Diaphragmatic Hernia: Etiology, Clinical Presentation, and Diagnosis*

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ABSTRACT: Diaphragmatic hernia in horses typically manifests as an acute abdominal crisis, but respiratory signs may be present. Certain aspects of the clinical presentation of horses with this condition, such as loud thoracic borborygmi combined with decreased respiratory sounds in the affected hemithorax, are suggestive of diaphragmatic hernia and should encourage further investigation. Intraoperative diagnosis of the condition is common. Awareness of the presence and the clinical manifestation of diaphragmatic hernia in the horse, combined with early use of available imaging modalities, can yield a preoperative diagnosis. Radiography and ultrasonography are the diagnostic modalities of choice. Early diagnosis allows better preoperative planning and postoperative results, thus improving the overall prognosis of horses with diaphragmatic hernia.

Although diaphragmatic hernia is an uncommon lesion in the horse, it is not exceedingly rare. In several retrospective studies that reviewed a combined total of more than 1,400 cases of equine abdominal surgery, diaphragmatic hernia accounted for 0.67% to 7.77% of the cases. We had eight cases of diaphragmatic hernia at our hospital between 1998 and 2005; abdominal surgery was performed in six of these cases. These six surgeries accounted for 1% of all surgical colic cases during that period; this rate is similar to reported percentages for ileocecal intussusception (1.3%) and small colon impaction (1.3%), which are not considered rare. Thus diaphragmatic hernia should be included in the differential diagnosis of horses presenting with abdominal pain.

By definition, in a true hernia, the migrating organs are contained within a hernial sac, whereas in the absence of a hernial sac, the condition is defined as a false hernia or rupture. Most congenital diaphragmatic hernias (CDH) and all acquired diaphragmatic hernias (ADH) are false hernias. Thus the term diaphragmatic rupture or diaphragmatic tear may be more accurate than diaphragmatic hernia to describe the condition commonly seen in horses. However, because of its prevalence in the literature, the term diaphragmatic hernia is used in this article.
Diaphragmatic hernia often presents a diagnostic challenge. The condition is usually acquired, but congenital cases have been reported. The history often reveals a potentially causative event, such as trauma or dystocia, that resulted in an increase in intraabdominal pressure. The intestines are typically herniated, but other viscera may be involved. Clinical signs most often include abdominal pain but may include respiratory compromise. The degree of abdominal pain is often severe, and securing an accurate preoperative diagnosis is sufficiently difficult that the correct diagnosis is often made intraoperatively or at necropsy. Diagnosis may be even more challenging in horses presenting with mild respiratory compromise or other vague clinical signs. Postmortem diaphragmatic hernia may also occur due to postmortem trauma or to bacterial fermentation that causes intestinal distention and leads to increased abdominal pressure. These lesions are typically located at the ventral midline just dorsal to the xiphoid process. Increased awareness of the condition, combined with astute clinical observation and improvements in the availability and quality of diagnostic imaging, may lead to earlier preoperative diagnosis of diaphragmatic hernia.

ANATOMY AND EMBRYOLOGY

The diaphragm is composed of two main components: the peripheral muscular part (pars costalis) and the central tendinous part. Three foramina perforate the central tendinous portion of the diaphragm for passage of the caudal vena cava, esophagus, and aorta (Figure 1). The diaphragm originates from five main embryonic components: the septum transversum, mesoesophagus, bilateral pleuropertitoneal folds, body wall, and posthepatic mesenchymal plate (Figure 2). The septum transversum develops early ventrally and forms the ventral central tendinous part of the diaphragm. The mesoesophagus expands dorsoventrally, thereby enlarging the bilateral pleuropertitoneal canals dorsally. These canals are closed by formation of the bilateral pleuropertitoneal folds, which fuse ventrally with the septum.
**Key Points**

- Diaphragmatic hernia in the horse is not as rare as previously reported.
- Findings in the history, physical examination, and initial clinical evaluation may have common characteristics suggestive of diaphragmatic hernia that can lead to early preoperative diagnosis.
- Congenital diaphragmatic hernia can be developmental or secondary to rib fractures from traumatic parturition. In general, left dorsal defects are developmental; ventral lesions are parturition related.
- Plain lateral thoracic radiography and ultrasonography are the diagnostic modalities of choice for equine diaphragmatic hernia. Fluoroscopy and contrast radiography can be of use if plain radiography and ultrasonography are equivocal.

