Case Study

Diaphragmatic Hernia of the Stomach with Gastric Rupture in a Domestic Pig

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A 5.5-mo-old castrated, male Red Duroc pig presented acutely with depression and abdominal pain 9 d after an altercation with another pig. A CT examination indicated right pneumothorax and herniation of the stomach into the thoracic cavity. Due to a poor prognosis, the pig was euthanized. A necropsy and gross examination revealed a tear of the diaphragmatic muscle in the region of the esophageal hiatus through which the stomach was displaced into the right side of the thoracic cavity. In addition, the herniated stomach had a rupture of the stomach wall through which the gastric mucosa was everted and exposed into the right thoracic cavity. The right thoracic cavity had acute fibrinous pleuritis, and the right lung was collapsed. CT scans performed every 1 to 2 wk for 2 mo prior to the pig's death did not reveal any abnormalities in the diaphragm. Trauma was considered the most likely cause of the diaphragmatic tear and subsequent herniation and rupture of the stomach.

Abbreviation: DH, diaphragmatic hernia

Hernias involving the diaphragm comprise 3 main types: peritoneopericardial, in which abdominal organs extend into the pericardial sac; pleuropertitoneal, in which abdominal organs are found within the pleural cavity; and hiatal, in which the abdominal esophagus, gastroesophageal junction, or portions of the stomach protrude through the esophageal hiatus of the diaphragm into the thoracic cavity.1

The esophageal hiatus lies in the muscular part of the diaphragm between the 2 medial divisions of the right crus. The esophagus with its supplying vessels and the vagal nerve trunks pass through this opening.11 Of the 3 openings in the diaphragm (caval, aortic, and esophageal), the esophageal hiatus is the weakest because it is formed by pliable muscle, in contrast to the fibrous tendons of the other 2 hiatuses, and is therefore more susceptible to herniation. Hiatal hernias are usually characterized by protrusion of the stomach into the thoracic cavity through a widening of the right crus of the diaphragm.7

Diaphragmatic hernia (DH) occurs in humans14 and in numerous other species including ruminants,5,8,10,35 horses,2 wild16 and domestic canids and cats,19 NHP,18 swine,14,15,26,31,40,42 and rabbits.12 In dogs, DH has been associated with muscular dystrophy3 and reported as a complication of tetanus.1 More specifically, hiatal DH has been reported in cattle,2 dogs,8,16 marine mammals,5,13,34 wild17 and domestic cats,24 and the maned wolf.18 In small animals, such as dogs and cats, automobile-related trauma is a common cause of DH, although congenital defects of the diaphragm also can result in herniation. In horses, in addition to trauma, strenuous activity or dystocia can be contributing factors. In cattle and water buffalo, trauma can lead to herniation of the reticulum.21 DH in conjunction with intrathoracic gastric rupture has been described in humans; contributing factors include pregnancy,22 gastric ulceration,23 strangulation,24 gastroplasty,39 and bariatric surgery29 and volvulus.30

DH is uncommon in swine. There have been a few reports of fatal epizootics of DH in growing swine (birth to 4 mo of age), but a conclusive etiology could not be determined in any of the cases.14,15,26,31,40,42 We here report a unique case of a pig with a diaphragmatic hiatal tear and herniation of the stomach into the thoracic cavity with subsequent rupture of the herniated stomach wall.

Case Report

History and clinical observations. The 5.5-mo-old castrated male Red Duroc pig had been purchased for a research project from a producer whose primary business interest is to sell purebred boars, gilts, show pigs, and semen. All new sows added to the herd are isolated for 45 d and tested for pseudorabies, brucellosis, and porcine reproductive and respiratory syndrome. Sows and boars are routinely vaccinated against porcine parvovirus, leptospirosis, erysipelas, porcine reproductive and respiratory syndrome, and swine influenza. At 5 and 2 wk prior to farrowing, sows are vaccinated with Clostridium perfringens type C, Escherichia coli bacterin-toxoid, Bordetella bronchiseptica, erysipelas, and Pasteurella multocida bacterin-toxoid. At 2 wk after farrowing, sows are vaccinated against leptospirosis and erysipelas. Piglets and adult animals are routinely dewormed. Neonates are injected with iron, penicillin, and tulathromycin (Drarixin, Pfizer Animal Health, New York, NY) and are vaccinated against Mycoplasma hypopneumoniae. At 3 to 4 wk of age, pigs are vaccinated against M.
*Hyopneumoniae*, erysipelas, circovirus, swine influenza, *M. hyorhinis*, *M. hyosynoviae*, and *Streptococcus parasuis*.

