Spontaneous pneumothorax is an accumulation of free air or gas in the pleural space in the absence of traumatic or iatrogenic causes. Primary spontaneous pneumothorax develops from the rupture of pulmonary bullae or blebs without underlying disease. Pneumothorax as a sequela of pulmonary disease is termed secondary spontaneous pneumothorax. The free air in the pleural space results from chronic inflammation, weakening of the pleura, and pulmonary destruction. Tension pneumothorax, a life-threatening condition, occurs when air accumulates via a one-way valve effect during inspiration, allowing air to enter but not leave the pleural space.

Rupture of pulmonary bullae or blebs is the most common cause of spontaneous pneumothorax, occurring in 36% to 68% of cases. Bullae and blebs are differentiated based on the layer of the pleura or parenchyma involved. Pulmonary blebs occur when air escapes from the lung, such as through a ruptured alveolus, and collects between the visceral pleura and the lung parenchyma. They are typically less than one to several centimeters in diameter. Bullae are air-filled spaces within the lung parenchyma resulting from confluence of adjacent alveoli. Bullae vary in size and are ultimately confined by the connective tissue septa within the lung and the visceral pleura.

Clinical signs of spontaneous pneumothorax are secondary to the decrease in lung expansion and venous return caused by the volume of air trapped within the pleural cavity and the resulting compromise of the cardiovascular and respiratory systems. The severity of clinical signs is, therefore, related to the amount of escaped air and the loss of negative intrapleural pressure.

**DIAGNOSTIC CRITERIA**

**Historical Information**

**Gender and Age Predisposition**

- None.

**Breed Predisposition**

- Siberian huskies are overrepresented.
- Possible increased risk for medium- to large-breed dogs.

**Owner Observations**

- Tachypnea and dyspnea.
- Anxiety.
- Decreased appetite.
- Decreased exercise tolerance.
- Vomiting.
- Cough.

**Other Historical Considerations/Predispositions**

- Primary spontaneous pneumothorax has not been identified in cats, and secondary spontaneous pneumothorax has been reported only rarely in cats, likely secondary to feline asthma.

**Physical Examination Findings**

- Pale or cyanotic mucous membranes.
- Tachypnea and/or dyspnea.
- Tachycardia.
- Decreased breath sounds dorsally; muffled heart sounds.
- Hyperresonant on thoracic percussion.
- Poor femoral pulse quality.

**Laboratory Findings**

- Complete blood count, serum biochemical profile, and urinalysis are usually within normal limits. $\$
- Pulse oximetry and arterial blood gas analysis may reveal evidence of hypoxemia. $\$

**Other Diagnostic Findings**

- Unstable patients with a high index of suspicion for pneumothorax should not undergo imaging procedures such as radiography, ultrasonography, or computed tomography (CT). Instead, thoracocentesis should emergently be performed (Box 1). — Thoracocentesis may be diagnostic and therapeutic. Aspiration of air during thoracocentesis confirms the diagnosis of pneumothorax. $\$

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*SGroup discloses that he has received financial support from Dechra Pharmaceuticals, Waltham, and Animal Clinical Investigation LLC.
Radiographic evidence supportive of spontaneous pneumothorax includes increased width of an air-filled pleural space, partial pulmonary collapse, retraction of lung margins from the chest wall, and, in a lateral view, elevation of the heart off the sternum. Radiographs are a relatively poor modality for consistently identifying bullae and blebs.

CT has been used in humans as a more sensitive method for detection of bullae and blebs than radiography.

CT should not be performed to diagnose pneumothorax in cases of respiratory distress. In cases of severe respiratory compromise, stabilization procedures such as needle thoracocentesis should be performed before imaging.

Correction of pneumothorax with either thoracocentesis or chest tube placement should be instituted before anesthetizing the patient for CT.

Placement of unilateral or bilateral chest tubes is indicated when severe pulmonary disease is suspected because there are times during CT when the veterinarian is separated from the patient.

Care should be taken when anesthetizing and ventilating these patients. Intermittent positive-pressure ventilation may rupture intact bullae or accelerate air leakage from the damaged lung. Pressures in excess of 10–12 cm H₂O should be avoided.

In a recent study in dogs, almost 2.5 times as many lesions were identified with CT as with radiography.

Blebs and bullae appear as areas of low attenuation and vascular alteration on CT.

CT allows identification of more lesions, better definition of lesion size and locations, and better differentiation of anatomic structures and their relationship to the lesions. The superiority of CT over radiography aids in the surgical approach. However, CT does not eliminate the requirement for a thorough surgical exploration of the thorax.

