Canine Pleuroperitoneal Diaphragmatic Hernia

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Introduction

Automobile accidents and other traumatic events are unfortunate, but common reasons that dogs (as well as cats) are brought in for emergency examination and treatment. With these events, the anatomical and physiological implications are rarely limited to a single lesion or body system. Many trauma patients can present with cutaneous lesions and abrasions, neurologic deficits, orthopedic fractures and dislocations, internal injuries, and respiratory compromise, just to name a few broad categories. Upon treatment, all of these factors must be taken into account when determining the best plan for diagnostics and treatment options.

The diaphragm is the muscular and tendinous organ that serves as the physical barrier between the thoracic and abdominal cavities and aids in ventilation via the use of negative pressure within the thoracic cavity to draw air into the lungs. Disruption of the diaphragm causes there to be a direct communication between the abdominal and thoracic cavities which, depending on the size of the rent, can cause various absent, mild, or severe clinical implications for the patient.

History and Presentation

Pleuroperitoneal diaphragmatic hernias can be either acute or chronic in nature. There have not been any breed or sex predilections identified, but historically young males (1-3 years old) are more commonly affected.[3] Congenital pleuroperitoneal diaphragmatic hernias are possible, but are rarer and often incidental findings discovered post-mortem.[2]

Diaphragmatic hernias are often presented due to acute onset of clinical signs associated with a traumatic event, most often automobile accidents but can also include kicks by livestock, penetrating trauma, impacts from falls, and rapid changes in barometric pressure. There are

reports of dogs suffering from pulmonary lesions and diaphragmatic hernias from barotrauma caused by tornadoes.[1] Diaphragmatic hernias are a relatively uncommon, but possible problem encountered by working dogs as well. The traumatic environment may of these working dogs (military and police) may be exposed to often provide the possibility of a diaphragmatic hernia occurring in the field.[2] Animals can present for a history of trauma, shock, trouble breathing, or pale or cyanotic mucus membranes. Secondary complications can occur due to obstruction and strangulation of the abdominal organs including the liver, leading to compromise of hepatic circulation. These signs can include icterus, biliary obstruction, ascites, and pleural effusion. Hemothorax, chylothorax, bile pleuritis, and pneumothorax are often complicating factors that may occur as well. The traumatic cause of hernia development in the case of acute and chronic cases could also have caused additional injuries including musculoskeletal and neurologic dysfunction and should not be overlooked upon presentation and assessment.[2]

Alternatively, a large proportion of diaphragmatic hernias are chronic in nature, classified by being present for greater than two weeks duration with or without the presence of clinical signs.[7,10] Dogs can present for very nonspecific signs including dyspnea, lethargy, exercise intolerance, anorexia, weight loss ranging from weeks to years in duration. Other presenting complaints can include vomiting, dysphagia, diarrhea, constipation, and abdominal distension.[3] It is not unusual for diaphragmatic hernias to occur without any clinical signs or a known history of trauma by the owner; therefore, discovery of the herniation may be an incidental radiographic finding.[4,7]

Physical examination of these patients can reveal signs of hypovolemic shock, dyspnea, tachypnea, tachycardia, arrhythmias, muffled heart and lungs sounds, borborygmi in the thorax, tucked-up abdomen, abdominal distension (+/- fluid wave), absence of normal abdominal organs

on palpation, hyper-resonance on percussion of the chest wall (gastric tympany), or hypo-resonance on percussion of chest wall (pleural effusion). In some cases, the myocardium may be injured resulting in arrhythmias.[8]

Pathophysiology

Congenital diaphragmatic hernias, pleuroperitoneal and peritoneopericardial, are rare and will be minimally discussed within this manuscript. For congenital pleuroperitoneal diaphragmatic hernias, the defect is most commonly found in the dorsolateral aspect of the diaphragm.[3,4] There may be missing parts of the lumbar musculature of the crus as well as more extensive defects including missing parts of the central tendon. Peritoneopericardial diaphragmatic hernias are also relatively rare and are due to an embryologic development defect of the dorsolateral septum transversum in the region known as the 'sternocostal triangle'. This defect creates a direct communication between the pericardial space and the peritoneal cavity.[3,5]

