

Pneumothorax

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Abstract: *Pneumothorax may be classified as open or closed and as traumatic, spontaneous, or iatrogenic. The most common cause of pneumothorax is thoracic trauma. Spontaneous pneumothorax is often a result of bullous emphysema, and iatrogenic pneumothorax is an important complication of procedures involving the thoracic cavity. Most animals present with tachypnea, tachycardia, respiratory distress, and anxiety. Radiography and thoracocentesis are useful diagnostic aids. Traumatic and iatrogenic pneumothorax are commonly treated with thoracocentesis or thoracostomy tube placement. Spontaneous pneumothorax usually requires surgical resection of the affected lobe(s). The prognosis for traumatic pneumothorax is excellent if there are no other life-threatening injuries; for spontaneous pneumothorax, the prognosis depends on the underlying cause and method of treatment. The prognosis for iatrogenic pneumothorax is considered good.*

Pneumothorax is classified as open or closed and according to the causative mechanism. *Open pneumothorax* results from a penetrating thoracic injury that permits entry of air into the chest, while *closed pneumothorax* is the accumulation of air originating from the respiratory system within the pleural space. In some cases, the air may come from both sources (e.g., severe thoracic bite wounds with lung punctures).

Causative Mechanisms

Pneumothorax is classified as traumatic, spontaneous, or iatrogenic according to its cause¹ (**BOX 1**).

Traumatic

Traumatic pneumothorax is the most common form of pneumothorax in dogs.¹⁻⁶ Traumatic pneumothorax can be open or closed¹; however, it is usually closed.² Closed traumatic pneumothorax is often the result of blunt trauma (e.g., automobile accident). When the chest is compressed against a closed glottis, the bronchial tree or lung parenchyma can rupture with resultant air leakage into the pleural space.^{3,4} If a large airway is injured, pneumomediastinum may be present.^{5,6} Fractured ribs can lacerate lung lobes, resulting in closed traumatic pneumothorax.³ Open traumatic pneumothorax

results from a penetrating thoracic injury such as a stab, gunshot, or bite wound.

Spontaneous

Spontaneous pneumothorax is not the result of traumatic injury and is classified as closed. Spontaneous pneumothorax is less common than traumatic pneumothorax,^{1,7-10}

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BOX 1

Types and Causes of Pneumothorax

► Traumatic

- Open: Stab, gunshot, bite wounds
- Closed: Impact (inflicted by person or car)

► Spontaneous

- Cavitory lung lesions: Bullae/blebs, cysts, abscesses/granulomas, pneumatoceles, parasitic cysts (*Paragonimus* spp)
- Grass awns/porcupine quills
- Pneumonia
- *Dirofilaria immitis*
- Neoplasia
- Feline asthma

► Iatrogenic

- Thoracic fine-needle aspiration
- Tracheal intubation
- Mechanical ventilation

has several different etiologies, and is classified as primary (no obvious clinical evidence of pulmonary disease) or secondary (obvious clinical evidence of pulmonary disease).^{4,11,12} The most common cause of spontaneous pneumothorax is the rupture of pulmonary blebs or bullae (bullous emphysema).^{1,7,8,10,12,13} Pulmonary blebs result from air that has accumulated within the visceral pleura.^{12,14,15} Bullae are the result of destruction, dilation, and convergence of contiguous alveoli^{14,15} secondary to obstruction of the small airways¹³ and are found within the lung parenchyma. Blebs most commonly arise at the apex of the lung lobes¹³ (FIGURE 1). In cases of single lung lobe involvement, the right middle lung lobe is overrepresented.¹⁶ Rupture of the bullae and blebs is thought to be due to obstruction of the small airways.

Blebs and bullae belong to a class of pulmonary lesions known as *cavitary lung lesions*.¹⁷ Other cavitary lung lesions that may result in secondary spontaneous pneumothorax include pneumatoceles, abscesses, cystic bronchiectasis, and parasitic cysts.