**Summary of Diagnostic Criteria**

- History of acute or chronic respiratory distress.
- Decreased breath sounds dorsally on thoracic auscultation.
- Radiographic, ultrasonographic, or computed tomographic evidence of air or gas in the pleural space.
- Aspiration of air via diagnostic thoracocentesis.

**Diagnostic Differentials**

- Causes of secondary spontaneous pneumothorax include bullous emphysema, neoplasia, bacterial pneumonia, pulmonary abscesses, chronic obstructive pulmonary disease, parasitic infections (dicrofilariasis, paragonimiasis, and *Filaroides osleri*),

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**Box 1. Tips for Performing Thoracocentesis**

- Place the patient in lateral or sternal recumbency. To minimize patient stress, the patient can stand or sit during the procedure.
- Mild sedation with butorphanol (0.2–0.4 mg/kg IM) or morphine (0.01–0.05 mg/kg IM) may be necessary.
- Determine the site for thoracocentesis based on auscultation, patient position, and radiographic findings. Blind thoracocentesis is performed at the 7th to 9th intercostal space (ICS) either with the patient in sternal recumbency at the mid to upper thorax or with the patient in lateral recumbency at the highest point (midthorax). If the patient is in the standing or sitting position, perform the procedure as if the animal were in sternal recumbency.
- Clip and prepare the site using sterile technique.
- The subcutaneous tissue and the pleura can be infiltrated using 2% lidocaine (1–2 mg/kg) or bupivacaine (1–2 mg/kg).
- Attach a 19-gauge butterfly catheter or a 20-, 18-, or 16-gauge over-the-needle catheter to extension tubing, a three-way stopcock, and a large syringe (20–60 mL).
- Slowly advance the needle or catheter cranial to the rib, angling caudally and ventrally to enter the pleural space just medial to the rib. This avoids iatrogenic lung laceration, especially when using a sharp needle.
- Use care to avoid the large vessels associated with the posterior segment of the rib margins.
- Perform aspiration until negative pressure is attained. The needle or catheter may need to be withdrawn a few millimeters at a time to maintain the catheter in the pleural space.
congenital cysts, migrating foreign bodies, feline asthma, and pulmonary thromboembolism.

- Traumatic or iatrogenic causes of pneumothorax should be identified and ruled out through a thorough history and identification of signs of trauma such as tracheal tears, rib fractures, and pulmonary contusions.

**TREATMENT RECOMMENDATIONS**

### Initial Treatment

The primary initial goal is to stabilize the patient until diagnostic tests can be performed to determine if surgical intervention is indicated.

- Thoracocentesis: Initial stabilization consists of removal of the free air in the pleural space. $\text{—}$
- It is preferable that all patients receive supplemental oxygen during thoracocentesis. This may be achieved with mask or flow-by oxygen administration; however, severely compromised or apneic patients may require intubation.

**Alternative/Optional Treatments/Therapy**

**Tube Thoracostomy**

- Thoracocentesis alone may not stabilize the patient if the bulla involves a bronchus with a diameter larger than the needle. If needle thoracocentesis is unsuccessful, tube thoracostomy should be emergently performed (Boxes 2 and 3). $\text{—}$—$\text{—}$
- Indications for tube thoracostomy include failure of needle thoracocentesis, the need for needle thoracocentesis more than twice during a 24-hr period, or detection of tension pneumothorax.

**BOX 2. MATERIALS FOR CHEST TUBE PLACEMENT**

- Sterile instrument pack including a hemostat, Kelly or Carmalt clamp forceps, a needle holder, scalpel holder, and suture scissors
- No. 10 or 15 scalpel blade
- Extension set
- Three-way stopcock
- Christmas tree adapter
- Syringe (20–60 mL)
- Commercial thoracostomy tube $^a$
  — Cat or dog <7 kg: 14–16 Fr
  — Dog 7–15 kg: 18–22 Fr
  — Dog 16–30 kg: 22–28 Fr
  — Dog >30 kg: 28–36 Fr
- Nonabsorbable suture

*A red rubber catheter can be substituted if a tube made of a more suitable material is not available; however, patient reactivity to red rubber catheters can lead to complications.