Traumatic diaphragmatic hernias can be further broken down into categories of direct and indirect. Direct herniations are more focal in origin and can be caused by incidents like stab injuries and gunshot wounds that involve the thorax and abdomen. Indirect diaphragmatic hernias are due to more blunt-force trauma which can include incidents such as automobile strikes. Onset of hernias from blunt-force trauma is primarily due to the sudden increase in abdominal pressure when the glottis is open (allowing the lungs to rapidly deflate) resulting in a profound gradient of pleuroperitoneal pressure. The tear(s) within the diaphragm usually occur within the muscular portions of the diaphragm (diaphragmatic costal muscles) as these are the weakest points of the complex structure. Location and extent of the tears are directly linked to both the direction and force of the impact in relation to the way that the animal was positioned

upon impact. Once the diaphragm is torn, there is then a direct communication between the thoracic and abdominal cavities. Abdominal viscera may translocate into the thoracic cavity. Ischemic injury can potentially occur if there is severe enough compromise or disruption to the blood flow. The liver is the most commonly herniated organ and is often associated with pleural and/or abdominal effusion due to actual entrapment of part of the liver, as well as, venous occlusion of one or more of the liver lobes.[3] In addition, other commonly herniated organs include the small intestine, stomach, omentum, and spleen.[8] Entrapment of the stomach through the diaphragmatic rent is viewed as a medical and surgical emergency due to gastric filling with gas after outflow obstruction.[3,4] As a result of the variability that can cause a diaphragmatic hernia, clinical signs may be solely respiratory in nature due to loss of diaphragmatic integrity or signs may directly result from malpositioning of the abdominal viscera into the thoracic cavity.[3]

Differential Diagnoses

Since the majority of pleuroperitoneal diaphragmatic hernias are associated with a traumatic event, the differential diagnoses depend on the clinical signs the dog is currently expressing and can be further narrowed down based on diagnostic findings. Pleural effusion is a common finding in dogs with diaphragmatic hernias, but can also be caused by a wide range of conditions and diseases. The fluid within the pleural space should be analyzed via thoracocentesis to further narrow down the list of differential causes based on the fluid being transudate (hydrothorax), blood (hemothorax), chyle (chylothorax), or pus (pyothorax).[3] The presence of a pneumothorax can also have many associated causes including pulmonary contusions, flail chest, asthma, and penetrating wounds to the thoracic wall such as fractures.[3,4] Other causes of abdominal distension or ascites could including an abdominal abscess, distension

of the bladder, cystic structure(s) within the abdomen, gastrointestinal dilation, Cushing's Disease (Hyperadrenocorticism), neoplasia, obesity, organomegaly, pregnancy, or pyometra.[3] Congenital diaphragmatic hernias must also be considered on the list of differentials pending diagnostic findings as well. Usually, though, diagnostic imaging modalities (discussed below) allow visualization of the abdominal organs within the thoracic cavity and greatly aid in narrowing down the differential diagnoses list.

Diagnostic Approach/Considerations

Due the traumatic history and nature of most diaphragmatic hernias, a minimum database consisting of a complete blood count, serum chemistry, and urinalysis should be run along with thoracic radiographs. Bloodwork and urinalysis results are highly variable based on the extent of injuries, time of presentation, and the organs that are displaced into the thorax. Thoracic radiographs may show loss of the diaphragmatic line, loss of the cardiac silhouette (organ overlap, air, fluid), dorsal displacement of the lungs (fluid, organs), pleural effusion, or the presence of gas (stomach and/or intestines present in the thorax).[3] If pneumothorax or pleural effusion is present, thoracocentesis may be necessary to remove the air/fluid for reassessment of the thoracic cavity. Abdominal radiographs may show cranial displacement of the abdominal organs and/or missing organs from their normal locations (small intestines commonly).

Under most circumstances the diaphragmatic hernia can be diagnosed with radiography. In some instances, though, radiographs may be inconclusive and additional diagnostic imaging can be utilized. Ultrasound can reveal a defect in the diaphragm due to absence of the diaphragmatic line (curved, hyperechoic line) at the diaphragm-lung interface.[3,12] Ultrasound can also allow visualization of abdominal organs herniating through the rent in the diaphragm or

abnormal positioning of the viscera. Contrast imaging can be performed to aid in identification of abdominal organs within the thorax. Barium sulfate is contraindicated, though, if any GI perforation is suspected to have occurred.[12] The use of positive-contrast celiography may also be performed if other methodologies for diagnosis have been nondiagnostic.[12] For this method of imaging, contrast medium (iodinated contrast agent) is injected directly into the abdomen near the umbilicus. Diagnosis for diaphragmatic herniation include presence of contrast in the thoracic cavity, absence of normal liver lobe outlines within the abdomen, or loss of the normal diaphragm outline.[3,10] Additionally, advanced imaging including CT and/or MRI can be utilized. In some animals, the diagnosis may be confirmed in abdominal exploratory surgery.

Identification of abdominal viscera in the thoracic cavity is not pathognomonic for a pleuroperitoneal diaphragmatic hernia, though. Peritoneopericardial diaphragmatic hernias also show signs of abdominal organs being present within the thorax radiographically, although increased soft tissue opacity and signs of abdominal organs are usually limited to overlap with the cardiac silhouette, which is often enlarged. This is due to the direct communication between the peritoneal and pericardial spaces. A distinct diaphragmatic line is often not evident on lateral and/or VD radiographs due to direct communication with the pericardial sac. In some cases, a dorsal mesothelial remnant may be visible on lateral radiographs just ventral to the caudal vena cava.[3] Upon auscultation of dogs with congenital peritoneopericardial diaphragmatic hernias, the heart sounds are often muffled while lung sounds tend to be normal. Many peritoneopericardial hernias are incidental findings and are usually diagnosed in young animals.[3] Confirmation can be done with ultrasound without or without contrast to allow visualization of the abdominal viscera within the pericardial space.[3] Surgical correction and additional treatment may be indicated if clinical signs are associated with the hernia.

