Resolution of persistent pneumothorax by use of blood pleurodesis in a dog after surgical correction of a diaphragmatic hernia

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Case Description—A 15-kg (33-lb) pregnant female mixed-breed dog of unknown age was referred because of a 10-day history of difficulty breathing.

Clinical Findings—Physical examination findings were dyspnea, tachypnea, decreased bronchovesicular sounds (bilateral), muffled heart sounds, and abdominal distention with palpable fetuses. Hematologic abnormalities included anemia, leukocytosis, and thrombocytosis. Abnormalities detected during serum biochemical analysis included decreases in concentrations of albumin, sodium, triglycerides, and total calcium and increases in activities of alkaline phosphatase, alanine aminotransferase, γ-glutamyltransferase, aspartate aminotransferase, lactate dehydrogenase, and creatine kinase. Thoracic radiography revealed a diaphragmatic hernia with fetuses and a soft tissue or fluid opacity within the thoracic cavity.

Treatment and Outcome—Exploratory celiotomy, ovariohysterectomy, partial sternotomy, placement of a right-sided thoracostomy tube, and herniorrhaphy were performed. After surgery, pneumothorax developed, and the thoracostomy tube was used to remove pleural effusion and free air. The pneumothorax did not resolve after continuous drainage of the thoracic cavity for 4 days. Autologous blood pleurodesis was performed by infusion of 80 mL (6 mL/kg [2.73 mL/lb]) of whole blood. The pneumothorax resolved immediately after injection of the blood.

Conclusions and Clinical Relevance—Blood pleurodesis was used for resolution of pneumothorax in a dog after correction of a diaphragmatic hernia. Blood pleurodesis may provide a simple, safe, and inexpensive medical treatment for resolution of persistent (duration > 5 days) pneumothorax when surgery is not an option. J Am Vet Med Assoc 2010;237:299–303

A 15-kg (33-lb) pregnant female mixed-breed dog of unknown age was referred to the Hebrew University Veterinary Teaching Hospital because of difficulty breathing. The dog had been adopted 5 months previously. There was no history of trauma after adoption. The owner reported a 10-day duration of increased breathing effort that progressed to dyspnea and a decrease in appetite.

A CBC and serum biochemical analysis were performed by the referring veterinarian on the day of referral. Hematologic abnormalities included leukocytosis (14.93 × 103 cells/µL; reference range, 5.2 × 103 to 13.9 × 103 cells/µL), anemia (RBC count, 4.45 × 1012 cells/µL [reference range, 5.7 × 1012 to 8.8 × 1012 cells/µL]; Hct, 28.5% [reference range, 37.1% to 57%]), and mild thrombocytosis (536 × 103 cells/µL; reference range, 143 × 103 cells/µL to 400 × 103 cells/µL). Results for all other hematologic values were within the respective reference ranges. Analysis of a differential count of leukocytes revealed a stress leukogram. Examination of a stained blood smear revealed nontoxic mature neutrophils, mild polychromasia, and a thrombocyte count that was estimated to be greater than that of the typical reference range. Abnormalities detected during serum biochemical analysis included decreases in concentrations of sodium (141 mmol/L; reference range, 142 to 159 mmol/L), triglycerides (37 mg/dL; reference range, 50 to 100 mg/dL), and total calcium (8.4 mg/dL; reference range, 9.0 to 11.7 mg/dL) and increases in activities of alkaline phosphatase (2,020 U/L; reference range, 0 to 150 U/L), alanine aminotransferase (325 U/L; reference range, 0 to 60 U/L), γ-glutamyltransferase (46 U/L; reference range, 0.0 to 6.0 U/L), aspartate aminotransferase (63 U/L; reference range, 0 to 50 U/L), lactate dehydrogenase (329 U/L; reference range, 50 to 320 U/L), and creatine kinase (295 U/L; reference range, 50 to 200 U/L). Results for all other variables were within the respective reference ranges.

On admission, the dog was quiet, alert, and responsive with a marked increase in breathing effort. Physical examination findings were a body condition score of 2 (scale, 1 to 9), abdominal distention with palpable fetuses, lactating mammary glands, tachypnea (respiratory rate, 64 breaths/min), decreased bronchovesicular sounds (bilateral), and muffled heart sounds. Prothrombin time was within the reference range (7.2 seconds; reference range, 6 to 8.5 seconds). Activated partial thromboplastin time was prolonged (23.1 seconds; reference range, 16 to 19 seconds).

