“Maggie’s Misadventure”

Virginia Huston

Mississippi State University

College of Veterinary Medicine

Class of 2022

Clinicopathologic Conference

July 30, 2021

Advisor

Dr. Seth Kettleman

Clinical Instructor of Small Animal Surgery

Introduction

The diaphragm is an essential anatomic structure that serves as the muscular separation between the thorax and abdomen. The diaphragm is responsible for maintaining and increasing negative pressure within the thorax, allowing the lungs to expand on inspiration. There are many documented conditions associated with the diaphragm, one of the most common being diaphragmatic hernias. Diaphragmatic hernias occur when an abnormal opening of the diaphragm creates discontinuation of the barrier between the thorax and abdomen. Diaphragmatic hernias have a variety of causes resulting in variations of clinical signs at presentation.

History and Presentation

Maggie is an approximately one-year-old female spayed Domestic Shorthair cat that presented to Mississippi State University College of Veterinary Medicine (MSU-CVM) on October 12, 2020, after referral from her primary care veterinarian. Maggie went missing from home for five days. Owners found her on October 10, at which point her owners brought her to an emergency clinic where unremarkable bloodwork was obtained, and Convenia was administered. On October 12, Maggie was brought back to her primary care veterinarian after declining at home, becoming inappetent, lethargic, and having increased respiratory effort. After this visit, she was referred to MSU-CVM for further evaluation.

Upon presentation, Maggie was bright, alert, and responsive. She weighed 4 kilograms and had an ideal body condition score of 4/9. During triage, Maggie began open-mouth breathing. Her temperature was 101.9 degrees Fahrenheit. Her heart rate was slightly elevated at 240 beats per minute with strong synchronous pulses. Her respiratory rate was 36 breaths per minute. Her mucus membranes were pink and moist with a capillary refill time of less than 2

seconds. On cardiopulmonary auscultation, no murmurs, arrhythmias, crackles, or wheezes were appreciated. However, lungs sounds were noted to be subjectively muffled on the left side of the thorax. A small hematoma was noted on her right ventral abdomen and a minor laceration on the medial aspect of her right hock. The remainder of the physical exam was unremarkable.

Diagnostic Tests

Maggie's history and physical exam indicated trauma and generated a list of differentials, including pneumothorax, pulmonary contusions, severe pneumonia, and diaphragmatic hernia. Ultrasound examination, complete blood count, serum chemistry, abdominal and thoracic radiographs were obtained to aid in diagnosing Maggie's condition.

AFAST and TFAST did not reveal any fluid in the thoracic or abdominal cavities. Complete blood count and serum chemistry revealed moderate eosinophilia (4592 /ul), moderate hyperphosphatemia (6.2 mg/dl), mild hypocholesterolemia (90 mg/dl), and mild hypermagnesemia (3.1 mg/dl). Three-view radiographs showed the left ventrolateral half of the diaphragm was discontinuous. There was a mediastinal shift to the right caused by extension of the liver, small bowel, and large bowel into the left pleural space as far cranially as the fourth intercostal space. The lungs had a multifocal unstructured interstitial pulmonary pattern with a corresponding decrease in lung volume. There was a moderate volume of subcutaneous and fascial gas along with the left dorsolateral aspects of the thorax. On abdominal radiographs, cranial displacement of numerous organs including the liver, stomach, spleen, majority of the small intestines, and transverse and ascending colon into the left aspect of the thoracic cavity was appreciated. This information confirmed a diagnosis of diaphragmatic hernia.