The University of Texas MD Anderson Cancer Center is an AAALAC-accredited institution, and all experimental manipulations were approved by the Center’s IACUC. Swine are housed and cared for in accordance with the *Guide for the Care and Use of Laboratory Animals*, Public Health Service policy, and the Animal Welfare Act and Animal Welfare Regulations. The health of all animals is monitored daily.

The pig arrived at our animal facility at the age of 3 mo. He was pair-housed in an indoor run on elevated, plastic-coated, wire-mesh flooring. A fecal examination performed on intake was negative for pathogenic parasites. At 15 d after arrival, the pig was entered into a study investigating a novel absorbable filter that was placed in the inferior vena cava for the prevention of pulmonary embolism. On the day of surgery, the pig was anesthetized, and blood was collected for baseline measurements (CBC, serum chemistry profile, and arterial blood gases). CT and a digital subtraction venacavagram were performed to determine the geometry of the inferior vena cava. Under ultrasound guidance, a 21-gauge needle was used to access the right common femoral vein. A 16-French sheath was advanced into the inferior vena cava to allow deployment of the resorbable filter. After filter deployment, inferior vena cava pressure was measured cephalad (cranial) and caudal to the inferior vena cava filter. Digital subtraction and CT venography were performed to evaluate filter positioning and detect potential filter-related complications. Blood was again collected to assess changes in hematology, serum chemistry, and arterial blood gas values. At 4 d after filter deployment, an autologous thrombus was introduced into the filter by using the same method of access. Pre- and postprocedural bloodwork, pressure measurements, CT imaging, and digital subtraction venacavagrams were performed. Bloodwork, pressure measurements, and imaging were repeated 5 times at intervals of 7 to 14 d. No abnormalities were detected in any of the diagnostic tests or imaging studies performed throughout the study, and the pig was clinically normal until the 61st day of the experiment, when he presented with a spontaneous, acute illness and was euthanized on the same day.

Social housing of social species is the default method at our institution. The subject pig’s social partner was euthanized in the course of the study. The next day (2 d after the subject’s most recent CT scan, which was normal), an attempt was made to house the subject (54.4 kg) with another pig of similar size. It became evident immediately that the animals were incompatible, because they engaged in an aggressive altercation. Therefore, a decision was made to house the 2 pigs separately for the remainder of the study. The only abnormality observed on examination of the subject after the fight was a shallow laceration of the pinna. At 9 d after the fight, the subject presented spontaneously with acute depression, anorexia, and reluctance to stand. On physical examination, palpation of the abdomen resulted in splinting of the abdominal musculature. The pig was anesthetized, and CT was performed. The constellation of CT imaging findings in combination with the pig’s acute clinical presentation were consistent with a rupture of the diaphragm with intrathoracic displacement of the stomach. In light of these results and the poor prognosis, the pig was euthanized.

Images acquired 2 d prior to the fight demonstrated a normal thorax and a normally positioned stomach lying below the diaphragm, with the gastroesophageal junction in the expected position (Figure 1). CT imaging on the day of necropsy showed that the majority of the stomach was herniated into the right lower thorax. In addition, a tension pneumothorax was present in the right thoracic cavity, with a small amount of extraluminal air below the diaphragm (Figure 2).

**Necropsy findings.** The pig was euthanized by exsanguination under general anesthesia, which was followed by a complete necropsy and gross examination of internal organs. Body weight at the time of necropsy was 59 kg. After opening the abdominal cavity, we observed that approximately 80% of the stomach was displaced into the thoracic cavity through a 5-cm linear tear or rupture of the diaphragmatic muscle in the region of the esophageal hiatus. The stomach was twisted and strangulated at the site of herniation through the diaphragmatic rupture (Figure 3 A). The abdominal surface of the diaphragm had a red area in the central portion of the ventral region, consistent with acute or subacute hemorrhage and trauma. The abdominal cavity contained a large amount of clear and pale-yellow proteinaceous fluid, which clotted within 10 min after exposure to room temperature air. The gallbladder was markedly distended with bile content, likely due to extension of the ductus choledochus which, combined with the displacement of stomach, impaired the normal flow of bile into the duodenum.

