Congenital retrosternal (Morgagni) diaphragmatic hernias in three horses

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Case Description—3 horses were examined and treated because of sudden onset of signs of abdominal pain.

Clinical Findings—All horses had a retrosternal (Morgagni) hernia involving the right side of the diaphragm. In each horse, the large colon was incarcerated in a right muscular defect in the diaphragm with a large hernial sac.

Treatment and Outcome—Definitive surgical repair of the hernia was not performed during the initial celiotomy. The hernia was repaired with mesh herniorrhaphy, but without resection of the hernia sac in 2 horses. For 1 horse, conservative management was applied. In the 2 horses treated with surgical correction, no major postoperative complications developed, and all 3 horses have been free of signs of abdominal pain.

Clinical Relevance—Horses with retrosternal hernias involving the diaphragm can develop clinical signs of intermittent obstruction of the large colon and chronic colic. In horses, retrosternal diaphragmatic hernias appear to develop exclusively in the right ventral aspect of the diaphragm and could represent an embryologic defect of diaphragm formation. Affected horses can be successfully treated with mesh herniorrhaphy or, in some instances, with conservative management. (*J Am Vet Med Assoc* 2007;231:427–432)

A 5-year-old 568-kg (1,250-lb) Hanoverian-Thoroughbred gelding (horse 1) was admitted to an equine hospital for evaluation because of sudden onset of signs of abdominal pain. Prior to admission, the owner had noticed that while riding the horse, it had resented application of leg pressure by the owner on the right side of the abdomen. Abdominal palpation per rectum revealed displacement of the large colon toward the left side. The horse became nonresponsive to analgesics, and an exploratory celiotomy was recommended to the owner. The horse was anesthetized and positioned in dorsal recumbency. A right paramedian laparotomy incision was performed. Exploration of the abdomen revealed that the large colon was incarcerated in a diaphragmatic defect located on the right ventral portion of the diaphragm. The edges of the hernia were palpably smooth and rounded. There was no evidence of a recent trauma to the diaphragm (eg, rough edges or signs of recent hemorrhage). A well-defined hernial sac was present. The width, height, and depth (extending cranially into the thoracic cavity) of the hernial opening and hernial sac were 20, 30, and 20 cm, respectively. The incarcerated segment of large colon was removed from the hernia without difficulty, but no attempts were made to surgically close the hernia. No other abnormalities were identified within the abdominal cavity. No postoperative complications developed, and the horse was discharged from the hospital 5 days after surgery.

Following discharge, horse 1 had multiple episodes of abdominal pain and was readmitted twice to the hospital for treatment during the 10-month period following the initial abdominal surgery. For each of these episodes, signs of abdominal pain resolved with conservative treatment that included administration of laxatives by nasogastric tube, IV administration of flunixin meglumine (1.1 mg/kg [0.5 mg/lb], q 12 h), and feed withdrawal. To minimize colonic bulk derived from feed material, the horse's usual diet of hay was changed to a complete pelleted feed.[a] On occasions when hay was provided with the pelleted feed, the horse developed signs of abdominal pain.

Because of persistent signs of abdominal pain, the owner elected to allow surgical repair of the diaphragmatic hernia, and the horse was referred to the Purdue University Large Animal Hospital 1 year after the initial exploratory celiotomy. Just prior to referral, the horse began to have signs of abdominal pain and was admitted on an emergency basis. Abnormal physical examination findings included obvious signs of abdominal pain (eg, pawing, stretching out, and looking at the flank), decreased gastrointestinal sounds, and moderate abdominal distension. No abnormal respiratory sounds were auscultated, and no referred gastrointestinal sounds were auscultated over the thorax. Abdominal palpation per rectum revealed a gas-distended large colon on the left aspect of the abdomen. The pelvic flexure of the large colon was not identified. Blood was collected and submitted for a CBC and serum biochemical analyses. The clinicopathologic findings were within reference ranges, with the exception of high serum total biliru-

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The authors thank Eleanor Grant for providing the illustration used in this manuscript.