Other causes of secondary spontaneous pneumothorax are grass awn migration, porcupine quill migration, pneumonia, chronic granulomatous infections, *Dirofilaria immitis* infections, and neoplasia.^{7,8,10,13,16,18–27} Seven cats with small airway disease secondary to feline lower airway disease (asthma) were reported to have closed spontaneous pneumothorax.^{28,29} Asthma can predispose cats to increased alveolar pressure and emphysema resulting in spontaneous pneumothorax.²⁹ Congenital lobar emphysema secondary to bronchial cartilage hypoplasia and bronchiectasis has also been reported in the literature as a cause of spontaneous pneumothorax.^{22,23,30}

Because bilateral involvement is common and tension pneumothorax can result, spontaneous pneumothorax should be considered a serious, life-threatening disease.⁷

Iatrogenic

Thoracic fine-needle aspiration is a common cause of closed iatrogenic pneumothorax.^{1,12,31} Chronic effusions such as chylothorax, pyothorax, and malignant pleural effusions increase the risk of pneumothorax after thoracic aspiration. Chronic effusions often result in fibrosing pleuritis, which leads to the persistence rather than

rapid closure of parenchymal–pleural fistulas.³²

Iatrogenic pneumothorax has rarely been associated with tracheal rupture due to intubation in cats if the pressure is high enough to rupture the mediastinum³³ (FIGURE 2). The most common cause of tracheal rupture is overinflation of the endotracheal tube cuff⁵; other causes include rotation of the animal without disconnection from the anesthesia machine tubing, traumatic intubation with a



FIGURE 1
Intraoperative photograph of a pulmonary bleb. Note that the bleb is at the apex of the lung lobe.

Courtesy of John V. Mauterer, DVM, DACVS



FIGURE 2
Radiograph of a cat with iatrogenic pneumothorax, pneumomediastinum, and subcutaneous emphysema (arrow) as a result of tracheal tear after tracheal intubation. The single arrowhead indicates cardiac silhouette elevation. The double arrowhead indicates lung lobe atelectasis.

style, and removal of the tube without deflation of the cuff.³³ Tracheoscopy is considered the method of choice for documenting tracheal tears.⁵

Positive end-expiratory pressure mechanical ventilation can lead to barotrauma and iatrogenic pneumothorax, especially in animals with pulmonary parenchymal disease requiring high pressure. Jugular venipuncture causing tracheal laceration and the lateral surgical approach to the thoracolumbar vertebrae are other reported causes of iatrogenic pneumothorax in cats and dogs, respectively.³

Effects

Bilateral pneumothorax is the most common condition^{1,7,12,13,34} because air diffuses through the thin mediastinum.⁴ Pneumothorax is considered a restrictive disorder of the lung.¹¹ A decrease in the lung's compliance due to extrapulmonary air is the primary defect.³¹ When air enters the pleural space, the negative pressure of the pleural space is diminished, allowing the lung's inherent elastic recoil to result in collapse (atelectasis). Atelectasis leads to a ventilation/perfusion mismatch.^{11,35} This can lead to arterial hypoxemia, which in turn may result in myocardial dysfunction, lactic acidosis, and ultimately death if not corrected.³⁵ Hypercapnia due to hypoventilation magnifies acidosis.³⁶

When the lungs collapse, the tidal volume is reduced, prompting tachypnea in an attempt to maintain the minute ventilation.³⁵ Local hypoxia induces vasoconstriction of pulmonary vessels, diverting blood flow to ventilated areas. Vasoconstriction, combined with collapse of blood vessels due to atelectasis, eventually leads to pulmonary hypertension and increased work for the right side of the heart.³⁵

Tension pneumothorax is the most severe form of pneumothorax. It can result from blunt or penetrating thoracic trauma or from spontaneous pneumothorax.⁷ In this form of pneumothorax, thoracic injuries or pulmonary lesions act as one-way valves, allowing air into the pleural space during inspiration and preventing expulsion during expiration. A slight increase in pressure in the pleural cavity results in a significant decrease in venous return. Blood pools in capacitance vessels, and shock results. The continued accumulation of air quickly results in supraatmospheric pressure within the thorax,

causing collapse of the lungs and great veins.¹¹ The patient rapidly deteriorates^{4,11,37} and dies. Radiographs should never be used for diagnosis in animals with tension pneumothorax because the associated delay and stress may result in the death of the patient.

Signalment

Traumatic

Traumatic pneumothorax is most common in young, intact male dogs because they are more apt to wander and be hit by cars.^{2,8}

Spontaneous

Primary spontaneous pneumothorax is most common in deep-chested, large-breed dogs.^{1,12,13} Studies have shown that Siberian huskies have a significantly greater incidence of primary spontaneous pneumothorax than other breeds.^{1,38} Animals of any age can develop pneumonia or become infected with respiratory parasites or heartworms. Older animals are more likely to develop pneumothorax secondary to neoplasia of the lungs.

Iatrogenic

Iatrogenic pneumothorax can occur in any animal undergoing thoracic surgery, anesthesia, or mechanical ventilation.

History

Traumatic

Patients with traumatic pneumothorax usually present with an obvious history of trauma, evidence of trauma, or a history consistent with trauma, such as, "came home breathing hard."