**ETIOLOGY AND PATHOGENESIS**

**Congenital Diaphragmatic Hernia**

Recent evidence suggests that the typical pleuroperitoneal CDH is secondary to pulmonary hypoplasia. Other types of CDH that have been described in horses include hiatal hernia, peritoneopericardial hernia, diaphragmatic diverticulum, and retrosternal (Morgagni) diaphragmatic hernia. Most horses with CDH have a pleuropertitoneal hernia with direct communication between the abdominal and thoracic cavities. Diaphragmatic diverticulum was described as an incomplete diaphragmatic defect in which abdominal contents protruded into the thoracic cavity covered by a membrane. In this type of CDH, there is no breach in the diaphragm and no direct communication between the abdominal and thoracic cavities; this condition can therefore be defined as a true pleuropertitoneal diaphragmatic hernia.

A recent report described Morgagni diaphragmatic hernia in three horses. These horses had large (approximately 20 to 30 cm in diameter), right-sided ventral hernias with a complete hernial sac precluding direct communication between the abdominal and the thoracic cavities. All horses showed abdominal pain, and none showed any respiratory compromise. The authors suggested that previously described cases of a right-sided ventral diaphragmatic hernia with a complete hernial sac are better defined as Morgagni hernias. The embryologic origin of Morgagni hernias is assumed to be failure of the pleuroperitoneal folds to fuse with the septum transversum.

It can be difficult to differentiate CDH and ADH in horses. Although several criteria can be used, in most cases, the available information is incomplete, and individual criteria, although valuable, are insufficient for differentiating the two forms. The criteria used include age, gross and histologic appearance of the opening borders, relation of the size of the opening to the volume of displaced abdominal content, absence of diaphragmatic tissue, and coexistence of other developmental anomalies.

**Age of animal.** The age of the animal is a useful criterion when diaphragmatic hernia is evident at or soon after parturition. However, because clinical signs associated with diaphragmatic hernia can be delayed for years, it can be difficult to ascertain whether a defect is congenital or acquired based solely on the patient’s age. Some cases of diaphragmatic hernia in adult and even geriatric horses are assumed to be congenital if the animal has no history of trauma, the opening is in the left dorsal aspect of the diaphragm, and the defect has smooth, rounded, thin edges. Histologic examination of congenital defects in the diaphragm reveals smooth, rounded borders and a lack of inflammation or excessive fibrosis.

In several reports of CDH in foals, the ascending colon was located in the thoracic cavity and the defect in the diaphragm was too small to accommodate the volume of herniated intestine. This finding indicates that the intestines had migrated into the thorax well before the time of diagnosis, supporting the congenital nature of the defect. Absence of a hemidiaphragm, a manifestation of agenesis, is another form of CDH. Occasionally, CDH is accompanied by other thoracic or skeletal developmental defects. It can result from defects in embryonic development, such as incomplete fusion of any of the contributing diaphragm components, or from intrauterine trauma associated with parturition. Trauma during parturition can cause rib fractures that may result in CDH. However, in most instances, the defect is presumed to be the result of incomplete fusion of the pleuropertitoneal folds.