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bin (3.9 mg/dL; reference range, 0.1 to 2.6 mg/dL) and unconjugated bilirubin (4.0 mg/dL; reference range, 0.1 to 2.2 mg/dL) concentrations. Abdominal radiography and ultrasonography were not performed. Repeated administrations of xylazine hydrochloride (0.3 mg/kg [0.14 mg/lb], IV) were necessary to relieve signs of abdominal pain. Prior to exploratory celiotomy and surgical repair of the hernia (day 0), penicillin G potassium (22,000 U/kg [10,000 U/lb], IV), gentamicin sulfate (6.6 mg/kg [3 mg/lb], IV), and flunixin meglumine (1.1 mg/kg, IV) were administered to the horse.

The horse was sedated with xylazine hydrochloride (1.1 mg/kg, IV), and anesthesia was induced with ketamine hydrochloride (2.2 mg/kg [1.0 mg/lb], IV) and diazepam (0.01 mg/kg [0.005 mg/lb], IV). Anesthesia was maintained with isoflurane in oxygen administered via a semiclosed circle circuit, and positive-pressure ventilation was applied. The horse was positioned in dorsal recumbency; to improve access to the cranial portion of the abdomen and aid in retraction of the small intestine and large colon, the end of the surgical table[b] supporting the horse's head was tilted upward to an angle of approximately 30°. Following aseptic preparation and routine draping of the abdomen, a ventral midline incision was made. The incision began at the xiphoid region and proceeded caudally for approximately 40 cm. Abdominal exploration confirmed the location of the diaphragmatic hernia. Portions of the sternal and diaphragmatic flexures of the right ventral and dorsal colons were incarcerated within the hernial ring and sac and were impacted with food material. The incarcerated segments were manually removed from the hernia, and the colon was exteriorized on an enterotomy tray[c] and covered with sterile towels soaked in saline (0.9% NaCl) solution. A Finochietto rib retractor was used to aid in retraction of the abdominal wall just caudal to the xiphoid process.

The diaphragmatic defect was visually and manually inspected. The opening to the hernia was located ventrally and to the right of the falciform ligament in the sternal muscular portion and in part of the central tendinous portion of the diaphragm, adjacent to the costosternal junction. The dimensions of the hernia had not changed since the initial celiotomy had been performed. The margins of the hernia were thick, smooth-edged musculofibrous bands that were confluent with the diaphragm on the medial, lateral, and dorsal sides (**Figure 1**). The ventral border of the hernia consisted of the ventral abdominal wall and the xiphoid process. The margins gave access to a large hernial sac located within the thoracic cavity (approx 30 cm in the dorsoventral plane, 20 cm in width and 20 cm in depth [extending cranially into the thoracic cavity]). The hernial sac prevented access to the pleural space or pericardium. No signs of pneumothorax developed during the surgical procedure. The hernial sac filled the space normally occupied by the margins of the right ventral lung lobe. The heart could be palpated through the hernial sac, indicating its close proximity to the pericardium. It was not possible to retract or invert the hernial sac towards the abdominal cavity. Because of the large size of hernial opening, it was not possible to suture the defect primarily and polypropylene mesh[d] was selected to close the defect. A 30 × 30-cm section of mesh was doubled (folded on 1 margin), and the cut edges of the mesh were sutured together with 3-0 polypropylene suture in a simple interrupted pattern. Starting at the most dorsal aspect of the hernia, the mesh was secured to the musculofibrous edges of the hernial ring with 25 preplaced sutures of No. 2 braided polyester material[e] in a horizontal mattress pattern (**Figure 2**). The suture material used to secure the mesh had a 3/8-inch circle, reverse cutting needle. The suture was double armed with a needle on each end of the suture strand. To place each horizontal mattress suture, 1 needle was placed through the edges of the diverticulum and the other