Spontaneous

The most common historical complaints from owners of animals presenting with spontaneous pneumothorax include difficulty breathing, anorexia, tachypnea, coughing, and vomiting.^{1,4,12,39} Lethargy, fever, cyanosis, gagging, exercise intolerance, and collapse are less commonly reported signs.¹ In one study,¹ the median duration of clinical signs before presentation to a veterinary hospital in dogs with spontaneous pneumothorax was 3 days (range: 0 to 28 days); in another study,³⁹ it was 1 day (range: 1 hour to 3.5 days).

Iatrogenic

Animals with iatrogenic pneumothorax have a

QuickNotes

Pneumothorax can result from traumatic, spontaneous, or iatrogenic causes.

recent history of thoracic aspiration, tracheal intubation, anesthesia, or other procedures related to the thoracic cavity.

Physical Examination

Traumatic

Animals with traumatic pneumothorax often have other injuries associated with the trauma (e.g., lacerations, scrapes, bruises, fractures). Animals with open pneumothorax secondary to penetration of the thoracic cavity may have an obvious wound, such as a “sucking thoracic wound” (a large open wound that allows the influx of air into the chest during inspiration).⁴ In other cases, the wound may not be immediately visible. This is particularly true for thoracic bite wounds.

Spontaneous

Tachypnea, tachycardia, respiratory distress, and anxiety are common findings during the physical examination of animals with pneumothorax. Shallow, rapid breaths with an abdominal component (restrictive breathing pattern) may be noted.^{1,4} Auscultation of the chest reveals muffled heart and lung sounds dorsally.^{3,4}

Iatrogenic

Subcutaneous emphysema may be present in cats with concomitant pneumomediastinum and pneumothorax secondary to tracheal tears after intubation³³ (FIGURE 2).

Diagnostic Evaluation

Laboratory Evaluation

Complete blood count and biochemical profile results are usually normal, nonspecific, or related to concomitant disease.^{12,39} Blood gas analysis may document hypoxemia as well as respiratory acidosis due to hypoventilation and hypercapnia.³⁶ In animals with pneumothorax secondary to heartworm disease, results of occult heartworm tests are positive. *Paragonimus* infections can be identified using Baermann sedimentation fecal examination^{18,40} or transtracheal aspiration.¹⁸

Radiography

Animals in severe distress should undergo thoracocentesis before radiography. Lateral thoracic radiographs show elevation of the cardiac silhouette from the sternum. Atelectatic lung lobes are radiopaque in contrast to the radiolu-

cent, air-filled pleural space created as the lungs retract from the parietal pleura (FIGURE 3). As the lungs collapse, the vascular pattern of the lungs no longer extends to the chest wall as it does in a healthy animal.

Traumatic

In animals with traumatic pneumothorax, other injuries are common, and the patient and the radiographs should be evaluated carefully for occult or subtle injuries. Diaphragmatic hernia, hemothorax, rib and vertebral fractures, and pulmonary contusions are common concurrent injuries.

Spontaneous

In animals with spontaneous pneumothorax, radiographs should be evaluated for potential underlying causes of pneumothorax. Pneumonia, abscesses, granulomas, neoplasia, and changes secondary to heartworm disease (e.g., tortuous vessels, enlarged pulmonary arteries) should be excluded. The presence of bullae or blebs may be difficult to appreciate; however, these lesions are occasionally visible (FIGURE 4). In studies of dogs with spontaneous pneumothorax, radiographic bullae have been detected in 4% to 31% of cases.^{1,7,12,39}

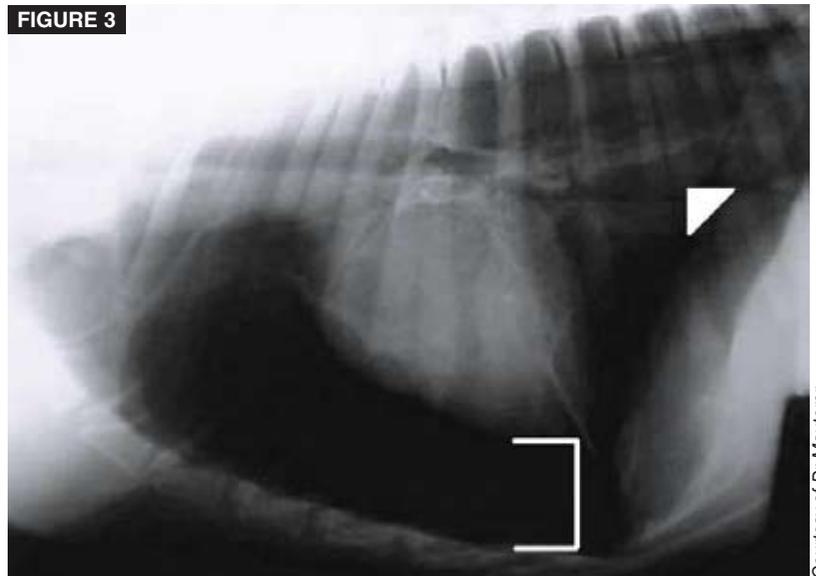
Iatrogenic

Animals with tracheal tears may have subcutaneous emphysema and pneumomediastinum,^{5,33} which is noted by the visualization of the cranial vena cava, aorta, and esoph-