**Defect location.** CDH typically occurs in the left dorsal tendinous part of the diaphragm, which is in keeping with the theory of incomplete pleuropertitoneal fold fusion. In 64% (9 of 14) of confirmed CDH cases...
in horses, the lesion involved the left side of the diaphragm.\textsuperscript{21,25–31,35} Two theories explain this left dominance.\textsuperscript{20,39,40} First, the left pericardioperitoneal canal is larger and closes later in embryonic development and thus may be more prone to malformation.\textsuperscript{39,40} Second, the left lung bud develops more slowly than the right and tends to be hypoplastic, and studies\textsuperscript{20} have suggested that lung hypoplasia can lead to CDH. In recently confirmed cases of traumatic parturition causing diaphragmatic hernia in three foals, all lesions were at the ventral aspect of the diaphragm. In addition, Santschi et al\textsuperscript{41} and Ethell et al\textsuperscript{42} reported a total of four ventral diaphragmatic hernias in immature horses; in two of the affected foals, healed rib fractures were found adjacent to the tear in the diaphragm. These findings indicate that the diaphragmatic defect location may help differentiate between traumatic and developmental CDH. It appears that left dorsal lesions are developmental in origin, while ventral ones are more likely to be related to trauma during parturition.\textsuperscript{17,32} The recently described Morgagni hernias are ventrally located but easily identified as developmental by their intact hernial sac.\textsuperscript{24}

### Defect size

CDH ranges in size from complete agenesis of the hemidiaphragm\textsuperscript{28,31} to defects less than 2 cm in diameter.\textsuperscript{30} However, half of confirmed reported cases (nine of 18) were large enough to allow herniation of multiple organs.\textsuperscript{5,22,23,25–29,31,35} CDH was most often confirmed in neonates. Therefore, there may be a bias toward detecting larger defects that are incompatible with life as opposed to small defects that may manifest later in life.

### Acquired Diaphragmatic Hernia

Most diaphragmatic hernias in horses are assumed to be acquired.\textsuperscript{9,41} Acute diaphragmatic lesions have raw, irregular, bleeding borders with histologic evidence of inflammation.\textsuperscript{5,14,41,43} Chronic lesions have thick, smooth borders with mature fibrous tissue and may be accompanied by visceral adhesions to the omentum and liver.\textsuperscript{5,14,41,44–50} More than 60% (36 of 58)\textsuperscript{b} of reported cases of ADH appeared chronic at the time of diagnosis; a few had evidence of recent enlargement of a previously existing tear.\textsuperscript{45,51–53} Horses with ADH usually present after an incident that caused increased intra-abdominal pressure.\textsuperscript{1,14,17,54,55} Nearly 70% (43 of 62)\textsuperscript{b} of cases in the literature included an event in the history that could be a potential cause, such as falling, running into an object, being hit by a car, or fighting with other horses.\textsuperscript{41,45,46,48,51,53,56–59} Other causes of increased intra-abdominal pressure, such as advanced pregnancy, parturition or dystocia, natural service, and strenuous exercise, have also been associated with diaphragmatic hernia.\textsuperscript{5,11,32,43,46,49,51,60–63} Fractured ribs—some old and healed and some fresh—were reported in several cases, supporting thoracic trauma as a cause.\textsuperscript{41,44,53,64–67} In some cases, omental adhesions link the fractured rib with the diaphragmatic tear and thus substantiate the fracture as the cause of the tear.\textsuperscript{51}

#### Defect location

Similar to CDH, ADH occurs more frequently on the left side.\textsuperscript{3,57} In published cases, nearly twice as many acquired diaphragmatic defects were on the left side than on the right (51 and 28 cases, respectively). This left-side dominance may be explained by the physical protection of the liver on the right side. Another possible explanation is that some defects categorized as acquired may actually be previously undetected long-standing congenital defects. In most cases, the tears were at the junction between the rigid tendinous and the pliable muscular portions of the diaphragm.\textsuperscript{11,17,43,54} This location is likely to be prone to damage because of the interface between two tissues with different mechanical properties. In seven of the eight ADH cases we have seen in recent years, the tears were at the left dorsal aspect of the tendinous muscular junction. Among 96 horses with ADH, the defect was in the dorsal portion of the diaphragm in 44 horses, the ventral portion in 44, and the middle portion in 17, and in one horse, it encompassed most of the length of the diaphragm.\textsuperscript{4,5,11,13,15,21–27,30,32–34,41–45,57,59–78} (Figure 3).