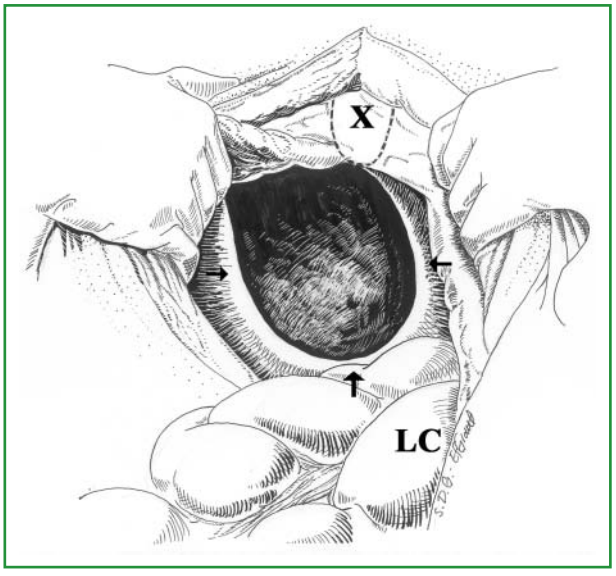

Figure 1—Illustration detailing the anatomical appearance of a retrosternal (Morgagni) hernia involving the right side of the diaphragm (arrows) in a horse that was evaluated because of a sudden onset of signs of abdominal pain. In this horse, the large colon was incarcerated within a large hernial sac in a right-sided muscular defect in the diaphragm. LC = Large colon. X = Xiphoid process.

Figure 2—Photograph obtained during surgical repair of a retrosternal diaphragmatic hernia in a horse that was evaluated because of a sudden onset of signs of abdominal pain. To close the diaphragmatic hernia, mesh herniorrhaphy was performed; in this view from the abdominal cavity, the polypropylene mesh is visible.

needle was placed in a similar fashion. The 2 needles were then placed through the mesh, and the needles were removed from the suture material. The ends were then secured with hemostats. Long-handled needle holders were used to aid in the placement of individual sutures. Once all of the sutures were placed, the sutures were hand tied individually without excessive tension, so that the mesh was positioned without bunching against the edges of the hernia. Ventrally, there was no edge of the hernia available, and the sutures therefore penetrated the ventral abdominal wall and xiphoid cartilage. Excess mesh was trimmed to minimize trauma (secondary to friction on the edges of the mesh) to the surrounding soft tissues. Following placement of the mesh, the abdominal cavity was lavaged with 15 L of lactated Ringer's solution.

A pelvic flexure enterotomy was performed to remove impacted feed material and decrease the size of the large colon, thereby minimizing pressure of the large colon on the mesh herniorrhaphy site during recovery from general anesthesia. The pelvic flexure enterotomy was closed as previously described.[1] The pelvic flexure was covered with sodium carboxymethylcellulose prior to replacing the large colon into the abdominal cavity, and 2 L of sodium carboxymethylcellulose was instilled in the peritoneal cavity prior to abdominal wall closure. The linea alba was closed by use of No. 3 polyglactin 910 suture in an inverted cruciate pattern. The subcutaneous tissue was closed with 2-0 polyglactin 910 suture in a simple continuous pattern, and the skin was closed with stainless steel staples.

Horse 1 recovered from anesthesia without complications. Following surgery, the horse was fed a complete pelleted ration.[a] Administration of penicillin G potassium, gentamicin sulfate, and flunixin meglumine as previously described was continued for 5 days after the surgical procedure. The horse did not develop any complications following surgery. The horse was discharged on day 8. The owner was instructed to provide stall rest for the horse for 1 month followed by turn out into a small paddock for 30 days. It was also recommended that the horse not be ridden for 90 days following surgery.

The owner was contacted 6 months following surgical closure of the hernia. At that time, the horse was being ridden and the diet consisted of pelleted feed, 2 flakes of hay daily, and daily access to pasture. No signs of abdominal pain had been observed since discharge from the hospital. At 2 years after surgery, the horse had been returned to its normal exercise level as a dressage horse. There had been no episodes of abdominal pain, and the horse was being fed a diet consisting of hay and grain. The owner did remark that the horse would cough 2 to 3 times following placement of the saddle prior to exercise, but no signs of exercise intolerance had been observed. The horse has performed to meet the expectations of the owner.

Standing lateral thoracic radiographic views were obtained 2 years following the second surgery. Abnormal radiographic findings included a round radiopaque area (approx 15 cm in diameter) cranial to the ventral aspect of the diaphragm (**Figure 3**). It appeared that the hernial sac contained a soft tissue density compatible with fibrous tissue or fluid. No abnormalities were detected via physical examination.