QuickNotes

Consequences of pneumothorax may include tachypnea, hypoxemia, tachycardia, and, if left untreated, cardiovascular collapse and death.

FIGURE 3



Radiograph showing severe pneumothorax. Note cardiac silhouette elevation (bracket) and lung lobe atelectasis (arrowhead).

Courtesy of Dr. Maurer

gus (normally not visible in healthy animals; **FIGURE 2**). In animals that develop pneumothorax after thoracocentesis, rounded lung margins, consistent with chronic effusion, may be seen (**FIGURE 5**).

Computed Tomography

Computed tomography (CT) is routinely used in people for the diagnosis of bullae and blebs because it is considered more sensitive than radiography.⁴¹ The accuracy of lesion identification using CT in humans has been shown to range from 88% to 91.8%.^{42–44} One study³⁹ comparing the accuracy of radiography and CT for bullae and bleb identification in dogs with spontaneous pneumothorax found radiography to be accurate in 16% of cases and CT to be accurate in 80% of cases. The authors of this study suggested that CT was a better diagnostic tool than radiography for the identification of lung lesions associated with spontaneous pneumothorax.³⁹ However, in many veterinary patients, a CT scan is not performed preoperatively because the findings may not change the surgical approach and because of the additional costs.

Thoracocentesis

Thoracocentesis is beneficial in that it may be both diagnostic and therapeutic (**BOX 2**). Often, radiography is conducted before thoracocentesis. However, thoracocentesis may be performed in a rapidly deteriorating patient without prior radiography.^{4,45}

Thoracocentesis carries the risk of lacerating or puncturing a lung lobe, which results in iatrogenic pneumothorax; however, proper technique, caution, and recognition of at-risk patients can minimize these complications.⁴⁵

Treatment

Supplemental Oxygen

Because atelectasis and ventilation/perfusion mismatch can lead to hypoxia, animals with pneumothorax may benefit from supplemental oxygen.³⁵ Oxygen therapy may also be beneficial because these animals may have respiratory and metabolic acidosis and hypercapnia.³⁶ In animals with closed pneumothorax, oxygen therapy can hasten the resolution of the pneumothorax. The full physiology behind this mechanism is beyond the scope of this article; however, it is based on differences in partial pressures of blood gases. The extrapulmonary air of pneumothorax contains mainly nitrogen and oxygen (~21%) and other minor constituents. The partial pressure of oxygen in the blood is approximately 100 mm Hg at sea level and normal barometric pressure (760 mm Hg).⁴⁶ When the oxygen content of the air delivered to an animal is higher than 21%, the partial pressure in the blood increases. This causes a decrease in the partial pressure of other gases in the blood (e.g., nitrogen), which in turn creates a pressure gradient for these gases to diffuse from the pneumothorax into the blood and eventually out of the system through respiration. Oxygen can be delivered by mask, nasal cannula, or cage/tank. It is important to minimize stress in these animals; therefore, for fractious or excited patients, an oxygen cage may be the best option.

Thoracocentesis

In animals with traumatic, closed pneumothorax, thoracocentesis can be curative, and recurrence is uncommon.^{4,37,45} Thoracocentesis should restore negative pressure within the thoracic cavity. If negative pressure cannot be reached, >10 mL/kg of air is aspirated within a 12-hour period, or repeated aspiration is required to alleviate respiratory distress, chest tube placement should be considered.^{2,8,47} Open chest wounds should be covered immediately with a sterile, occlusive dressing to prevent further equilibration with atmospheric pressure and allow effective aspiration of air.

QuickNotes

Radiographs readily depict pneumothorax; however, the underlying cause may not be evident on plain-film radiographs. Computed tomography may be useful in some cases.