Diaphragmatic Anatomy and Pathophysiology

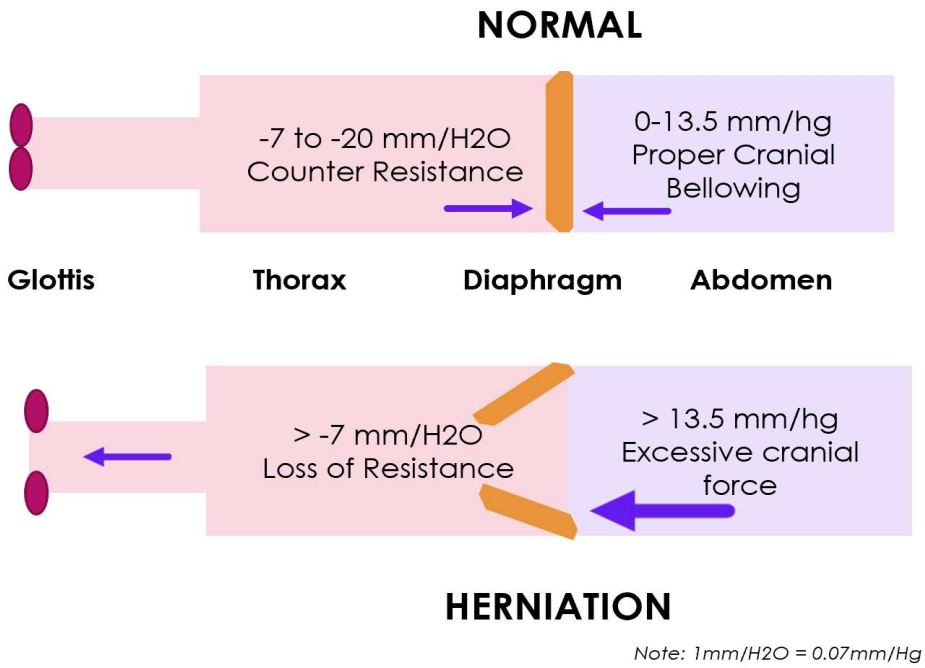
The diaphragm is composed of a singular layer of skeletal muscle that runs like a thin sheet dorsal to ventral and two layers of tendon. The muscular fibers arise from their attachments and travel inward to a tendonous center. The three sections of the diaphragm are based on the aforementioned attachments: lumbar, costal, and sternal. *(Levine, 1987)* Additionally, there are three normal openings within the diaphragm: the aortic hiatus for passage of the aorta, azygous vein, and thoracic duct; the esophageal hiatus for the esophagus along with the dorsal and ventral vagal trunks; and the caval foramen for the caudal vena cava to return to the heart *(Evans, 2016).*

Diaphragmatic hernias can be initially divided into two categories, acquired or congenital. However, it is possible that a congenital defect may yield a predisposition to acquired hernias compared to patients without anomalies *(Wilson, 1983*). Congenital defects are classified as pleuroperitoneal, peritoneopericardial (the most common), or hiatal. Acquired hernias are almost always a result of trauma, most commonly vehicular accidents but can include blunt force trauma, falls, or penetrating wounds *(Levine, 1987)*.

Transdiaphragmatic pressure gradient is the gradient pressure pattern between the abdomen and thorax. It is the disruption of this gradient at the time of trauma that results in intrabdominal pressure in excess of the diaphragms strength *(Toomey, 1980)*. Normal intraabdominal pressure in awake cats is 0-13.7 mm/hg (Rader, 2010). Inspiration creates a greater negative pressure within the thorax, and the glottis closes to keep the air in the lungs for gas exchange, therefore, creating a counter-resistance to normal increases in intrabdominal pressures. This pressure gradient is what allows the diaphragm to bellow cranially appropriately. However, if the glottis fails to remain closed during a traumatic event, intrathoracic pressure increases and results in less counter-resistance. Decreased resistance paired with physiologically

excessive pressure generated by trauma results in discontinuation of the diaphragm and herniation of organs into the thorax *(Levine, 1987).*

FIGURE 1 *(Image Designed by Virginia Huston)*



The muscular portion of the diaphragm is far weaker than the tendonous areas of the diaphragm and is, therefore, the location torn most commonly in traumatic diaphragmatic hernias. *(Levine, 1987)*. Tears can be designated as radial, circumferential, or a combination of the two. Radial tears travel ventral to dorsal. Circumferential tears occur along the outside rim of the diaphragm at or between attachment points. Where the tear occurs is likely due to where the point of impact of the inciting trauma is and any preexisting defects. A review of 116 cats and dogs with acquired traumatic diaphragmatic hernias showed that there