Treatment and Management Options

In the case of acute traumatic pleuroperitoneal diaphragmatic hernias, medical management for dyspnea and shock should be initiated as soon as possible to achieve stabilization of the patient including oxygen administration, fluid therapy, intravenous antibiotics, and analgesics.[3] Supplemental oxygen can be provided via face mask, nasal administration, or by placement in an oxygen cage for dyspneic patients. Making sure that the patient is in sternal recumbency with the front limbs elevated will assist with ventilation of the patient. This positioning aid in alleviating pressures from abdominal organs and/or fluid inside the thoracic cavity. If moderate to severe pleural effusion is present, thoracocentesis should be performed. Pain management is a vital part of management of diaphragmatic hernias as pain can lead to tachypnea and decreased tissue perfusion overall in the patient. Alleviation of pain will allow deeper breathing with more efficient gas exchange in the compromised thorax.

Surgical repair via herniorrhaphy is the treatment of choice for acute or chronic diaphragmatic hernias causing clinical signs. Generally speaking, diaphragmatic hernias are not considered surgical emergencies except in the case of intestinal strangulation, gastric involvement, severe ventilator compromise, or an inability to be stabilized. Recent studies have shown that there is a higher mortality rate associated with repairs performed within 24 hours of injury. For herniations involving the stomach (gastric herniation), surgical correction is indicated as soon as possible due to gastric distension within the thoracic cavity.[3,4] In severe cases, gastric compression can be accomplished by placement of a trocar or catheter into the stomach with or without utilization of ultrasound.

Prophylactic antibiotics are often initiated at presentation of traumatic diaphragmatic hernias, but should especially be administered in patients with hepatic involvement due to toxin release from strangulation and vascular compromise. Use of anesthetic agents with minimal respiratory depressant effects are preferred to reduce further respiratory compromise. Administration of supplemental oxygen for 3-5 minutes prior to induction has been shown to provide a safer induction due to improvement of myocardial oxygenation.[4] Intermittent positive pressure ventilation should be performed in all diaphragmatic hernia patients undergoing surgical correction. Positioning into dorsal recumbency causes the abdominal organs to further relax and add pressure to the lungs. Once the abdominal cavity is opened via ventral midline incision, the thoracic cavity is also open. Any negative pressure within the thoracic cavity is absent and positive pressure ventilation is required to force air into the lung tissue. Especially with chronic cases, care must be taken to avoid over inflation of the lungs with too high of pressures as they have been compressed over time. Prevention of reexpansion pulmonary edema, a potential complication after repair of chronic diaphragmatic hernias, is done by gradual reexpansion of the lung tissue and avoidance of immediate expansion of the lungs after repair. In general, the longer that lung tissue is collapsed then the longer that the tissue has time to thicken and become less flexible over time. Upon re-inflation of the lung to normal size, stretching of vessels leads to fluid leakage into the interstitium and reduction in perfusion.[6]

As with initial presentation, pain management is also a vital component of post-operative care for diaphragmatic hernia patients. Those with painful respiratory efforts will tend to take rapid and shallow breaths, creating additional stress on sutures. Under adequate pain management, the patient will take slow deep breaths to allow appropriate oxygenation as well as

avoid additional strain on the repaired diaphragm. This pain management can often be achieved with epidurals, intercostal nerve blocks, local blocks at the incision site, or intravenous opioids.[4]

Briefly, for surgical repair of diaphragmatic hernias, a ventral midline abdominal incision is made with the dog in dorsal recumbency. The abdominal organs are pulled gently from the thoracic cavity and replaced into the abdominal cavity. If needed, the defect in the diaphragm may need to be extended to accommodate removal and replacement of these organs. Adhesions may be gently broken down manually to prevent and minimize bleeding or trauma to tissues. For adhesions involving lung tissue, partial lung lobectomies may be indicated to prevent induction of pneumothorax, bleeding, and additional tissue trauma. In rare cases involving severe intrathoracic adhesions, a medial sternotomy may be implemented.[4] This should only be pursued in extreme instances, though. Anecdotally, bicavitary surgeries may be associated with a poorer outcome. In recent literature, freshening and debridement of tissue edges are no longer indicated before closure of the diaphragmatic rent.[9] A simple continuous suture pattern is most commonly used to close the diaphragm using either absorbable or nonabsorbable suture material (3-0 to 0). Suture placement should be started from the dorsal aspect of the lesion and moving ventrally. In the case that the diaphragm is avulsed from the thoracic wall, the rib should be incorporated into the suture pattern to provide additional strength to the repair – making note that the costal vessels run along the caudal aspect of the ribs.