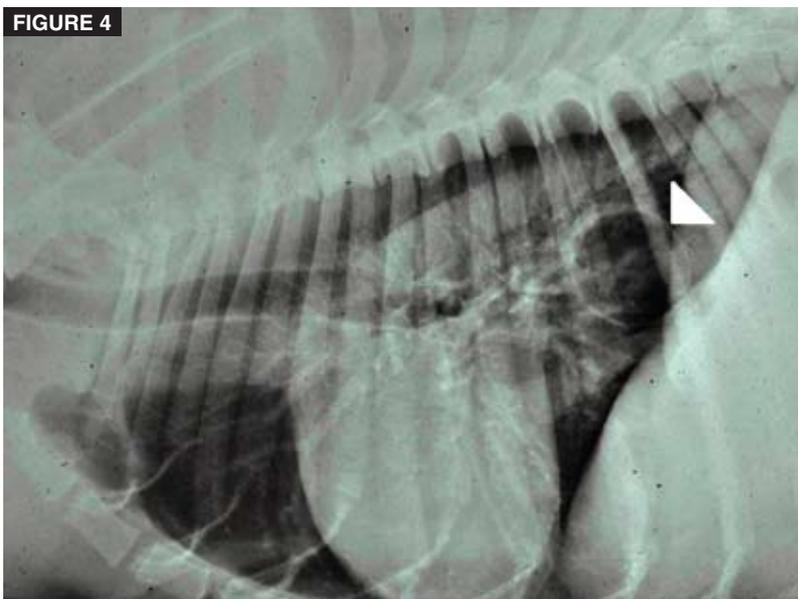


FIGURE 4 Radiograph of a pulmonary bulla (arrowhead).

Courtesy of Dr. Mauterer

BOX 2

Basic Steps of Thoracocentesis

- 1. Restrain the animal appropriately in either sternal or lateral recumbency.** With the patient in lateral recumbency, the 7th to 9th intercostal space at the level of the costochondral junction is an appropriate location for thoracocentesis.⁴ In standing or sternal animals, the same intercostal spaces can be used; however, needle placement should be in the dorsal two-thirds to one-third of the thorax.⁴
- 2. Clip and aseptically prepare** the 7th to 9th intercostal space.
- 3. A local anesthetic block** of the area is encouraged.⁴
- 4. In small dogs and cats, a butterfly catheter** (19 to 23 gauge) connected to a three-way stopcock may be used for aspiration.⁴⁴ In larger dogs or obese animals, a large-bore over-the-needle catheter connected to an extension set, three-way stopcock, and syringe may be used⁴⁴ (FIGURE A). A #11 blade can be used to make additional small holes in the catheter that are about one-third the diameter of the catheter.
- 5. Gently insert the needle** through the skin, subcutaneous tissue, fascia, and intercostal muscles cranial to the rib to avoid the intercostal vessels and nerves, which lie just caudal to the ribs. Aspirate while the needle is being advanced to allow appreciation of the proper depth.⁴ A gentle “pop” may be felt as entry into the pleural cavity is achieved.
- 6. Turn the needle** so that the bevel is facing medially and the needle is against the rib cage to reduce the risk of lung laceration.
- 7. Aspirate and quantitate** the amount of air removed from the pleural cavity.
- 8. Once negative pressure is achieved,** be sure not to aspirate while removing the needle/catheter from the pleural cavity.
- 9. If no air is aspirated, redirect,** tap a different site, or stop if the animal is no longer clinically dyspneic.⁴⁴

QuickNotes

Traumatic and iatrogenic pneumothorax are commonly treated by thoracocentesis or tube thoracostomy; spontaneous pneumothorax often requires exploratory thoracotomy or thoracoscopy for resection.

FIGURE A



Photograph showing proper needle placement and technique for thoracocentesis.

Tube Thoracostomy

Thoracostomy tube placement is indicated when reaccumulation of air in the pleural space is too rapid or severe to be controlled by thoracocentesis, thoracocentesis is performed more than three times in a 24-hour period, or severe or tension pneumothorax is present.^{1,7,8,10,47,48} Placement of a thoracostomy tube allows air to be removed intermittently or continuously, as necessary. **BOX 3** briefly describes tube placement and maintenance. This procedure has been more fully described elsewhere.^{47,48}

Intermittent drainage is usually sufficient if the amount of air accumulating is not life-threatening or very rapid. This method allows

quantification of the air accumulating within the chest. When the tube is not being used, a hemostat, C-clamp, or commercially available plastic clamp can be placed over the tube to prevent aspiration of air into the tube.⁴⁸

Continuous closed-suction drainage is indicated when air accumulation is very rapid and intermittent suction is not effective in achieving negative pressure. Continuous suction is based on the underwater suction system. Commercially available continuous-suction units include the Pleur-Evac (Teleflex Medical, Research Triangle Park, NC). These systems require constant monitoring (because patients can easily remove or damage the tubes) and do not allow quantification of the air removed