FIGURE 2 *(Worth, 2005)*

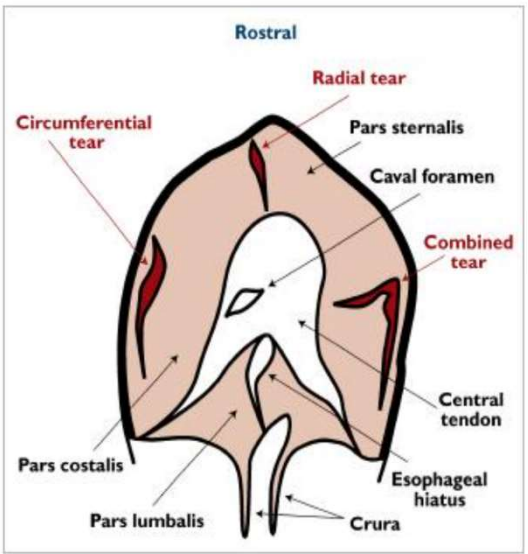


Figure 1. **Diagram of the diaphragm from a ventral abdominal perspective.** Radial, circumferential, and combined tears are represented but do not typically occur simultaneously in the same patient.

was no significant distinction between the occurrence of right versus left-sided tears *(Wilson 1971).* However, in another article, it has been reported that in dogs specifically, right disruption has a greater occurrence *(Garrison, 1980)*.

Clinical Signs

Clinical signs of traumatic diaphragmatic hernia will vary and can often be masked by other concurrent injuries. Organ herniation is based on the size and location of the defect. Respiratory distress with increased inspiratory effort is the most common clinical sign associated with traumatic diaphragmatic hernias. Displacement of abdominal organs cranially takes up space in the thorax and prevents proper expansion of the lungs. Additionally, trauma to the thorax can result in pulmonary edema or hemorrhage. These factors combined cause atelectasis and decreased lung capacity *(Levine, 1987)*.

The liver is the most common organ to enter the thoracic cavity; however, any organ in the abdomen can become displaced *(Wilson 1971).* The liver protrusion can result in liver damage leading to icterus, hemorrhage, ulceration, or abscess formation *(Levine, 1987)*. The small intestine and stomach are the second most common organs to enter the thoracic cavity *(Wilson, 1971).* This can result in gastric obstruction leading to further compression of respiratory and cardiovascular structures within the thorax. Small intestines can become obstructed, entrapped, or strangulated, resulting in the formation of adhesions and risk of bacterial leakage causing severe peritonitis, pleuritis, and overwhelming sepsis in an animal that is likely already compromised *(Levine, 1987)*.

Various pleural effusions, including hydrothorax, chylothorax, and hemothorax, are potential complications, further reducing lung capacity. Hydrothorax is more specifically linked to the liver. Herniation of the liver occludes hepatic venous drainage causing increased

intrahepatic pressures. Pressure elevation ranging from 5-10 mm/hg is sufficient enough to cause accumulation of large amounts of fluid into the thorax and abdomen (Punch, 1985). Chylothorax can result from either thoracic duct rupture secondary to trauma or increased hydrostatic pressure caused by occlusion of a portion of the thoracic duct secondary to compression by herniated organs. Hemothorax can result from any aspect of trauma causing the diaphragmatic hernia but is less likely to be a direct result or consequence of the diaphragmatic hernia itself.

Physical exam findings in patients who have suffered a diaphragmatic hernia are often those associated with shock. Patients may have pale or cyanotic mucus membranes, tachycardia, tachypnea, oliguria, decreased peripheral circulation as indicated by weak pulses or cold extremities, and depression. The patient may present as restless with abducted elbows and extended necks as they try to breathe more comfortably *(Carb, 1975)*. Muffled heart sounds or borborygmi can be appreciated over various lung fields. Percussion of the chest can have a decreased resonance due to increased contents in the thoracic cavity or increased resonance, similar to cattle pings from a displaced stomach filled with gas *(Wilson, 1971).* Arterial blood gas analysis on these patients tend to reveal respiratory acidosis, low pH, and elevated CO2 *(Brasmer, 1984)*, while complete blood counts and serum chemistries may indicate hepatic, renal damage, or electrolyte abnormalities associated with gastrointestinal obstruction *(Engen, 1974).* These patients often have other findings related to their trauma, such as fractures or neurologic deficits.