#### Defect size

ADH defects vary in size from 2 to 3 cm to more than 50 cm long\textsuperscript{68}; in 64% (44 of 69) of reported cases of ADH, the defect was at least 10 cm long.

### CLINICAL SIGNS

The clinical signs related to diaphragmatic hernia in horses vary greatly, with most horses showing signs of acute abdominal pain.\textsuperscript{1,15,16} The variability in clinical signs is due to the different organs involved, the level of damage to the intestine, and the degree of respiratory compromise. Abdominal pain may result from impaction, incarceration, or strangulation of the intestine in the thorax. Respiratory signs can arise from compromised lung function secondary to cranial migration of abdominal contents, pleural effusion, pneumothorax, loss of diaphragmatic function, and pain during respiration. In
reported cases of diaphragmatic hernia involving only the small intestine, clinical signs included acute, severe colic in 86% (38 of 44) of horses. Large colon herniation may result in abdominal pain, respiratory signs, or both. In nearly 80% (31 of 39) of published cases involving the large colon, either solely or combined with the small intestine, the affected horse showed signs of abdominal pain; of these, 14 horses had acute colic, four had recurrent colic, and 13 had a combination of colic with respiratory signs. In seven cases involving the large colon, dyspnea was the only sign; one horse had exercise intolerance and lethargy.

In cases of acute abdominal crisis, increased respiratory rate and effort are often attributed to severe pain, and some horses with diaphragmatic hernia appear to present with only abdominal signs but may in fact show respiratory signs related to the hernia. Some horses with diaphragmatic hernia may exhibit abnormal body postures, such as crouching down on their hind feet (“dog-sitting”) or adopting an exaggeratedly wide forelimb stance. Others experience peracute cardiopulmonary collapse and die before complete clinical evaluation. In more than 60% (35 of 57) of the reported ADH cases, the lesion appeared chronic. A significant period of time (weeks to years) existed between the event believed to cause the tear and demonstration of clinical signs. Conversely, there are several reports in which clinical signs manifested immediately or soon after diaphragmatic rupture. In several cases involving a chronic lesion, clinical signs were noticed immediately after strenuous exercise. Diaphragmatic tears lacking herniated viscera have been reported to cause clinical signs, however, some horses with herniated viscera were identified at necropsy after showing no or minimal ante-mortem clinical signs.

PHYSICAL EXAMINATION
Thoracic auscultation may reveal decreased respiratory sounds and increased intestinal borborygmi in the affected hemithorax, combined with muffled heart sounds and dullness on percussion. Referred intestinal sounds may normally be heard on thoracic auscultation of nonaffected horses as opposed to direct, loud intestinal sounds heard in affected horses. Rectal palpation may reveal an empty abdomen when the large colon is involved, whereas distention of the small intestine may be palpable with small intestinal incarceration. All these physical examination findings are nonspecific, inconsistent, and subjective. However, in conjunction with relevant history and clinical signs, they should prompt the clinician to conduct further diagnostic tests to confirm or rule out a diagnosis of diaphragmatic hernia.

Nasogastric Intubation
When a large volume of abdominal viscera lies within the thoracic cavity, the esophagus may be compressed. In these cases, expansion of the esophageal lumen by the passage of a nasogastric tube or the administration of a small volume of fluid by tube may cause acute abdominal distress. However, response to nasogastric intubation does not differentiate diaphragmatic hernia from other gastrointestinal crises. Any horse suffering from an abdominal crisis—and even healthy horses—may respond in a similar manner to nasogastric intubation and gastric filling.