BOX 3

Basic Steps of Thoracostomy Tube Placement

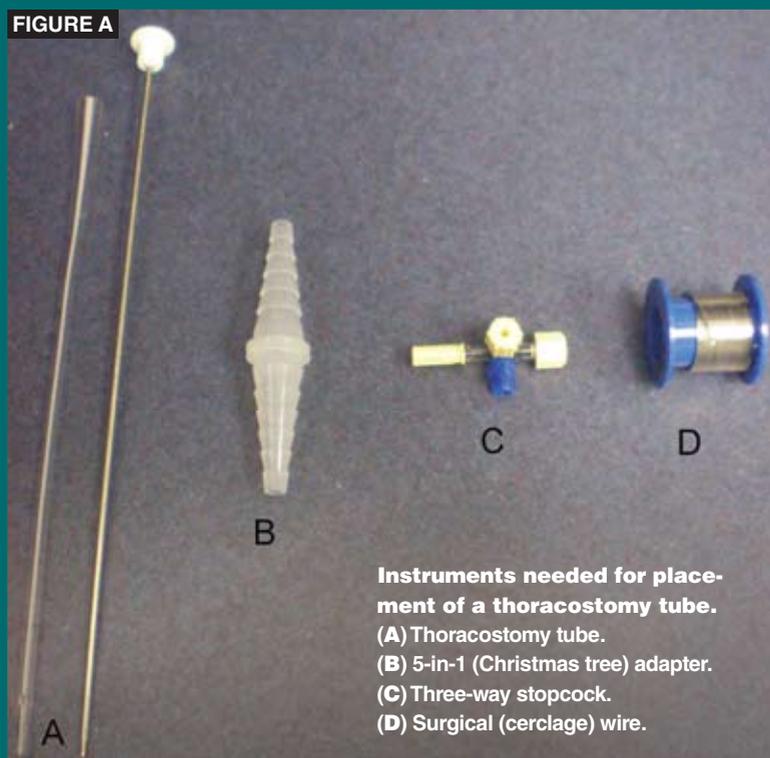
▶ The tubes should be flexible but firm and resistant to collapse.⁴⁷ Polyvinyl thoracic drainage tubes with stylets to assist with placement are commercially available (Argyle, Sherwood Medical) (**FIGURE A**). Red rubber feeding tubes may cause tissue reaction but may be used if other commercial tubes are unavailable and long-term placement is not anticipated.²

▶ The appropriate size of the tube is determined by the size of the mainstem bronchus on radiographs.^{45,47} Commercial tubes come with preplaced holes; however, additional holes can be added to achieve a total of three to five holes, which is sufficient for drainage. Many commercial tubes also have an incorporated longitudinal radiopaque marker to allow visualization of the tube on radiographs. If additional holes are placed, the last hole should be on the radiopaque marker line to allow assessment of the tube's placement within the thoracic cavity.

▶ The tube is generally placed with the animal under general anesthesia. If the animal's status precludes general anesthesia, local intercostal nerve blocks that include the parietal pleura may be used.^{45,47}

▶ The lateral thorax is clipped and prepared aseptically before tube placement.

FIGURE A



Instruments needed for placement of a thoracostomy tube.
(A) Thoracostomy tube.
(B) 5-in-1 (Christmas tree) adapter.
(C) Three-way stopcock.
(D) Surgical (cerclage) wire.

For medium and large dogs:

1. Make a small stab incision in the skin in the dorsal one-third of the thorax at the 10th to 12th intercostal spaces.
2. Make a tunnel in the subcutaneous tissue three to four intercostal spaces cranially using the tube with the stylet. If using a red rubber catheter or a tube without a stylet, use a pair of large hemostatic forceps to create the tunnel and advance the tube.⁴⁸
3. Rotate the tube perpendicular to the thoracic wall.

from the thoracic cavity. Some clinicians prefer these systems because they can maintain lung inflation, which may facilitate healing.

Heimlich valves are designed to use the pressure generated by expiration to expel pleural air while preventing air from entering the pleural cavity during inspiration. These devices should only be used in medium- to large-breed dogs because small dogs and cats may not produce enough pressure on expiration to expel the air.^{4,47} They should not be used in patients with pleural effusion because the valve will fill and seal, preventing air expulsion.⁴⁷ If a Heimlich valve is oriented incorrectly, iatrogenic tension pneumothorax results. Salci et al⁴⁹ reported successful treat-

ment of spontaneous pneumothorax secondary to infective pleuropneumonia using only a thoracostomy tube with a Heimlich valve.