A 1-year-old 300-kg (660-lb) Paint filly (horse 2) was admitted to the hospital for evaluation of acute signs of abdominal pain. At admission (day 0), rectal temperature and respiratory rate were within reference ranges, but the heart rate was mildly high (48 beats/min; upper reference limit, < 40 beats/min). No abnormal respiratory sounds were auscultated, and no referred gastrointestinal sounds were auscultated over the thorax. Abdominal palpation per rectum was performed and revealed large intestinal distension with a taenia coursing adjacent to the nephrosplenic ligament. No other intestinal abnormalities were identified via palpation. A preliminary diagnosis of left dorsal displacement of the large intestine was made, and the horse was treated with phenylephrine (3 µg/kg [1.4 mg/lb], IV). Nine hours after admission, signs of abdominal pain again developed. Abdominal palpation per rectum was repeated and revealed that the large intestine was distended with gas and was positioned against the left body wall. Continued conservative management (including administration of mineral oil via nasogastric tube) was performed, and within 14 hours of admission, horse 2 began to pass feces mixed with mineral oil. No further signs of abdominal pain were observed, and the horse was returned to a normal diet. The horse was discharged from the hospital on day 4.

Six months following discharge, the horse was readmitted for evaluation because of the sudden onset of signs of abdominal pain. During physical examination, no signs of abdominal pain were detected and heart rate, respiratory rate, and rectal temperature were within reference ranges. Abdominal palpation per rectum revealed hard fecal balls within the small colon and mild gas distension of the cecum and large intestine. Conservative management including IV fluid therapy (1 to 2 L/h) and withholding of feed was elected. Within 5 hours of admission, the horse developed signs of abdominal pain. Flunixin meglumine was administered

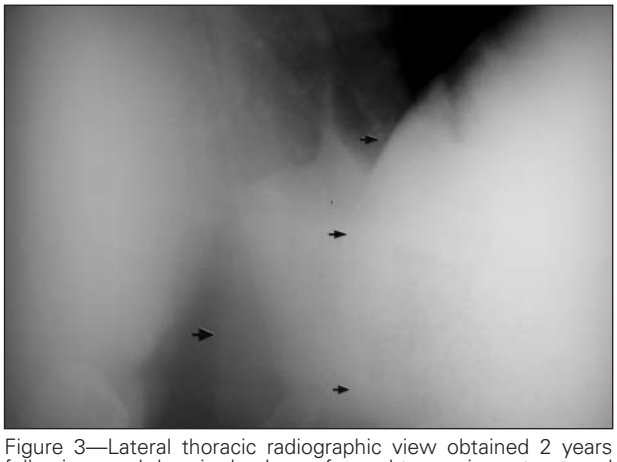

Figure 3—Lateral thoracic radiographic view obtained 2 years following mesh herniorrhaphy performed to repair a retrosternal diaphragmatic hernia in a horse (horse 1). Abnormal radiographic findings included an area of soft tissue density (large arrow) compatible with fibrous tissue or fluid (approx 15 cm in diameter) cranial to the ventral aspect of the diaphragm. The intact diaphragmatic border following surgical correction of the diaphragmatic hernia is visible (small arrows).

(1.1 mg/kg, IV), and signs of abdominal pain resolved. By 12 hours following admission, signs of abdominal pain returned (eg, rolling and becoming cast in stall). Abdominal palpation per rectum revealed moderate gas distension of the cecum and large intestine. An abnormal amount of gastric reflux (> 3 L) was obtained following passage of a nasogastric tube. Because of the continued signs of abdominal pain and abnormal rectal examination findings, an exploratory celiotomy was recommended to the owner.

The horse was anesthetized routinely and positioned in dorsal recumbency. A right paramedian laparotomy incision was performed. Exploration of the abdomen revealed that the pelvic flexure was rostrally displaced and incarcerated in a diaphragmatic defect located in the right ventral aspect of the diaphragm. The position and type of the defect were identical to those in horse 1. In addition to the large intestine, the right aspect of the liver was displaced into the hernia. The edges of the hernia were palpably smooth and rounded. There was no evidence of recent trauma to the diaphragm (eg, rough edges or signs of recent hemorrhage). The width, height, and depth (extending cranially into the thoracic cavity) of the hernia were 20, 30, and 20 cm, respectively. The incarcerated segment of large colon was removed from the hernia without difficulty, but no attempts were made to close the hernia during this initial surgical procedure. No other abnormalities were identified within the abdominal cavity.

Recovery from anesthesia was uneventful, and no postoperative complications developed following surgery. To minimize the risk for reincarceration of the large colon into the diaphragmatic hernia, horse 2 was fed a complete pelleted feed but no grass or hay. The horse was discharged from the hospital on day 12.