**BOX 3. TIPS FOR CHEST TUBE PLACEMENT**

- Clip the lateral thorax from behind the scapula to the last rib, and prepare the area using sterile technique.
- Place the animal in lateral recumbency.
- Have an assistant pull the skin cranially over the lateral thorax. $^a$
- Approximate the length of tube to be inserted by holding the chest tube alongside the chest to the second rib.
- Make a small skin incision in the dorsal third of the lateral thoracic wall at the level of the 7th to 8th ICS (with the skin pulled cranially).
- With a large hemostat, bluntly dissect the subcutaneous tissue and muscle layers.
- With the Carmalt forceps, bluntly penetrate the pleura.
- Keeping the Carmalt forceps in place, open the forceps to allow the tube into the thorax.
- Advance the tube cranioventrally, then remove the Carmalt forceps.
- Insert the tube to the level of the second rib, allowing for all tube fenestrations to be within the thoracic cavity.
- Remove the stylet, and clamp off the tube with the hemostat.
- As the skin is released over the tube, a subcutaneous tunnel is created from approximately the 10th–11th ICS to the 7th–8th ICS.
- Place a purse-string suture in the skin around the tube and a finger-trap suture pattern around the tube. One interrupted suture may be placed from the skin through the periosteum of the rib and around the tube to secure it in place.
- Connect the Christmas tree adapter, extension tubing, stopcock, and syringe or, alternatively, the continuous suction device.
- Thoracic radiographs should be obtained after placement in order to verify the correct position of the tube.

*If no assistant is available, the skin incision should be performed at the 10th to 11th ICS and a subcutaneous tunnel created cranially to the desired site of penetration (7th to 8th ICS).

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- Total IV anesthesia (TIVA) using an opioid/benzodiazepine combination ± ketamine may be preferred to inhalant anesthesia for chest tube placement in severely compromised patients because TIVA has fewer depressant effects on the cardiovascular and respiratory systems.
- Opioids (good cardiovascular stability, mild respiratory depression [canine dosages below; use half dose for feline dosage IV]):
  - Hydromorphone: 0.05–0.1 mg/kg IV. $\text{—}$
  - Oxymorphone: 0.025–0.1 mg/kg IV. $\text{—}$
  - Fentanyl: 2–5 μg/kg IV. $\text{—}$
  - Morphine: 0.1–0.3 mg/kg IV. $\text{—}$
ON THE NEWS FRONT

In humans, the use of underwater seal devices has achieved statistically better rates of early chest tube removal and increased avoidance of pleurodesis compared to patients treated with traditional management. An underwater seal device is an airtight system to maintain subatmospheric intrapleural pressure. It acts as a one-way valve through which air is expelled from the pleural space and prevented from reentering during the next inspiration.

Heliox, an inert helium-oxygen mixture comprising 80% helium and 20% oxygen, has been shown to be as effective as oxygen in reducing the degree of experimental spontaneous pneumothorax. The mechanism of this reduction is not fully understood but may be related to denitrogenation.

Heliox avoids the potential adverse effects of treatment with pure oxygen.

The low density and viscosity of heliox reduce turbulent airflow and increase laminar airflow, thereby decreasing the work of breathing.

Heliox is available as a prehomogenized mixture. Alternatively, the mixture may be created by connecting a helium tank to an established oxygen line through a Y-connector and adjusting both gas flows to achieve the desired ratio.

— Diazepam/midazolam: 0.1–0.25 mg/kg IV (good cardiovascular/respiratory stability).
— Ketamine: 2–4 mg/kg IV (good cardiovascular/respiratory stability).
— Double all doses for IM administration.

Inhalation anesthesia using isoflurane or sevoflurane. $$$–$$$$

Inhalant anesthetics decrease ventilation in a dose-dependent manner and possess cardiovascular-depressant properties.

Positive-pressure ventilation should be avoided until the tube is in place because it can exacerbate pneumothorax and rupture additional bullae and blebs.

Patients maintained on inhalant anesthesia for tube placement should be premedicated with an opioid (see above for doses) for pain management.

Local anesthetic blocks for the skin and pleura should be performed using 2% lidocaine (1–2 mg/kg) or 0.25% bupivacaine (1–2 mg/kg).

— Lidocaine may take 5–10 min and bupivacaine 20–30 min for full effect.

— Thoracic exploration and partial or complete lobectomy. $$$–$$$$

— Results of recent studies show that dogs treated with early surgical intervention have lower recurrence rates and higher success rates than dogs maintained with intermittent thoracocentesis or tube thoracostomy.

— The median sternotomy approach is preferred to lateral thoracotomy because it provides better exposure of the entire pleural cavity and access to both lungs.