Thoracostomy tubes can be removed when air production is absent for 24 to 48 hours. These tubes may cause a small amount of effusion (2 to 4 mL/kg/day), which resolves when the tube is removed.^{4,2,45,48} The tube is removed with steady traction and the site covered with an occlusive bandage for 6 to 24 hours; the incision is allowed to heal by second intention.⁴⁸

Treatment of spontaneous pneumothorax by thoracocentesis or thoracostomy tube alone is usually insufficient because recurrence is common.^{1,7,8,10,12,50}

4. With one quick, brisk thrust, pass the tube (or hemostat) through the intercostal musculature into the thoracic cavity. However, use caution, as too brisk an entry into the thoracic cavity may cause inadvertent damage to thoracic organs. Also, as for thoracocentesis, be careful to avoid the large intercostal vessels and nerves just caudal to the ribs.
5. Once penetration is achieved, lay the tube parallel to the spine, advance it slightly, and remove the stylet, passing the tube cranially and ventrally into the cranial pleural space.
6. Obtain a radiograph to ensure proper placement of the tube in the cranioventral pleural space to approximately the level of the second rib⁴⁸ (FIGURE B).
7. Place a purse-string suture at the entry site into the thoracic cavity to prevent leakage of air or fluid into the subcutaneous tissue.⁴⁸
8. Suture the tube to the skin using a Chinese finger-trap suture pattern or variation thereof.⁴⁸
9. Attach the tubing to a three-way stopcock, either directly or with a five-in-one (Christmas tree) adapter.
10. Secure the tubing to the stopcock with surgical wire to allow intermittent drainage.
11. Cover the tube entry with a few gauze sponges impregnated with a small amount of iodine ointment, followed by a soft, padded bandage or tubular stockinet over the chest to protect the tube.
12. Apply an Elizabethan collar to prevent premature pulling by the animal.



FIGURE B
Radiograph showing proper placement of a thoracostomy tube.

For small dogs, puppies, and cats, in which the chest is too compressible for any technique that requires force, or to avoid having to thrust the tube into the thorax in larger dogs, use the following technique:

1. After proper preparation of the area, pull the skin forward to the appropriate space.⁴⁸
2. Make the skin incision, followed by dissection down through the chest wall.⁴⁸
3. Insert the tube in an open fashion or use it to gently penetrate the inner intercostal layer.⁴⁸
4. Allow the skin to retract to its normal position, resulting in subcutaneous tunneling of the tube.⁴⁸
5. Follow steps 6 through 12 above.



Courtesy of Elizabeth Rozanski, DVM, DACVECC, DACVIM

FIGURE 5
Radiograph of a cat with chronic pleural effusion and pneumothorax secondary to fine-needle aspiration.

Surgical Intervention

Traumatic

Surgery is rarely needed to correct traumatic pneumothorax. Thoracocentesis or thoracostomy is usually sufficient to allow pulmonary healing in 3 to 5 days, and mild pneumothorax may require only monitoring.^{3,37} However, surgery may be indicated to repair open chest wounds or other wounds related to the trauma.

Spontaneous

Spontaneous pneumothorax is considered a surgical disease because dogs rarely respond to conservative therapy alone. A lateral or median approach may be used. Median sternotomy is the procedure of choice for exploration of the thorax^{1,7,8} because it allows visualization of both hemithoraces, which facilitates location of the air leak. Details of this and other surgical techniques have been published in various surgical texts.

Iatrogenic

Thoracocentesis or thoracostomy tube placement is usually sufficient for treatment of iatrogenic pneumothorax; however, if conservative therapy is unsuccessful, surgery is indicated.³

Thoracoscopy

Thoracoscopy can be used therapeutically and as a diagnostic tool if radiography and CT cannot localize a lesion.^{34,51,52} All structures within the thorax can be sufficiently observed using thoracoscopy.^{34,51,53} In a 2003 study,⁴⁰

spontaneous pneumothorax was successfully diagnosed and treated in three dogs using thoracoscopy, with no evidence of recurrence at 18 to 29 months after surgery. Lung lobectomy or biopsy can be performed with less morbidity and mortality using thoracoscopy.⁵² Minimally invasive surgery is associated with decreased morbidity, less pain, shorter hospitalization, and a quicker recovery.^{34,54-56} The experience of the operator is a large variable in the outcome of this procedure.