In acute cases, the lungs can often be re-expanded without a great risk injury to the lung tissue. Any remaining air within the pleural space will be gradually reabsorbed by the body over time. In chronic cases, immediate inflation of the lungs should be avoided to prevent reexpansion pulmonary edema, which is often fatal when it occurs.[6] For management of pneumothorax post-

operatively, a thoracostomy tube or transdiaphragmatic tube can be placed intraoperatively to allow management of pneumothorax post-operatively.

After closure of the diaphragmatic rent, abdominal organs should be closely inspected for signs of injury, tissue hypoxia, or devitalization.[4] Tissues that are purple or dark red should be reassessed 5-10 minutes after being replaced in their normal anatomical location within the abdomen as normal coloration will often start to appear. Green, black, and white tissue should be surgically resected as appropriate as they are devitalized and possibly necrotic. Assessment of the gastric wall can include color assessment of tissue, palpation for wall thickness, and the presence of capillary bleeding if necessary.

In less common cases, there may be deficient amount of tissue to close the diaphragmatic defect. Ideally the patient's own tissues should be used compared to foreign materials. In these cases, the use of a flap or graft may be utilized. A flap can be created using the peritoneum and transverse abdominus muscle and placed over the defect. The flap can then be sutured to the remaining parts of diaphragm.[4] Grafts consisting of synthetic material (Silastic sheeting) or porcine small intestinal submucosa are also available as alternatives.[4]

Often times, especially in chronic diaphragmatic hernia cases, there is not enough tissue to close the abdominal wall once the diaphragm has been repaired and the abdominal organs have been placed back into the abdomen. This predicament is termed 'loss of domain'. This can be due to distension and congestion of the abdominal organs themselves or from the abdominal wall tightening down around an abdomen with less volume after translocation of its organs into the thorax. Closure of abdomens with loss of domain may indicate surgical removal of the spleen and/or liver lobes until appropriate closure can be made.

Expected Outcome and Prognosis

Post-operatively, these patients should be monitored closely for signs of respiratory distress or hypoventilation. Pneumothorax is the most common complication.[3,4] These can be dealt with relatively easily if a chest tube is in place to aid in gradual removal of air from the thoracic cavity to stabilize the patient. Reexpansion injury is another complication associated with these procedures due to the rapid reexpansion of the lung, especially chronically affected patients whose lung(s) may have been partially or fully collapse for an extended period of time. Pain management should be addressed to prevent hypoventilation and worsening of hypoxia. Chronic hernia repairs can occasionally result in "abdominal compartment syndrome" due to the sudden increase in intraperitoneal pressures after the abdominal organs are replaced into the abdominal cavity.[4] Intraabdominal pressures greater than 20-25 mmHg along with damage to abdominal organs has been associated with abdominal compartment syndrome due to compromised blood flow and perfusion. As a result, complications can include respiratory compromise, oliguria or anuria (due to renal dysfunction), intestinal edema, bacterial translocation, sepsis, liver failure, increased intracranial pressure (neurologic signs can occur), and local ischemia and edema of the abdominal wall.[11]

Prognosis for diaphragmatic hernias, including both acute and chronic forms, is good to excellent with surgical repair.[3] More specifically, due to the traumatic nature of these cases, patients that survive the early postoperative period (12-24 hours) have an excellent prognosis. Recurrence of the diaphragmatic defect is relatively uncommon with secure repair of the defect initially at surgery. Mortality rates for animals with diaphragmatic hernias range from 12% to 48% according to Fossum.[4] In the current literature, dogs and cats undergoing surgical repair of chronic diaphragmatic hernias had a 16% mortality rate.[8] Higher mortality rates have been

associated with those undergoing surgical repair within 24 hours of occurrence (unstable patients) and in those chronic cases that have been present for over a year.

Conclusion

Although diaphragmatic hernias are often associated with traumatic events, it is important to remember that these patients may possibly present clinically normal and the herniation can be an incidental finding on examination or while screening for other problems. Although not discussed in great detail within this paper, an important congenital differential diagnosis is a peritoneopericardial diaphragmatic hernia that is less often associated with traumatic events, but can present for similar clinical signs. With patients presenting for clinical signs associated with diaphragmatic hernias, it is imperative that the patient be stabilized, if possible, before surgery is pursued. Involvement of the stomach within the hernia, though, is a surgical emergency and is extremely time sensitive for survival of the patient. Surgical correction is indicated for patients suffering from diaphragmatic hernias and overall have a good prognosis with survival after the early post-operative period.[3]

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