— Lesions have been reported in multiple lung lobes in 37% of cases and bilaterally in 26% of cases.

— If the source of the pneumothorax cannot be visualized, the pleural cavity can be filled with saline to identify the leak as air bubbles escape.

— Stapling equipment or suture techniques may be used for partial lobectomy, removal of peripheral lesions such as bullae or blebs, or total lobectomy for infiltrative lesions such as pulmonary neoplasia or abscesses.

— A thoracostomy tube should be placed before surgically closing the thorax.

Thoracoscopy $$$–$$$$

— This technique has been used diagnostically and therapeutically for spontaneous pneumothorax in dogs.

— Thorough exploration of the thorax may require bilateral thoracoscopic evaluation and pulmonary exclusion. Pulmonary exclusion requires selective intubation or specially designed endotracheal tubes to ventilate one mainstem bronchus.

— The inconsistent location of pulmonary lesions makes careful examination of all parts of all the lung lobes necessary.

— Thoracoscopic partial lobectomies can be performed to remove ruptured bullae and blebs and focal areas of diseased lung.

Oxygen Therapy

— Trapped air will be absorbed from the pleural space over several days to weeks (cost depends on hospital fees). $$$$$

— Patients with normal vital signs and oxygenation parameters and without significant clinical signs of pneumothorax may be managed with oxygen therapy alone.

— If the concentration of inhaled oxygen is increased and the concentration of inhaled nitrogen decreased, the partial pressure of nitro-
gen in the capillaries will be reduced, leading to a greater diffusion gradient and increased speed of resolution of pneumothorax.

- Success has been reported with medical treatment of the underlying disease combined with intermittent thoracocentesis, tube thoracostomy, and/or oxygen therapy in nonsurgical secondary spontaneous pneumothorax caused by pneumonia, dirofilariasis, and paragonimiasis.

**Supportive Treatment**

- Care of the patient after thoracostomy tube placement:
  - Secure the chest tube in place and apply a sterile bandage to keep the site clean and covered. Bandages should be changed at least once daily using strict aseptic technique.
  - An Elizabethan collar may be placed on the patient.
  - Patients require 24-hr monitoring of respiratory rate and effort. The patient should be kept sternal or turned frequently (every 2–4 hrs) to prevent atelectasis of the recumbent lung.
  - The tube should be aspirated every 30 min to 4 hr as needed. Generally, it is best to aspirate the tube every 30 min to 1 hr for the first 4 hr, then once every 4–6 hr.
  - The tube may be removed once negative pressure has been achieved for 12–24 hr. When the tube is removed, a nonadherent pad with antibiotic ointment may be pressed over the exit site. A light bandage is then placed over the site to allow healing by second intention.
  - Continuous suction with a pleural drainage device should be instituted if the accumulation rate of air becomes life threatening. $$$–$$$$
    - Many commercial systems based on the underwater bottle principle are available, but the three-chambered water seal suction apparatus is recommended. A suction pressure of 10–15 cm H₂O is used.
    - Advantages of continuous suction include allowing sustained lung expansion and better healing of leaks by pleural adhesion.
    - The disadvantages of this method are that the drained air is not quantifiable and that the apparatus requires 24-hr monitoring.
  - Postoperative pain medications are indicated for surgical patients while in the hospital and at home.
    - Hydromorphone: 0.05–0.2 mg/kg IV q4–6h. $
    - Oxymorphone: 0.025–0.1 mg/kg IV q4–6h. $
    - Fentanyl CRI: 2–8 μg/kg/hr IV. $
    - Morphine/lidocaine/ketamine CRI IV (see formula below). $
- Morphine: 0.1–0.2 mg/kg/hr (may substitute fentanyl: 2–8 μg/kg/hr).
- Lidocaine: 10–25 μg/μl/min.
- Ketamine: 2–5 μg/kg/min.
- Fentanyl patch. $
  - Variable absorption and time to reach analgesic levels.
- Cats and dogs <10 kg: 25 μg/hr.
- Dogs 10–20 kg: 50 μg/hr.
- Dogs 20–30 kg: 75 μg/hr.
- Dogs >30 kg: 100 μg/hr.
- If indicated, these patients should be sent home with an oral pain medication such as tramadol at 2–4 mg/kg PO q8–12h or codeine at 1–2 mg/kg PO q6–8h. $
- NSAIDs may be added for multimodal pain relief if there is no evidence of renal or liver disease. $
  - Carprofen: 2.2 mg/kg SC or PO q12h (approved for dogs only).
  - Meloxicam: 0.1–0.2 mg/kg SC or PO q24h (dogs only). Reduced dosage for cats is 0.1–0.2 mg/kg SC/PO on the first day, then 0.05–0.1 mg/kg SC/PO for 3–4 days, then 0.025 mg/kg SC/PO 2 to 3 times weekly. Injectable is approved for dogs and cats; however, the oral dose is used off-label in cats.
  - Deracoxib: 3–4 mg/kg PO q24h (approved for dogs only).

