlanc MM, et al. The effect of uterine torsion on mare and foal survival: a retrospective study, 1985–2005. Equine Vet J 2007;39:33–6.
25. Maney JK, Quandt JE. Anesthesia case of the month. J Am Vet Med Assoc 2012;241:562–5.
26. Doyle AJ, Freeman DE, Sauberli DS, et al. Clinical signs and treatment of chronic uterine torsion in two mares. J Am Vet Med Assoc 2002;220:349–53.
27. Röcken M, Schubert C, Mosel G, et al. Indications, surgical technique, and long-term experience with laparoscopic closure of the nephrosplenic space in standing horses. Vet Surg 2005;34:637–41.
28. Farstvedt E, Hendrickson D. Laparoscopic closure of the nephrosplenic space for prevention of recurrent nephrosplenic entrapment of the ascending colon. Vet Surg 2005;34:642–5.
29. Epstein KL, Parente EJ. Laparoscopic obliteration of the nephrosplenic space using polypropylene mesh in five horses. Vet Surg 2006;35(5):431–7.
30. Mariën T, Adriaenssen A, Hoeck FV, et al. Laparoscopic closure of the renosplenic space in standing horses. Vet Surg 2001;30(6):559–63.
31. Hendrickson DA. A review of equine laparoscopy. ISRN Vet Sci 2012;492650: 1–17. http://dx.doi.org/10.5402/2012/492650.
32. Muňoz J, Bussy C. Standing hand-assisted laparoscopic treatment of left dorsal displacement of the large colon and closure of the nephrosplenic space. Vet Surg 2013;42:595–9.
33. Barrell EA, Kamm JL, Hendrickson DA. Recurrence of renosplenic entrapment after renosplenic space ablation in a seven-year-old stallion. J Am Vet Med Assoc 2011;239:504–7.
34. Rodgerson DH. Laparoscopic assisted nephrectomy and nephrosplenic space ablation. In: Proceedings of American College of Veterinary Surgeons. 2008. p. 60–2.
35. Röcken M, Mosel G, Stehle C, et al. Left- and right-sided laparoscopic-assisted nephrectomy in standing horses with unilateral renal disease. Vet Surg 2007; 36(6):568–72.

36. Keoughan CG, Rodgerson DH, Brown MP. Hand-assisted laparoscopic left nephrectomy in standing horses. Vet Surg 2003;32(3):206–12.
37. Cokelaere SM, Martens A, Vanschandevijl K, et al. Hand- assisted laparoscopic nephrectomy after initial ureterocystostomy in a shire filly with left ureteral ectopia. Vet Rec 2007;161(12):424–7.
38. Romero A, Rodgerson DH, Fontaine GL. Hand assisted laparoscopic removal of a nephroblastoma in a horse. Can Vet J 2010;51(6):637–9.
39. Mariën T. Laparoscopic nephrectomy in the standing horse. In: Fischer AT, editor. Equine diagnostic surgical laparoscopy. Philadelphia: Saunders; 2002. p. 273–81.
40. Schott HC. Obstructive disease of the urinary tract. In: Reed SM, Bayly WM, Sellon DC, editors. Equine internal medicine. 3rd edition. St Louis (MO): Saunders Elsevier; 2010. p. 1201–43.
41. Ehnen SJ, Divers TJ, Gillette D, et al. Obstructive nephrolithiasis and ureterolithiasis associated with chronic renal failure in horses: eight cases (1981-1987). J Am Vet Med Assoc 1990;197:249–53.
42. Frederick J, Freeman DE, MacKay RJ, et al. Removal of ureteral calculi in two geldings via a standing flank approach. J Am Vet Med Assoc 2012;241(9): 1214–20.
43. Arnold CE, Taylor T, Chaffin MK, et al. Nephrectomy via ventral median celiotomy in equids. Vet Surg 2013;42(3):275–9.
44. Lansdowne JL, Bouré LP, Pearce SG, et al. Comparison of two laparoscopic treatments for experimentally induced abdominal adhesions in pony foals. Am J Vet Res 2004;65(5):681–6.
45. Bleyaert HF, Brown MP, Bonenclark G, et al. Laparoscopic adhesiolysis in a horse. Vet Surg 1997;26(6):492–6.
46. Bouré L, Pearce SG, Kerr CL, et al. Evaluation of laparoscopic adhesiolysis for the treatment of experimentally induced adhesions in pony foals. Am J Vet Res 2002;63(2):289–94.