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Thoracic radiography revealed diffuse opacification of the thoracic cavity (Figure 1). The cardiac silhouette and diaphragmatic crura were obscured by a soft tissue or fluid opacity. The caudodorsal lung lobe was collapsed, and the skeletons of 7 fetuses were identified (+ in the thoracic cavity and 3 in the abdominal cavity). On the basis of interpretation of the radiographic findings, a diagnosis of diaphragmatic hernia, which included 4 fetuses and a soft tissue mass (suspected to be the liver) within the thoracic cavity, was made. On the basis of a typical heart rate of the fetuses as determined by use of ultrasonography, the health of the gestating fetuses was apparently uncompromised.

Oxygen was initially administered to the dog via a flow-by system and was later provided via an intranasal tube. A catheter was inserted into the right cephalic vein and used to administer lactated Ringer’s solution\(^a\) (5.0 mL/kg/h [2.3 mL/lb/h]). Despite treatment, the clinical status of the dog deteriorated, which was typified by orthopnea, dyspnea, and marked discomfort. Thus, exploratory celiotomy with herniorrhaphy was initiated approximately 3 hours after admission.

The dog was premedicated with butorphanol tartrate\(^b\) (0.40 mg/kg [0.18 mg/lb], SC) and acepromazine maleate\(^c\) (0.01 mg/kg [0.0045 mg/lb], SC). Anesthesia was induced via the administration of propofol\(^d\) (2 mg/kg [0.91 mg/lb], IV) and diazepam\(^e\) (0.50 mg/kg [0.23 mg/lb], IV) and maintained with 2% isoflurane\(^f\) and positive-pressure ventilation. A ventral midline incision was used to enter the abdominal cavity. A 20-cm circumferential hernia in the ventral portion of the diaphragm with herniation of the gravid left uterine horn, left lateral and medial liver lobes, and omentum was observed.

The hernia was enlarged via a radial incision to facilitate reduction of the herniated organs. The herniated uterine horn was reduced into the abdomen, and an ovariohysterectomy was performed. Seven puppies were delivered from the uterus; despite resuscitation attempts, 1 did not survive. Reduction of the liver lobes and omentum could not be accomplished via the hernia opening because of multiple adhesions between the herniated organs and the lungs. Thus, reduction of those organs required partial sternotomy. The lung lobes on the right side were collapsed and adhered to the thoracic wall, liver, and omentum. Partial lung lobectomies could not be successfully performed because of the friability of the lung tissues. Therefore, simple ligations were performed in several locations along the margin of the middle and caudal right lung lobes. The abdominal organs were then reduced into the abdomen. The remaining thoracic organs did not appear to have any gross pathological changes. The thoracic cavity was filled with saline (0.9% NaCl) solution, and no air leakage was detected from the lung lobectomy sites. A thoracostomy tube\(^g\) (width, 8.0 mm; length, 40 cm) was inserted through the skin at a location 2 intercostal spaces caudal to the point at which the tube was inserted through the intercostal musculature (between ribs 8 and 9) and into the thoracic cavity. Purse-string and finger-trap sutures were used to secure the thoracostomy tube. Gauze pads impregnated with povidone-iodine were placed over the insertion site of the thoracostomy tube, and the thoracic wall was bandaged. To avoid a profound vacuum condition, suction was applied to the tube on an hourly basis thereafter. During surgery, Hct and total protein concentration decreased from 28% to 22% and from 5.3 to 4.2 g/dL, respectively. The dog was transfused with 200 mL of a packed RBC solution. The Hct increased to 32%; however, the total protein concentration decreased from 4.2 to 3.0 g/dL. A routine 3-layer closure was used to repair the celiotomy incision.

The dog was admitted to the intensive care unit for recovery from anesthesia. The rate of administration for the lactated Ringer’s solution\(^h\) was increased to 6 mL/kg/h (2.73 mL/lb/h) during recovery from anesthesia to help maintain blood pressure; however, once the clinical condition of the dog stabilized, the rate of fluid administration was decreased to 2.5 mL/kg/h (1.14 mL/lb/h) to support homeostatic requirements. Other postoperative treatments included administration of morphine hydrochloride\(^i\) (0.12 mg/kg/h [0.05 mg/lb/h]), lidocaine hydrochloride\(^j\) (0.60 mg/kg/h [0.27 mg/lb/h]), ketamine hydrochloride\(^k\) (0.12 mg/kg/h), and metoclopramide\(^l\) (0.04 mg/kg/h [0.018 mg/lb/h]) via constant rate infusion; application of a lentanyl transdermal patch\(^m\) (50 µg/h); and administration of cefazolin sodium\(^n\) (25 mg/kg [11.36 mg/lb], IV, q 8 h), ranitidine\(^o\) (2 mg/kg, IV, q 12 h), and sucralfate\(^p\) (1 g, PO, q 8 h).