The stomach was herniated through the diaphragmatic rupture only into the right side of the thoracic cavity. The herniated part of the stomach had diffuse, marked congestion and edema and a 4-cm tear of the stomach wall through which the gastric mucosa was everted (Figure 3 B and D). The right side of the thoracic
Figure 2. CT images on the day of necropsy: (A) A scout image demonstrates a tension pneumothorax on the right (arrowheads). (B) Axial, (C) coronal, and (D) sagittal images demonstrate displacement of the stomach into the right lower chest (arrows). The tension pneumothorax is located anteriorly (ventrally) on the axial image (**).
cavity contained a large amount of yellow to pale-red fluid and copious yellow fibrinous material attached to the pleural surface of the lung and thoracic wall, which were mixed with a small amount of gastric ingesta (Figure 3 C and D). The right lung was collapsed and diffusely red. These lesions confirmed the diagnosis of acute hiatal hernia of the stomach into the right thoracic cavity through a diaphragmatic tear, with subsequent rupture of the herniated stomach wall, acute fibrinous pleuritis, and diffuse atelectasis of the right lung. The tear of the diaphragmatic muscle was longitudinal or parallel to the muscle fibers and had rough margins, with a small amount of blood on the surface.

Discussion

Inguinal and umbilical hernias are the most prevalent congenital disorders in pigs, and the heritability of these abnormalities has been confirmed. Conversely, DH is uncommon in pigs. Although many studies suggest that genetic factors are involved in development of congenital DH in humans, heritability of DH has been proposed but not conclusively demonstrated in swine. One report involved 3 families of swine in which DH was observed from birth to 4 mo of age. Bilateral and right- or left-sided defects were observed. An autosomal recessive mode of inheritance was suspected but not verified. There have been a few reports of fatal epizootics of DH in growing swine (birth to 4 mo of age), but a conclusive etiology could not be determined in any of the cases. The nature of the diaphragmatic defects varied. A report of DH in a commercial production herd involved animals between 21 and 70 d of age. Diaphragmatic defects with smooth, rounded edges (indicating chronicity) involved the right midportion of the diaphragm (with herniation of the large and small intestines), the right and left fibrous portions, or the central part of the diaphragm in the area of the esophageal hiatus (resulting in herniation of abdominal organs into the pericardial sac. The anomalies were so prevalent that elimination of the entire herd was necessary. No etiology could be determined. Epizootics in 4 different herds in another report involved swine between 3 and 16 wk of age. Defects involved the right, tendinous portion of the diaphragm with herniation of the right lobe of the
liver, intestine, cecum, and colon. A genetic predisposition was not confirmed by the evidence, nor was trauma. An association with injectable combinations of vitamin E and sodium selenite was proposed but could not be verified.11

Possible predisposing factors to DH in pigs include congenital malformation, abnormal weakness of the diaphragmatic muscle, vitamin E or selenium deficiency, and trauma. In our case, congenital malformation was ruled out because there was no history of DH in the herd of origin. The serial CT images obtained until 2 d prior to the fight did not reveal any abnormalities in the diaphragm, and the gross examination of the diaphragm did not reveal any developmental abnormalities. Rather, the red area of the tendinous diaphragm in the midventral region, distant from the area of diaphragmatic tear (Figure 3 A), was consistent with hemorrhage and trauma of the diaphragm. The lesion could have been the result of trauma to the sternal region, although the ribs, sternum, and other surrounding tissues were normal grossly.

The experimental manipulation of the pig had no identifiable association with the diaphragmatic tear and intrathoracic herniation of the stomach. The accumulation of large amounts of proteinaceous, clear fluid in the abdominal cavity was likely unrelated to the experimental implantation of the intravascular filter, because the filter was in the expected location, with no lesions or injuries to the surrounding tissues. In addition, gross findings and CT results likewise support the conclusion that the experimental procedure performed did not contribute to the diaphragmatic tear and stomach hernia.

The reason why the pig appeared clinically normal for 9 d after the fight could not be determined with certainty. The CT imaging results, the spontaneous acute clinical illness of the pig, and the gross findings of acute lesions of the stomach indicate that the stomach herniated into the thoracic cavity and ruptured within 24 h prior to necropsy, although the initial tear of the diaphragmatic muscle in the esophageal hiatus region may have occurred 9 d earlier. A possible scenario is that a smaller diaphragmatic tear occurred at the time of the fight and that a subsequent event causing increased abdominal pressure had enlarged the original tear, resulting in intrathoracic herniation and strangulation of the stomach. Increased intraabdominal pressure, such as from coughing, distension of the gastrointestinal tract, or straining to defecate, might have played a role. The subsequent rupture of the stomach in this pig was likely secondary to entrapment and gaseous distension of the stomach, with concurrent ischemia and edema that weakened the stomach wall.

In conclusion, diaphragmatic trauma was the most likely cause of this unusual case of DH of the stomach with intrathoracic rupture of the gastric wall in a domestic pig. DH should be considered as part of the differential diagnosis for swine that develop acute abdominal pain or respiratory distress secondary to a traumatic event. To our knowledge, this report is the first description of DH complicated by gastric rupture in swine.

References