It is important to account for variability in severity and consistency of respiratory signs. Signs may be intermittent as organs can move back and forth freely between the thoracic and abdominal cavities. Additionally, if the tear is small enough, then there may be little to no movement of abdominal organs between cavities. The diaphragm's function in respiration is to

aid primarily in inspiration. However, patients are able to compensate without an intact diaphragm, as long as there is no damage or loss of function to the intercostal, scalenus, or serratus dorsalis muscles *(Punch, 1985).* The wide range in all of these factors means that patients may present immediately after initial injuries in shock or years later with vague respiratory or gastrointestinal signs. One report says that 80 percent of traumatic diaphragmatic hernias are diagnosed less than four weeks from the initial injury, while another suggests that number is lower at 57 percent *(Garrison, 1980).*

Diagnosis, Treatment, and Prognosis

Diagnosis of diaphragmatic hernias is usually confirmed with imaging, radiographs, or computed tomography scans. The abdominal viscera within the thorax is the classic radiographic sign seen with traumatic diaphragmatic hernias but not required for a diaphragmatic hernia to be present. Depending on the organs displaced and area of the thoracic cavity, mediastinal shifts and distorted vasculature may be present. There are a few things that can alter the images and make identification of a diaphragmatic hernia difficult. For example, if the stomach herniates and is gas-filled, it may appear as a left-sided pneumothorax. Pleural effusions will appear the same opacity as solid parenchyma organs and can obscure the condition. (Thrall, 2018).

While there is controversy among professionals over the repair of chronic hernias with minimal clinical signs, it remains undisputed that acute injuries with clinical signs need emergency surgery. There are various surgical approaches used for correcting diaphragmatic hernias, including ventral midline celiotomy, lateral thoracotomy, paracostal, and transthoracic *(Levine, 1987)*. Ventral midline celiotomy is advantageous because it allows for easy visualization of abdominal organs. However, one of the disadvantages of this approach is that the liver may block more dorsal tears and make them difficult to get to. Thoracic adhesions of

intestinal viscera make this approach less desirable as more access to the thorax is required *(Levine, 1987).* Lateral thoracotomy provides good visualization and the ability to remove thoracic adhesions if they are present. When performing a lateral thoracotomy, surgeons lose the ability to evaluate abdominal organs more thoroughly, which can be imperative with the risk of gastric volvulus, intestinal strangulation, and damage to the liver or spleen. The most important diagnostic prior to this approach is imaging that is able to localize the region of the tear. If the location is unknown or misdiagnosed and extends bilaterally, then the surgery may have to be converted to a transthoracic approach or ventral midline in order to reach all affected areas *(Brasmer, 1984).* The paracostal approach is preferred by some for better access to dorsal tears. If needed, a ventral midline celiotomy can be paired with the paracostal approach *(Brasmer, 1984).* Lastly, a transthoracic approach has been historically documented but is rarely used or indicated *(Boothe, 1977*). The most common complications following repair are re-expansion pulmonary edema, reperfusion ischemic injury, and compartment syndrome.

Prognosis for patients with traumatic diaphragmatic hernias was once guarded but has improved with a better understanding of complications. However, prognosis is highly associated with comorbidities. The survival rate after surgery of diaphragmatic hernia is reported to vary between 54-90% *(Schmiedt, 2002)*. Rapid surgical intervention is also thought to play a role in prognosis. One study of 92 cats and dogs with acute traumatic diaphragmatic hernias showed that survival rates for patients who received surgery within twenty-four hours of admission had an overall 89.7% survival *(Gibson, 2005).*

Case Outcome

Ultimately Maggie's owners decided to pursue surgical correction of the diaphragmatic hernia. A ventral midline celiotomy was performed, where a circumferential tear was identified

just left to the esophageal hiatus measuring approximately 5 centimeters in length. The patient's spleen and portions of the liver were located in the thoracic cavity. These organs were gently removed from the thorax and visually examined for damage. The left lung lobes were noted to be diffusely atelectatic. The hernia was repaired dorsally to ventrally with 2-0 PDS in a simple continuous pattern. At the end of the closure, a red rubber catheter was inserted into the thoracic cavity, and the air was extracted until negative pressure was achieved, and the defect completely closed rapidly after removal of the tube. Additionally, a partial thickness defect was discovered on the right lateral aspect of the diaphragm measuring approximately 4 centimeters in length. This defect was also closed using 2-0 PDS in a simple continuous pattern. An abdominal exploratory was then performed to ensure there was no damage to any other organs, and bellowing of the diaphragm was noted.