Surgical correction of the diaphragmatic hernia (as described for horse 1) was recommended to the owner. However, the owner did not elect corrective surgery. During a telephone follow-up conversation with the owner 3 years after the initial abdominal surgery was performed, it was reported that the horse was still being fed a complete pelleted feed and had developed no complications since surgery. The horse had grown as expected and had performed satisfactorily according to the owner.

A 1-year-old 393-kg (865-lb) Standardbred filly (horse 3) was admitted to the hospital for evaluation of signs of abdominal pain of 12 hours' duration. At the initial evaluation, the horse had mild signs of abdominal pain. Heart and respiratory rates were within reference ranges, but the rectal temperature was high (38.7°C [101.6°F]; upper reference limit, 38.3°C [101.0°F]). The PCV was 29% (reference range, 30% to 40%), and serum total protein concentration was 5 mg/dL. No gastric reflux was obtained following placement of a nasogastric tube. No abnormal respiratory sounds were auscultated, and no referred gastrointestinal sounds were auscultated over the thorax. Abdominal palpation per rectum revealed a mildly distended large colon on the left side of the abdomen. A presumptive diagnosis of left dorsal displacement of the large colon was made. Phenylephrine (3 µg/kg, IV) was administered to promote splenic contraction. Following 12 hours of conservative management, signs of abdominal pain persisted and the horse became nonresponsive to analgesic administration. Abdominal palpation per rectum revealed moderate to severe large colon distension, and a large colon volvulus was suspected. An exploratory celiotomy was recommended to the owner.

The horse was anesthetized routinely and positioned in dorsal recumbency. A right paramedian abdominal incision was made. Abdominal exploration revealed that the ventral colon was entrapped in a diaphragmatic hernia and hernial sac involving the right ventral aspect of the diaphragm, as described for horses 1 and 2. In addition to the large colon entrapment, the colon was displaced around the base of the cecum. To rehydrate the colonic contents, the large colon was infused with lactated Ringer's solution. No other abnormalities were identified, and the abdominal cavity was closed as previously described. The horse did not develop any postoperative complications and was discharged 9 days after surgery.

The owner was instructed to feed a completed pelleted feed[a] and eliminate hay from the diet. No signs of abdominal pain developed while the horse was receiving the complete pelleted feed. The owner elected to allow surgical correction of the diaphragmatic hernia. The horse was admitted to Purdue University Large Animal Hospital 46 days following the initial exploratory celiotomy. Physical examination revealed no physical abnormalities. To further evaluate the diaphragmatic hernia, lateral thoracic radiographic views were obtained. Radiographic findings included the presence of the large colon in the thorax; a membrane representing the hernial sac separated the large colon from the pleural space (**Figure 4**).

In preparation for surgery, food but not water was withheld from the horse for 48 hours. The horse was anesthetized and positioned in dorsal recumbency, as described for horse 1. A 30-cm ventral midline incision extending caudally from the xiphoid process was made to allow access to the abdominal cavity. Finochietto retractors were used to retract the abdominal wall, just caudal to the xiphoid process. Abdominal exploration revealed that the large colon, a portion of the spleen, the small colon, and several loops of jejunum were lo-

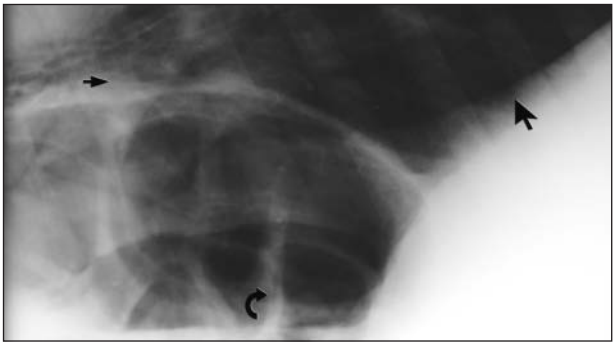

Figure 4—Lateral thoracic radiographic view obtained 46 days following an initial exploratory celiotomy during which a retrosternal diaphragmatic hernia was detected in a horse (horse 3). The intact dorsal border of the diaphragm (large arrow) and the radiographic margins of the hernial sac (small straight black arrow) are visible. Sacculations and haustra of the large colon incarcerated in the diaphragmatic hernia can be seen (small curved arrow).