Abdominocentesis
The peritoneal fluid is within normal limits in most horses with diaphragmatic hernia. The typical changes that follow intestinal incarceration, both in gross appearance (serosanguineous or cloudy fluid) and in laboratory values (e.g., elevation in cell count and protein concentration), are not common in these cases. Because the compromised intestine lies within the tho-
racic cavity, the abdominal fluid does not reflect the degree of intestinal damage and therefore will not aid in diagnosis. In horses with a recently torn diaphragm, the abdominal fluid may show inflammatory and hemorrhagic changes (serosanguineous appearance, elevated cell count and protein level).

**Ultrasonography**

In the normal thorax, the ultrasonographic image is limited to a bright line that represents the air-filled lungs and moves with each breath. A 3.5- to 5-MHz sector probe is suitable for imaging the equine thorax. Ultrasonography can be helpful in the diagnosis of diaphragmatic hernia involving the small intestine by identifying gas- and fluid-filled tubular structures within the thorax. When the large colon is involved, a thick-walled, sacculated, fluid-filled structure can be imaged within the thorax (Figure 4). Ultrasonography can be especially useful when intestinal motility is demonstrated and when excessive pleural effusion is present. Abdominal ultrasonography is routinely used for initial evaluation of horses presenting with colic in referral and primary care clinics. Simultaneous ultrasonographic screening of the abdomen and thorax may provide a rapid and accurate diagnosis of diaphragmatic hernia.

**Thoracic Radiography**

Preoperative diagnosis of diaphragmatic hernia was confirmed solely by plain lateral thoracic radiography in 60% (17 of 28) of published cases. Radiographic diagnosis is typically based on identifying intrathoracic ascending colon as a large, thick-walled, sacculated structure filled with gas and fluid (Figure 5). To verify the involved hemithorax, left and right lateral thoracic radiographs should be obtained. Acquiring consecutive radiographic images of the same region may reveal positional changes in the suspected intrathoracic tissue that are consistent with intestinal motility. Contrast radiographs can help delineate intestinal loops within the thorax and ascertain the diagnosis.

**Arterial Blood Gas Measurement**

Sampling arterial blood from the transverse facial artery is simple and minimally invasive and can yield important information regarding respiratory dysfunction. Arterial blood gas values obtained at admission and intraoperatively may be consistent with respiratory acidosis and hypoxemia rather than with metabolic acidosis associated with severe gastrointestinal crises.

**Thoracentesis**

Fluid can be collected from the pleural space using ultrasonographic assistance. Pleural fluid evaluation may be helpful in the diagnosis of diaphragmatic hernia. The changes in the fluid would be typical of the changes seen in peritoneal fluid when an intestine is compromised and may include increases in protein con-
centration and cell counts. Thoracentesis carries potential major complications, such as pneumothorax and enterocentesis; therefore, special attention should be given to proper technique.

Laparoscopy

Laparoscopy is indicated in horses with abdominal pain that is refractory to medical management and is either recurrent and chronic or not acute enough to warrant immediate surgical exploration. Diaphragmatic hernia should be included in the differential diagnosis in such cases, and laparoscopy can provide a definitive diagnosis. Laparoscopy is contraindicated in horses with acute colic with severe intestinal distention.

Thoracoscopy

Thoracoscopy can be helpful when diaphragmatic hernia is suspected. The procedure enables the clinician to ascertain the diagnosis and helps in characterizing the lesion and planning the surgical repair.

Exploratory Celiotomy

Diaphragmatic hernia is often diagnosed during abdominal exploration. Abdominal exploration provided the diagnosis in 30% (26 of 86) of reported cases either during surgery or at a postmortem examination. However, diaphragmatic hernia can be missed during surgery, especially if another lesion is found that explains the abdominal crisis. Consequently, special attention should be given to the diaphragm when a free portion of compromised intestine is found with no apparent cause, and every abdominal exploration should include thorough palpation of the diaphragm.