The dog recovered from anesthesia and was ambulatory 4 hours after surgery. The dog was walked on a leash, but it became tachypneic and dyspneic and the mucous membranes became pale during the walk. The dog was returned to the intensive care unit, and manual suction on the chest tube revealed pneumothorax. Manual suction did not resolve the pneumothorax, and the dog continued to be dyspneic. The pneumothorax condition was controlled only after the thoracotomy tube was connected to a continuous drainage system. Bandages surrounding the thoracostomy tube were removed so clinicians could verify there were no underlying mechanical problems with the tube or tube insertion site. The dog regurgitated and vomited 6 hours after surgery; and there was evidence of digested and fresh blood in the vomitus. The cause of regurgitation was attributed to postoperative esophagitis. Because of a decrease in total protein concentration and a suspect-
ed decrease in colloidal osmotic pressure in the dog, fresh-frozen plasma (10 mL/kg [4.55 mL/lb], IV) was administered over a 4-hour period, which was followed by administration of a 20% solution of human albumin® (1 g/h [diluted in lactated Ringer's solution], IV) for 10 hours and by administration of hetastarch® (1 mL/kg/h [0.45 mL/lb/h], IV) for 2 consecutive days. Clinical status of the dog improved during the next 4 days, except for a nonresolving pneumothorax. Attempts were made to replace the continuous suction system with a Heimlich chest drain valve. However, tachypnea (respiratory rate, > 80 breaths/min) developed within 15 minutes after the start of each attempt. Examination of a right lateral radiographic view, which was obtained while the dog was connected to the Heimlich chest drain valve, revealed obscuring of the cardiac silhouette and diaphragmatic crura by a fluid opacity and collapse of the caudodorsal and other lung lobes (Figure 2). These findings were consistent with pneumothorax and pleural effusion. Because there was no clinical improvement in the condition of the dog and the owner could not afford an additional thoracotomy procedure for locating and sealing the site or sites of air leakage from the lungs, blood pleurodesis was performed.

Blood pleurodesis was performed in the intensive care unit by use of aseptic conditions. Sedatives or analgesics were not needed because blood was delivered via the thoracostomy tube. Eighty milliliters of whole blood was collected from the right jugular vein by use of a 16-gauge needle into four 50-mL syringes that contained no additives. After 20 to 25 mL of blood was collected into each syringe, the blood aliquot was immediately injected into the thoracic cavity via the thoracostomy tube, and each syringe, the blood aliquot was immediately injected into the thoracic cavity. Thus, an additional 150 mL of the packed RBC solution was administered IV 12 hours after the injection of blood into the thoracic cavity. Because the Heimlich valve was filled with fluids and clinical signs of tachypnea or dyspnea were not detected, 400 mL of a serosanguineous pleural effusion was removed from the thoracic cavity once 12 hours after the injection of 80 mL of blood into the thoracic cavity. A differential list for the cause of the pleural effusion included insufficient oncotic pressure, postoperative tissue damage within the thoracic cavity, or an inflammatory process induced by injection of the blood into the thoracic cavity. However, an inflammatory process induced by the blood injection has been suggested as a mechanism by which blood pleurodesis causes adhesions and resolution of pneumothorax.

Following the pleurodesis procedure, the Heimlich valve remained connected for 24 hours; however, the valve appeared to be nonfunctional because it was filled with fluid. The thoracostomy tube was then purposefully occluded because the breathing rate and pattern had remained stable in the dog. The thoracostomy tube was removed 36 hours after the injection of blood into the thoracic cavity (6 days after surgery), and the dog was discharged 48 hours after removal of the thoracostomy tube (8 days after surgery). Six days after the injection of blood into the thoracic cavity (4 days after removal of the thoracostomy tube), thoracic radiography revealed pneumothorax, pleural effusion, and fissure lines that were suggestive of pleuritis (Figure 3).