cated within the hernia. All of the intestinal contents were removed from the defect, which measured 20 × 20 × 10 cm. The diaphragmatic defect was closed with prosthetic mesh, as described for horse 1. To secure the mesh, 25 sutures of No. 2 braided polyester suture material were placed. Prior to abdominal wall closure, an omentectomy was performed by application of transfixation sutures of No. 1 polyglactin 910 suture. Because the large colon was fairly empty, an enterotomy was not performed. Two liters of sodium carboxymethylcellulose was placed into the peritoneal cavity prior to abdominal wall closure. The abdominal incision was closed as previously described. Horse 3 recovered from anesthesia without complication.

The only complication that developed following abdominal surgery was an incisional infection. Numerous skin staples were removed from the draining portions of the incision. The horse was administered trimethoprim sulfamethoxazole (30 mg/kg [13.6 mg/lb], PO, q 12 h) and metronidazole (25 mg/kg [11.4 mg/lb], PO, q 8 h). No signs of abdominal pain developed following surgery, and the horse was discharged 18 days after surgery. The owner was instructed to administer the antimicrobials for an additional 6 days and then discontinue those treatments. The owner was also instructed to gradually reintroduce the horse's regular diet. The horse was to receive stall rest for 1 month and then turn out into a small paddock for 30 days. It was also recommended that the horse not be trained until 90 days following surgery.

The horse was readmitted to the hospital for reevaluation 5 months following discharge. The horse appeared to have normal body condition, and no physical examination abnormalities were identified. The owner reported that the horse had not developed signs of abdominal pain since its discharge from the hospital. The abdominal incision had healed without complication. To further evaluate the diaphragm, lateral thoracic radiographic views were obtained. Thoracic radiography revealed that the diaphragm was intact with no signs of intestinal herniation through it. No abnormalities were detected in the lung parenchyma, and there was no evidence of fluid accumulation in the hernial sac, as evident in horse 1. Fourteen months following surgical correction of the diaphragmatic hernia, horse 3 had no signs of abdominal pain and was in race training.

Discussion

Embryologically, the diaphragm is formed by the septum transversum, dorsal embryonic mesentery, pleuroperitoneal folds, and body wall mesenchyme.[2-7] The septum transversum develops opposite the third, fourth, and fifth cervical somites. The ventral portion of the septum transversum separates the pericardial cavity from the extension of the peritoneal cavity between the liver and the primordial diaphragm.[8] The septum transversum becomes the central tendinous portion of the diaphragm. The embryonic mesentery becomes the caudal mediastinum. The pleuroperitoneal folds originate from the mesonephros and later expand and fuse with the septum transversum ventrally and with the caudal mediastinum medially to complete formation of the diaphragm. Retrosternal hernias develop when the septum transversum and the pleuroperitoneal folds do not fuse completely.[3-7] This lack of fusion leaves a defect in the diaphragmatic musculature that later develops into the hernial sac. The hernial sac consists of both peritoneum and pleura. It is believed that, as individuals age, the hernial sac enlarges with increased intra-abdominal pressure that develops secondary to increasing intestinal bulk and deposits of intra-abdominal fat.[3-7] Enlargement of the hernial sac results in a space in which portions of the intestine can become incarcerated.

Retrosternal hernias are congenital and not traumatic in origin.[3-7] This is supported by the fact that in all affected horses described in published reports[9-11] and in the 3 horses of this report, the borders of the hernias were smooth, fibrous, and thickened, indicating that the defect was chronic or congenital. We believe that trauma was an unlikely cause of the diaphragmatic defect in the horses of this report because there was no open connection between the thoracic and abdominal cavities and because the margins of the hernia had no signs of recent hemorrhage or inflammation. Furthermore, there was no history of trauma in any of the 3 cases. In a horse of a previous report,[9] histologic examination revealed that the edges of the diaphragmatic hernia were composed of mature fibers running parallel to the defect without evidence of granulation or scar tissue.[9] This also supports that retrosternal hernias are congenital and not acquired.