Postmortem Examination

In the past, many cases of diaphragmatic hernia were diagnosed after death because abdominal exploration was not often performed and imaging modalities were not commonly available. Based on a review of published diaphragmatic hernia cases, more than 40% (36 of 89) were diagnosed by postmortem examination. Severe CDH is often diagnosed after death.

REFERENCES

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1. Which statement regarding diaphragmatic hernia is true?
   a. Diaphragmatic hernia is one of the most common surgical findings at abdominal exploration.
   b. Diaphragmatic hernia is as common as some other intestinal lesions.
   c. Diaphragmatic hernia rarely involves the intestines; thus it is extremely rare compared with other surgical findings at abdominal exploration.
   d. Diaphragmatic hernia is found during approximately 50% of abdominal explorations performed at most referral centers.

2. What is the typical location of developmental CDH?
   a. varies according to breed
   b. ventral midline
   c. left dorsal
   d. left dorsal in males and left ventral in females

3. Which statement regarding diagnosis of diaphragmatic hernia is most accurate?
   a. With the advanced diagnostic modalities currently available, more than 90% of cases are diagnosed before surgery.
   b. Exploratory celiotomy and plain radiography combined represent the mainstay of diagnosis.
   c. Due to lack of sufficient penetration, ultrasonography cannot be used for diagnosis.
   d. Most cases are currently diagnosed postmortem.

4. Which statement regarding differentiation of CDH from ADH is true?
   a. Histologic examination showing lack of inflammation provides a definitive diagnosis of CDH.
   b. Clinical evaluation of the horse allows rapid and definitive differentiation.
   c. There is no definitive answer in many chronic cases.
   d. There is no clear distinction between the two; the differentiation is one of theoretic value and arbitrary definition.

5. Which statement regarding the location of diaphragmatic hernias is true?
   a. It is unclear why congenital hernias appear on the left side, but acquired hernias appear at midline due to the protective coverage of the liver on the right.
   b. Congenital hernias probably appear on the left side due to later development of the left lung bud and the larger left pleuroperitoneal canal; acquired hernias may appear more often on the left because of the protective coverage of the liver on the right side.
   c. Congenital lesions appear on the left side due to slower development of the posthepatic mesenchymal plate, while acquired hernias are more often on the right side.
   d. Congenital lesions are more common on the left side due to slower lung development on that side; acquired lesions are more common in the right hemidiaphragm.

6. What is the typical clinical presentation of equine diaphragmatic hernia?
   a. variable levels of respiratory compromise
   b. chronic exercise intolerance and lethargy
   c. a combination of respiratory signs and mild or recurrent abdominal pain
   d. acute abdominal pain

7. How common is it for a horse with ADH to have predisposing signs, such as evidence of a recent traumatic event?
   a. extremely rare (<0.1% of cases)
   b. very common (nearly all cases)
   c. common in male horses but rare in mares
   d. common (>50% of cases)

8. Which initial patient evaluation findings may be suggestive of diaphragmatic hernia?
   a. painful nasogastric intubation, emptiness on rectal palpation, borborygmi on thoracic auscultation
   b. incomplete diaphragm on rectal palpation, intestinal sounds on auscultation of the thorax
   c. general malaise, poor body condition, referred intestinal sounds on thoracic auscultation
   d. large colon distention on rectal palpation, tachycardia, load harsh heart murmur on the affected side

9. Which organ(s) is/are commonly involved in equine diaphragmatic hernia?
   a. none
   b. liver
   c. small intestine or ascending colon
   d. spleen, stomach, and descending colon

10. What are the diagnostic modalities of choice for diaphragmatic hernia?
    a. plain lateral thoracic radiography and ultrasonography
    b. contrast radiography and nuclear scintigraphy
    c. thoracic low-frequency ultrasonography and venous blood gas analysis
    d. magnetic resonance imaging and exploratory celiotomy