Figure 2—Right lateral radiographic view of the dog in Figure 1 obtained 4 days after surgery to correct the diaphragmatic hernia and before a blood pleurodesis procedure. Notice that the cardiac silhouette and diaphragmatic crura are obscured by a fluid-like opacity (white arrowhead) and that there is collapse of the caudodorsal lung lobe (black arrows); these findings are consistent with pleural effusion and mild pneumothorax (white arrow), respectively. The dog was connected to a Heimlich chest drain valve during acquisition of this radiographic view.

Figure 3—Right lateral radiographic view of the dog in Figures 1 and 2 obtained 10 days after surgery to correct the diaphragmatic hernia and 6 days after injection of 80 mL of blood into the thoracic cavity. Notice the pneumothorax (black arrow), fine lines and enhanced lung borders (white arrows), and pleural effusion (white arrowhead). The fine lines and enhanced lung borders are suggestive of pleuritis.
Two months after discharge from the hospital, the dog was doing well at home, and all 6 puppies were alive.

Discussion

Chronic diaphragmatic hernia becomes a life-threatening condition when adverse clinical events (eg, dyspnea) develop. Several surgical techniques for the reduction of chronic diaphragmatic hernia have been reported. In most patients with chronic diaphragmatic hernia, dissection of mature adhesions between the lungs or diaphragm and the herniated organs is necessary prior to reduction of the organs through the hernia.

A potentially lethal but rare complication of chronic diaphragmatic hernia repair is reexpansion pulmonary edema in previously atelectic lungs. Fatal reexpansion pulmonary edema after pectus excavatum surgery in a kitten has been reported. The pathophysiologic aspects or characteristics of this complication are unknown; however, it can potentially be avoided by the administration of reduced tidal volumes of delivered gases during anesthesia and gradual expansion of atelectic lungs after reduction of the herniated organs.

The most commonly reported complication for repair of a chronic diaphragmatic hernia is pneumothorax. Prevention of pneumothorax requires repeated thoracocentesis procedures or placement of a thoracostomy tube. The method chosen is dependent on the rate of air accumulation within the thoracic cavity. Pulmonary lesions typically heal within 3 to 5 days; thus, intermittent or continuous pleural drainage may be used thereafter. Thoracotomy is seldom required for animals with trauma-induced or postsurgical pneumothorax; however, pleurodesis is recommended in patients with pneumothorax in which air leakage persists for >5 days and surgery is not an option.

Mechanical pleurodesis has been reported to prevent recurrence of spontaneous pneumothorax in dogs. Mechanical pleurodesis typically involves abrasion of the surface of the lung and body wall with a dry gauze sponge during thoracotomy. The pathophysiologic process of mechanical pleurodesis is typified by damage to the pleura to induce an inflammatory process that results in adherence of the visceral and parietal pleura during healing. An efficacy study of mechanical pleurodesis suggested that limited air leakage from pulmonary blebs and bullae after treatment is more likely caused by fibrosis of the pulmonary pleura, rather than the result of obliteration of the pleural space.

Chemotherapeutic agents may also be used to cause mechanical pleurodesis. The ideal chemotherapeutic agent (eg, chemical agent or antimicrobial) is highly effective, is easy to apply, is inexpensive, and causes minimal adverse effects. Bleomycin, tcalc, and tetracycline antimicrobials (eg, tetracycline, minocycline-2 through minocycline-4, and doxycycline) have been used for chemical pleurodesis. An inflammatory effect results in the cessation of air leakage within 3 to 5 days after application of tetracycline or tcalc. In human medicine, tcalc is the most common agent used in patients with spontaneous pneumothorax or recurrent pleural effusion. In an evaluation study for the treatment of pneumothorax in humans by use of tcalc pleurodesis, investigators reported a success rate of 91% with short-term adverse effects that included fever, pain, infection, and respiratory failure (which may have been dose-related phenomena). A review of 1,168 human patients treated with chemical agents for malignant pleural effusions from 1966 through 1994 revealed that tcalc was the most effective agent for pleurodesis (success rate, 93%). However, there were at least 32 patients that developed acute respiratory distress syndrome after the application of tcalc. Conversely, tcalc pleurodesis does not appear to be effective in healthy dogs.