The type of diaphragmatic hernia identified in the 3 horses of this report here is best described as retrosternal because these hernias were located lateral to the xiphoid cartilage and extended cranially into the thoracic cavity. In humans, this type of congenital diaphragmatic herniation is known as a Morgagni hernia.[3-7] The foramen of Morgagni is a triangle-shaped space between the muscular portion of the diaphragm that originates from the xiphoid and the costal margin and inserts on the central tendinous region of the diaphragm. Retrosternal or Morgagni hernias are located on the ventral (anterior) surface of the diaphragm and always have a hernial sac. In humans, 90% are located on the right side, 5% are located on the left side, and 5% are bilateral.[3-7] In most instances, humans with retrosternal hernias have no clinical signs, but some individuals have clinical signs of intestinal tract obstruction. The most common segment of intestine to herniate is the transverse colon, followed by the stomach and omentum. Surgical repair is recommended whenever segments of the intestinal tract become incarcerated in the hernia and clinical signs of intestinal tract obstruction or chronic, cranially located abdominal pain develops.[3-7]

To our knowledge, there are 2 case reports[9,10] of a diaphragmatic diverticulum and 1 case report[11] of peritoneopericardial diaphragmatic hernia in horses in the veterinary medical literature. We propose that the abnormality in the first 2 cases should be termed retrosternal hernias rather than diaphragmatic diverticula (as classified in humans). Of the 3 previously reported cases[9-11] and the 3 cases of this report, all horses had right ventral diaphragmatic defects with incarceration of the large colon. The abnormality in the report[11] of the third horse was described as a peritoneopericardial hernia, although this was somewhat different from the hernias in the horses of this report in that there was a direct communication between the peritoneal cavity and the pericardium;

nevertheless, the diaphragmatic defect was in the same location. A similar type of hernia (diaphragmatic diverticulum) has also been reported in a dog.[12]

Among the horses of this report, none had physical examination findings that are commonly attributed to a diaphragmatic hernia. All horses had signs of abdominal pain only and were initially diagnosed with left dorsal displacement of the large colon. Retrosternal hernias are different from other types of diaphragmatic hernias because the presence of the hernial sac prevents the displacement of portions of the intestinal tract into the thoracic cavity. Similarly, the hernial sac is wide enough to decrease the likelihood of intestinal strangulation, but not obstruction or obstipation. Intermittent or chronic signs of abdominal pain are evident depending on whether the large colon is incarcerated in the hernial sac. When incarcerated, the large colon becomes impacted and this results in signs of abdominal pain. Relief of such impaction accounts for the initial response to medical management in horse 2 and the improvement in clinical signs following the removal of roughage from the diet subsequent to the initial abdominal surgery in all 3 horses of this report.

The surgical approach to a diaphragmatic hernia in horses is typically difficult because of limited access to the diaphragm, especially with dorsally located defects, and because of the difficulty in excluding viscera from the diaphragmatic defect. For horses 1 and 3 that underwent surgical repair of the hernia, the use of a surgical table that could be tilted was particularly helpful in displacing viscera from the surgical field. The ventral position of this type of diaphragmatic hernia makes surgical access easier than that associated with dorsally located hernias. If possible, feed withdrawal prior to surgery is helpful in reducing colonic bulk. Despite the improved exposure of the defect achieved via tilting of the surgical table, it was still necessary to isolate the large colon and small intestine from the surgical field by use of towels soaked in saline solution in horses 1 and 3. However, the only specialized surgical instrumentation required were long-handled needle holders and thumb forceps and Finochietto rib retractors.

Of the 6 horses with retrosternal hernias (horses 1, 2, and 3 and the 3 horses of previous reports[9-11]), 4 were repaired with a prosthetic mesh; closure of the defect with prosthetic mesh was required because the hernial defect was too large to be closed primarily. Polypropylene mesh was used because it is readily available and inert and is one of the strongest mesh materials currently available. However, it is expensive, compared with the cost of plastic-type meshes. The use of double-armed suture material and preplacement of all sutures before tying securely facilitated tensionless placement of the mesh. The most serious complication associated with polypropylene and plastic-type meshes that are placed within the peritoneal cavity is intra-abdominal adhesion formation.[13] The 2 horses of this report that were treated by use of a mesh did not develop clinical signs of intra-abdominal adhesion formation during follow up. To lessen the risk for intra-abdominal adhesion formation, we recommend that sodium carboxymethylcellulose is added to the abdominal cavity prior to abdominal wall closure. In humans, surgical repair of retrosternal hernias has been historically performed via the abdominal cavity. Currently, most individuals with retrosternal hernias undergo repair procedures via laparoscopic techniques involving primary closure with either laparoscopic implantation of polypropylene- or polytetrafluoroethylene-based material or small intestinal submucosa bioabsorbable mesh.[14-16]