Postoperative Thoracotomy and Monitoring

After surgery, patients should be monitored closely for pain, respiratory distress, tachypnea, hypoventilation, and recurrence of pneumothorax. The thoracostomy tube should be aspirated every hour for the first 4 to 6 hours postoperatively until negative pressure is achieved. Aspiration can then be conducted every 4 to 6 hours. In almost all cases, there should be little or no ongoing air production. When negative pressure has been maintained for approximately 24 to 48 hours, the thoracostomy tube can be removed. Some serosanguineous discharge may be present while the tube is in the chest (approximately 2 to 4 mL/kg/day).⁴⁸ This will resolve once the tube is removed. If the animal shows any signs of respiratory distress or tachypnea, thoracic radiography should be conducted to assess for pleural effusion, recurrence of pneumothorax, atelectasis, or any other potential lesion.

Postoperative pain is an important consideration in animals undergoing surgical exploration of the thoracic cavity. Intercostal nerve blocks, interpleural regional anesthesia, continuous-rate infusion of drugs such as fentanyl or other opioid analgesics, and NSAIDs are all viable options to decrease the morbidity associated with these procedures. Appropriate dosages of these agents have been published in anesthesia/analgesia texts.

Prognosis

Traumatic

The prognosis for animals with traumatic pneumothorax is considered excellent¹² if there are no other life-threatening injuries.

Spontaneous

The prognosis for spontaneous pneumothorax depends on the method of treatment. Surgery

is considered the treatment of choice for spontaneous pneumothorax, with recurrence rates of 0% to 25% versus 50% to 100% with conservative therapy alone.^{1,7,10,12} Surgery may also be more economical than thoracostomy or thoracocentesis when long-term hospitalization and care costs are calculated.⁷

Iatrogenic

The prognosis for animals with iatrogenic pneumothorax is fair to good. Most animals can be treated conservatively.³ In animals with pneumothorax resulting from diagnostic procedures to the thoracic cavity or mechanical ventilation, the ultimate prognosis depends on the underlying disease.

Conclusion

A basic understanding of normal respiratory anatomy and physiology is important in understanding the pathophysiologic effects of pneumothorax. Early recognition of the clinical signs of pneumothorax is important, especially in animals with tension pneumothorax, which can cause rapid deterioration and death. A thorough understanding of lifesaving procedures such as thoracocentesis and thoracostomy tube placement is invaluable. Most animals with traumatic pneumothorax do well with conservative therapy alone, whereas animals with spontaneous pneumothorax frequently require surgical intervention for complete resolution. Iatrogenic pneumothorax can usually be treated conservatively. **C**

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3 CE
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- Iatrogenic pneumothorax secondary to intubation in cats has not been associated with**
 - overinflation of the cuff.
 - turning the patient without disconnecting the tube.
 - tracheal injury from a stylet.
 - laryngospasm.
- Pneumothorax is classified as a(n) _____ disorder of the lung.**
 - obstructive
 - restrictive
 - vascular
 - parenchymal
- Which of the following is the most common cause of pneumothorax?**
 - tracheal tears secondary to intubation
 - thoracic trauma
 - bullous emphysema
 - pulmonary neoplasia
- The most common cause of spontaneous pneumothorax is**
 - bullous emphysema.
 - parasitic cysts.
 - pulmonary neoplasia.
 - grass awn migration.
- Which breed has been shown to have a greater incidence of spontaneous pneumothorax?**
 - golden retriever
 - Siberian husky
 - Chihuahua
 - shih tzu
- Which is not a typical radiographic feature of pneumothorax?**
 - cardiac elevation from the sternum on the lateral recumbent projection
 - atelectasis or partial atelectasis
 - loss of the vascular pattern adjacent to the chest wall
 - air bronchograms
- Which statement is true regarding the use of CT in diagnosing pneumothorax?**
 - It is not helpful.
 - It is more accurate than radiography in the diagnosis of underlying lesions causing spontaneous pneumothorax.
 - It should be used to diagnose traumatic pneumothorax.
 - It is used in human medicine to diagnose traumatic pneumothorax.
- Which of the following is an indication for placement of a thoracostomy tube?**
 - Negative pressure can be obtained by thoracocentesis.
 - More than 2 mL/kg of air is aspirated over 12 hours.
 - Only one thoracocentesis procedure is required to alleviate respiratory distress.
 - Tension pneumothorax is present.
- Which statement about thoracoscopy is true?**
 - It results in less morbidity and mortality for lung lobectomy than median sternotomy.
 - It cannot be used as a diagnostic tool.
 - It does not allow sufficient visualization of thoracic structures.
 - It has not been attempted in animals with pneumothorax.
- Which type of pneumothorax routinely requires surgery for correction?**
 - closed traumatic
 - closed spontaneous
 - open traumatic
 - iatrogenic