Pleurodesis by infusion of blood (ie, blood pleurodesis) into the pleural cavity has been used in human medicine for the treatment of several conditions, which include primary and secondary pneumothorax, persistent postoperative air leakage, and chronic effusions refractory to chemical pleurodesis. The pathophysiologic characteristics of the sealing effect of blood are probably multifactorial; possible mechanisms include actual pleurodesis that results in pleural adhesions, an inflammatory reaction within the pleural cavity contributing to adhesion between the parietal and visceral pleura, or sealing of the air leakage site by blood clots. The resolution of air leakage by blood clots is supported by the rapid resolution of air leakage, which happens more rapidly than can be expected for the formation of pleural adhesions. A retrospective study of postsurgical autologous blood pleurodesis in human patients with persistent (mean duration, 16.7 days) air leakage by use of a single infusion of 50 to 250 mL of blood revealed resolution of air leakage in all treated patients within 24 hours. Adverse effects (ie, pain, respiratory difficulty, fever, or episodes of coughing) were not reported in these human patients. In another prospective study, a success rate of 100% was reported in 11 patients with persistent air leakage that were treated by blood pleurodesis; most (72.7%) air leakage resolved within 12 hours after treatment. After blood pleurodesis, empyema did not develop in any patient. However, fever developed in 2 patients, and Staphylococcus spp were cultured from pleural fluid collected after blood pleurodesis. An additional prospective randomized case-control study revealed that air leakage was resolved by the next day (median air leakage, 5 days) in 58.6% of patients after blood pleurodesis, which was significantly (P < 0.01) less than that for the control group (median air leakage, 11 days). Furthermore, the median times to chest drain removal and hospital discharge were both significantly (P < 0.001) less in the blood pleurodesis group, when compared with these variables in the control group.

To our knowledge, the dog reported here is the first in which the treatment of pneumothorax by blood pleurodesis has been reported in veterinary medicine (excluding laboratory animals). In another study, investigators compared the efficacy of pleurodesis by the infusion of blood or application of doxycycline or tcalc in rabbits. The application of doxycycline was effective but caused severe local adverse effects. The application of tcalc and doxycycline were both associated with histologic changes in the contralateral lung lobes and increases in serum liver transaminase activity that suggest undesirable systemic effects. Conversely, the infusion of autologous blood caused no substantial short-term pleurodesis.
Possible complications of blood pleurodesis described in humans include bacterial infection and tension pneumothorax. Bacterial infection is a result of the initial surgical procedure or unsterile conditions during the infusion of blood, which both sequentially cause empyema. Empyema is the complication most frequently reported with blood pleurodesis. Studies have revealed the incidence of empyema to be 9%. Tension pneumothorax is another complication of blood pleurodesis that may be a sequel to the obstruction of a thoracostomy tube by blood clots. However, tube obstruction by blood clots was reported only once and rapidly resolved after the thoracostomy tube was flushed with 50 mL of sterile saline solution. Recommended guidelines for avoiding blood pleurodesis–associated complications include the infusion of autologous blood (ie, blood patching) through large-bore catheters only, performance of phlebotomy via a catheter (or needle) that has the largest internal diameter possible and 50-mL syringes, rapid blood infusion, and flushing of the thoracostomy tube with 10 mL of saline solution to prevent obstruction of the thoracostomy tube by blood clots.

Generally accepted guidelines regarding the volume of blood infused during blood pleurodesis do not exist. However, investigators in a randomized control trial reported that 100 mL of infused autologous blood is more effective than is 50 mL when treating postoperative air leakage in humans. In the present clinical report, 80 mL of autologous blood was infused on the basis of body weight and Hct of the dog.

In the present clinical report, blood pleurodesis was used to treat persistent pneumothorax that resulted from traumatic tearing of alveoli during reduction of a chronic diaphragmatic hernia. We suggest that blood pleurodesis should be considered (when surgery is not feasible) in patients with traumatic or spontaneous pneumothorax that does not resolve with a thoracostomy tube. In this dog, the owners could not afford an additional thoracotomy or thoracostomy tube placement, and blood pleurodesis was used because a reduction in the amount of air leakage was not observed.

The present clinical report does not provide definitive proof that treatment with blood pleurodesis for the resolution of pneumothorax will be successful in all dogs. Blood pleurodesis is inexpensive, safe, and easy to perform. Blood pleurodesis does not require advanced equipment or technical skills, and injection of blood into the thoracic cavity is likely to cause less pain and require less time than would be expected with an exploratory thoracotomy. Furthermore, resolution of pneumothorax may be observed shortly after injection of blood into the thoracic cavity. We propose that blood pleurodesis be considered as an alternative medical intervention for the treatment of dogs with pneumothorax from unresolved air leakage.