**Patient Monitoring**

- Patients should be monitored closely for recurrence of pneumothorax by monitoring respiratory rate and effort, heart rate, pulse oximetry, and blood pres-
sure. Respiratory rate and effort should be monitored every 30 min–1 hr for the first 12–24 hr postoperatively.

- Postoperative thoracotomy patients should be managed in a hospital ward with 24-hr nursing care.
- Cage rest for a 24-hr period is recommended.

**Home Management**
- Exercise restriction is recommended in the immediate postoperative period.
- Owners should monitor respiratory rate and effort.

**Milestones/Recovery Time Frames**
- Median duration of hospitalization for dogs treated with surgery is 6 days; median duration of hospitalization for dogs treated medically is 4 days.
- Postoperative median sternotomy patients are typically very painful and may take several weeks to completely recover.

**Treatment Contraindications**
- Before stabilization, exercise caution when administering any medications that may result in apnea or cardiopulmonary depression (e.g., propofol, acepromazine, medetomidine).
- Inhalant nitrous oxide should be avoided as it may cause a rapid increase in the volume of the pneumothorax.

**PROGNOSIS**
- The prognosis depends on the underlying pulmonary disease process.
- The recurrence rate is 3.3% in surgically treated dogs and 50% in medically managed dogs.
- The mortality rate is 12.1% in surgically treated dogs and 53% in medically managed dogs.

**Favorable Criteria**
- Identifiable and resectable focal disease.
- Aggressive medical management and early surgical intervention.

**Unfavorable Criteria**
- Tension pneumothorax.
- Pneumothorax associated with disease processes of poor prognosis (e.g., neoplasia).
- The underlying disease of bullous emphysema has a guarded prognosis due to its recurrent nature.
- Recurrence of pneumothorax.

**RECOMMENDED READING**


**ARTICLE #2 CE TEST**

**1. The most common cause of spontaneous pneumothorax is**

a. pulmonary abscess.

b. the rupture of bullae or blebs.

c. *Filaroides osleri*.

d. neoplasia.

e. migrating foreign material.

**2. Which statement is false regarding treatment of spontaneous pneumothorax?**

a. Pleurodesis for ruptured bullae has been shown to result in longer survival times compared with surgical management.

b. Surgical management results in lower recurrence and mortality than medical management.

c. Needle thoracocentesis is a quick, easy initial step to stabilize a spontaneous pneumothorax patient.

d. Median sternotomy is recommended over lateral thoracotomy.

e. CT is superior to radiography for determining the location and number of pulmonary lesions.

**3. Typical radiographic findings with spontaneous pneumothorax include**

a. loss of the cardiac silhouette due to pleural effusion.

b. enlarged heart and collapsing trachea.

c. retraction of lung margins from the chest wall.
d. fractured ribs and pulmonary contusions.
e. an alveolar pattern in the right middle lung lobe.

4. Which statement is false regarding stabilization and treatment of dogs with spontaneous pneumothorax?
a. If pneumothorax is suspected based on the physical examination and the patient is stable, chest radiography should be performed to confirm the diagnosis before instituting treatment.
b. Propofol, acepromazine, and medetomidine should be avoided as sedative choices.
c. Intermittent thoracocentesis is superior to surgical management.
d. Postoperative thoracostomy tubes may be removed once negative pressure has been achieved consistently for 12–24 hrs.
e. Owners should be instructed to monitor their pet’s respiratory rate and effort at home.

5. Which statement is true regarding heliox therapy?
a. Heliox is a mixture of 80% oxygen and 20% helium gas.
b. This therapy has been shown to be superior to treatment with 100% oxygen.
c. The high viscosity of heliox increases laminar airflow, thereby decreasing work of breathing.
d. The low density of heliox reduces turbulent airflow, thereby decreasing work of breathing.
e. Heliox has a noxious odor, allowing easy detection of leaks.