Postoperatively, Maggie was recovered in the oxygen cage. The following day she was slowly transitioned to room air to ensure that she was able to oxygenate sufficiently on her own. Her pain was managed with 0.2 mg/kg of buprenorphine buccally every 8 hours. She maintained a pain score of 1/20, indicating sufficient pain control. Maggie was discharged two days after her surgery. She was seen by her primary care veterinarian for a post-operative recheck, and the veterinarian and owner both report that she was healthy and healing appropriately.

It is likely that Maggie's hernia was a result of trauma to the abdomen that caused increased abdominal pressures in excess of the strength of the diaphragm. However, a congenital defect exacerbated by trauma cannot be ruled out. Maggie benefited from a good prognosis with surgical correction and lack of other injuries or comorbidities.

References:

Boothe HW, Hobson HP, Van Stavern N, Hurov LI: Dorsal diaphragmatic hernias in the dog: Surgical repair. J Vet Surg IV(2):60, 1977.

Brasmer TM: The acutely traumatized small animal patient. Philadelphia, WB Saunders Co, 1984

Carb A: Diaphragmatic hernia in the dog and cat. Vet Clin North Am [Small Anim Pract) 5:477, 1975

Engen MH, Weirich WE, Lund JE: Fibrinolysis in a dog with diaphragmatic hernia. J Am Vet Med Assoc 164:152, 1974.

Evans, H. E., & De Lahunta, A. (2016). *Guide to the dissection of the dog* (8th ed.). Saunders.

Garrison HH, Dodman NH, Baker GJ: Diaphragmatic hernia. Analyses of fifty-six cases in dogs and cats. J Small Anim Pract 21:469, 1980

Gibson, T. W., Brisson, B. A., & Sears, W. (2005). Perioperative survival rates after surgery For diaphragmatic hernia in dogs and cats: 92 cases (1990-2002). *Journal of the American Veterinary Medical Association*, *227*(1), 105–109. https://doi.org/10.2460/javma.2005.227.105

Levine, S. H. (1987). Diaphragmatic Hernia. Veterinary Clinics of North America: Small Animal Practice, 17(2), 411–430. https://doi.org/10.1016/s0195-5616(87)50033-x

Punch PI, Slatter DH: Diaphragmatic hernias. In Slatter DH (ed): Textbook of Small Animal Surgery. Philadelphia, WB Saunders Co, 1985

Rader RA, Johnson JA. Determination of normal intra-abdominal pressure using urinary bladder catheterization in clinically healthy cats. J Vet Emerg Crit Care 2010; 20(4):386–392.

Schmiedt C, Tobias K, Stevenson M.Traumatic diaphragmatic hernia in cats: 34 cases (1991- 2001). JAVMA. 2003; 222 (9): 1237-1240.

Thrall, D. E., & Widmer, W. R. (2018). In *Textbook of veterinary diagnostic radiology* (pp. 636–644). essay, Elsevier.

Toomey A, Bojrab MJ: Traumatic diaphragmatic hernias. Compendium Contin Ed Pract Vet 11:866, 1980

Wilson GP, Muir WW: Diaphragmatic hernia. In Bojrab MJ (ed): Current Techniques in Small Animal Surgery. Edition 2. Philadelphia, Lea & Febiger, 1983

Wilson GP, Newton CD, Burt JK: A review of 116 diaphragmatic hernias in dogs and cats. JAm Vet Med Assoc 159:1142, 1971.

Worth, A. J., & Machon, R. G. (2005, March). *Traumatic Diaphragmatic Herniation: Pathophysiology and Management: Surgery Compendium* VetFolio. https://www.vetfolio.com/learn/article/traumatic-diaphragmatic-herniation-pathophysiology-and-management-article.