Surgical removal of the hernial sac is controversial in human surgery.[3-7,14-16] Advocates of hernial sac removal think that removal of the sac is necessary to avoid leaving a loculated space-occupying lesion in the thoracic cavity. Surgeons that do not advocate resection of the hernial sac believe that leaving the sac in place has no clinical importance, lessens the risk for development of pneumothorax and pneumopericardium, and minimizes iatrogenic damage to the lung parenchyma or pericardium during disruption of adhesions associated with the hernial sac. The hernial sac was not removed in any of the 3 horses described in the previous reports, and no complications were identified as a consequence. In the horses of this report, there were no clinical complications associated with leaving the sac in situ, even though a fluid density was radiographically evident in the hernial sac of horse 1 after surgery.

a. Equine senior, Purina Mills, St Louis, Mo.
b. Equine surgical table, Kimzey Welding Works Inc, Woodland, Calif.
c. Equine enterotomy tray, Kimzey Welding Works Inc, Woodland, Calif.
d. Prolene mesh, Ethicon Inc, Somerville, NJ.
e. No. 2 Mersilene (double armed), Ethicon Inc, Somerville, NJ.

References

1. Adams S, Fessler J. Enterotomy techniques. In: Adams S, Fessler J, eds. *Atlas of equine surgery*. Philadelphia: WB Saunders Co, 2000;93–96.
2. Cullen ML, Klein MD, Philippart AI. Congenital diaphragmatic hernia. *Surg Clin North Am* 1985;65:1115–1138.
3. Comer TP, Clagett OT. Surgical treatment of hernia of the foramen of Morgagni. *J Thor Cardiovasc Surg* 1966;52:461–468.
4. Ketonen P, Mattila SP, Mattila T. Surgical treatment of hernia through the foramen of Morgagni. *Acta Chir Scand* 1975;141:633–636.
5. Paris F, Tarazona V, Casillas M. Hernia of Morgagni. *Thorax* 1973;28:631–636.
6. Thomas GG, Clitherow NR, Laine K. Herniation through the foramen of Morgagni in children. *Br J Surg* 1977;64:215–217.
7. Wolloch Y, Grunebaum M, Glanz I. Symptomatic retrosternal (Morgagni) hernia. *Am J Surg* 1974;127:601–605.
8. Moore KL. Body cavities, primitive mesentries, and the diaphragm. In: Moore K, Persuad TVN, eds. *Before we are born: essentials of embryology and birth defects*. 5th ed. WB Saunders Co, 1983;187–192.
9. Wyn-Jones G, Baker JR. A probable congenital diaphragmatic defect in an adult pony. *Vet Rec* 1979;105:251–252.
10. Proudman CJ, Edwards GB. Diaphragmatic diverticulum (hernia) in a horse. *Equine Vet J* 1992;24:244–246.
11. Orsini JA, Koch C, Stewart B. Peritoneopericardial hernia in a horse. *J Am Vet Med Assoc* 1981;179:907–910.
12. Cato WR. Diverticulum in the diaphragm of a dog. *Vet Med Small Anim Clin* 1962;57:706–707.
13. Tulleners EP, Fretz PB. Prosthetic repair of large abdominal wall defects in horses and food animals. *J Am Vet Med Assoc* 1983;182:258–262.
14. Tarim A, Nursal T, Yildirim S. Laparoscopic repair of bilateral morgagni hernia. *Surg Laparosc Endosc Percutan Tech* 2004;14:96–97.
15. Holcomb G, Ostlie D, Miller K. Laparoscopic patch repair of diaphragmatic hernias with Surgisis. *J Pediatr Surg* 2005;20:E1–E5.
16. Percivale A, Stella M, Durante VJ. Laparoscopic treatment of Morgagni-Larrey hernia: technical details and report of a series. *J Laparoendosc Adv Surg Tech A* 2005;15:303–307.