47. Bouré L, Marcoux M, Lavoie JP, et al. Use of laparoscopic equipment to divide abdominal adhesions in a filly. J Am Vet Med Assoc 1998;212(6):845–7.
48. Mair TS, Sherlock CE. Surgical drainage and postoperative lavage of large abdominal abscesses in six mature horses. Equine Vet J Suppl 2011;43(39):123–7.
49. Scheffer CJ, Drijfhout PN, Boerma S. Subperitoneal cyst in a Friesian mare. Tijdschr Diergeneeskd 2004;129(14–15):468–70.
50. Brugmans F, Deegen E. Laparoscopic surgical technique for repair of rectal and colonic tears in horses: an experimental study. Vet Surg 2001;30(5):409–16.
51. Sutter WW, Hardy J. Laparoscopic repair of a small intestinal mesenteric rent in a broodmare. Vet Surg 2004;33(1):92–5.
52. Wilderjans H, Meulyzer M, Simon O. Standing laparoscopic peritoneal flap hernioplasty technique for preventing recurrence of acquired strangulating inguinal herniation in stallions. Vet Surg 2012;41(2):292–9.
53. Röcken M, Mosel G, Barske K, et al. Thoracoscopic diaphragmatic hernia repair in a warmblood mare. Vet Surg 2013;42(5):591–4.
54. Laverty S, Pascoe JR, Ling GV, et al. Urolithiasis in 68 horses. Vet Surg 1992;21: 56–62.
55. Byars TD, Simpson JS, Divers TJ, et al. Percutaneous nephrostomy in short-term management of ureterolithiasis and renal dysfunction in a filly. J Am Vet Med Assoc 1989;195:499–501.
56. Wood T, Weckman TJ, Henry PA, et al. Equine urine pH: normal population distributions and methods of acidification. Equine Vet J 1990;22:118–21.

57. Reimillard RL, Modransky PD, Welker FH, et al. Dietary management of cystic calculi in a horse. J Eq Vet Sci 1992;12:359–63.
58. Rodger LD, Carlson GP, Moran ME, et al. Resolution of a left ureteral stone using electrohydraulic lithotripsy in a thoroughbred colt. J Vet Intern Med 1995;9: 280–2.
59. Mavangira V, Cornish JM, Angelos JA. Effect of ammonium chloride supplementation on urine pH and urinary fractional excretion of electrolytes in goats. J Am Vet Med Assoc 2010;237:1299–304.
60. McKenzie EC, Valberg SJ, Godden SM, et al. Plasma and urine electrolyte and mineral concentrations in thoroughbred horses with recurrent exertional rhabdomyolysis after consumption of diets varying in cation-anion balance. Am J Vet Res 2002;63:1053–60.
61. MacHarg MA, Foerner JJ, Phillips TN, et al. Electrohydraulic lithotripsy for treatment of cystic calculus in a mare. Vet Surg 1985;14:325–7.
62. Eustace RA, Hunt JM. Electrohydraulic lithotripsy for the treatment of cystic calculus in two geldings. Equine Vet J 1988;20:221–3.
63. Koenig J, Hurtig M, Pearce S, et al. Ballistic shock wave lithotripsy in an 18-year-old thoroughbred gelding. Can Vet J 1999;40:185–6.
64. Verwilghen D, Ponthier J, Van Galen G, et al. The use of radial extracorporeal shockwave therapy in the treatment of urethral urolithiasis in the horse: a preliminary study. J Vet Intern Med 2008;22:1449–51.
65. Howard RD, Pleasant RS, May KA. Pulsed dye lithotripsy for treatment of urolithiasis in two geldings. J Am Vet Med Assoc 1998;212:1600–3.
66. May KA, Pleasant RS, Howard RD, et al. Failure of holmium:yttrium-aluminum-garnet laser lithotripsy in two horses with calculi in the urinary bladder. J Am Vet Med Assoc 2001;219:957–61.
67. Judy CE, Galuppo LD. Endoscopic-assisted disruption of urinary calculi using a holmium:YAG laser in standing horses. Vet Surg 2002;31:245–50.
68. Macharg MA, Foerner JJ, Phillips TN, et al. Two methods for the treatment of ureterolithiasis in a mare. Vet Surg 1984;13:95–8.
69. Lillich JD, DeBowes RM. Urethra. In: Auer JA, Stick JA, editors. Equine surgery. 3rd edition. St Louis (MO): Elsevier; 2006. p. 887–93.
70. Abuja GA, García-López JM, Doran R, et al. Pararectal cystotomy for urolith removal in nine horses. Vet Surg 2010;39(5):654–9.