INTRODUCTION AND EPIDEMIOLOGY

Pneumothorax occurs when free air enters the potential space between the visceral and parietal pleura. **Primary pneumothoraces** occur without clinically apparent lung disease, either spontaneously or from penetration of the intrapleural space by trauma. **Secondary pneumothoraces** occur in patients with underlying lung disease.

The incidence of **primary spontaneous pneumothorax** is 10 to 18 cases for men and 2 to 5 cases for women per 100,000 population.\(^1\) Associated factors include cigarette smoking, male gender, mitral valve prolapse, Marfan's syndrome, and changes in ambient pressure. Familial patterns also suggest an inherited association.\(^2\) Physical activity or exertion can precipitate but is not a common pneumothorax-triggering factor. **Traumatic pneumothoraces** are subdivided into iatrogenic and noniatrogenic. Noniatrogenic pneumothoraces will be further discussed in the chapter 261, "Pulmonary Trauma."

Causes of **secondary spontaneous pneumothorax** are listed in Table 68-1. Chronic obstructive pulmonary disease remains the most common cause.\(^3\) Pneumothorax occurs in 5% of patients with acquired immunodeficiency syndrome, is associated with subpleural necrosis by *Pneumocystis* infection, and carries a high mortality. Because of necrosis of lung tissue and continued air leak, simple aspiration fails in this group of patients. Hemopneumothorax occurs in 2% to 7% of patients with secondary pneumothorax and, if associated with a large amount of blood in the pleural cavity, can be life threatening.\(^4,5,6,7\) Treating the underlying disease may help decrease the risk of future pneumothorax.
TABLE 68-1
Causes of Secondary Pneumothorax

<table>
<thead>
<tr>
<th>Airway disease</th>
<th>Chronic obstructive pulmonary disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asthma</td>
<td></td>
</tr>
<tr>
<td>Cystic fibrosis (8%–20% will develop one in lifetime)</td>
<td></td>
</tr>
<tr>
<td>Interstitial lung disease</td>
<td>Sarcoidosis</td>
</tr>
<tr>
<td>Pulmonary fibrosis</td>
<td>Tuberous sclerosis</td>
</tr>
<tr>
<td>Infection</td>
<td></td>
</tr>
<tr>
<td>Human immunodeficiency virus infection, <em>Pneumocystis</em> pneumonia</td>
<td></td>
</tr>
<tr>
<td>Tuberculosis</td>
<td></td>
</tr>
<tr>
<td>Bacterial pneumonia, necrotizing</td>
<td></td>
</tr>
<tr>
<td>Lung abscess</td>
<td></td>
</tr>
<tr>
<td>Connective tissue disease</td>
<td>Marfan's syndrome</td>
</tr>
<tr>
<td>Ehlers-Danlos syndrome</td>
<td>Scleroderma</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td></td>
</tr>
<tr>
<td>Cancer</td>
<td></td>
</tr>
<tr>
<td>Primary lung or metastatic disease</td>
<td></td>
</tr>
<tr>
<td>Catamenial pneumothorax</td>
<td></td>
</tr>
</tbody>
</table>

**PATHOPHYSIOLOGY**

Under normal conditions, the parietal and visceral pleura are in close apposition. The pleural space is negatively pressured at ~5 mm Hg with fluctuations of 6 to 8 mm Hg between inspiration and expiration. The inherent tendency of the chest wall is to expand and for the lungs to collapse from elastic recoil. With the loss of the normal negative pressure in the pleural space that "adheres" the visceral pleura (lungs) to the parietal pleura (ribs), the affected lung collapses. A primary spontaneous pneumothorax occurs when a subpleural bleb ruptures, disrupting pleural integrity. Rupture in primary spontaneous pneumothoraces usually involves the lung apex.\(^6,7,8\) In secondary spontaneous pneumothoraces, disruption of the visceral pleura occurs secondary to underlying pulmonary disease processes.
Once there is a break in the visceral pleura, air travels down a pressure gradient into the intrapleural space, until pressure equilibrium occurs with partial or total lung collapse. Altered ventilation–perfusion relationships and decreased vital capacity contribute to dyspnea and hypoxemia. If air continues to enter the pleural space, intrapleural pressure becomes positive. Tension pneumothorax develops as inhaled air accumulates in the pleural space but cannot exit due to a check-valve system. As intrathoracic pressure (>15 to 20 mm Hg) increases, the great vessels and heart are compressed and shifted contralaterally, severely restricting venous return, diastolic filling, and cardiac output causing ventilation-perfusion mismatch, and resulting in hypoxia and shock. Tension pneumothorax can develop in the presence of a chest tube if gas egress is obstructed, including from the adjacent lung.

**CLINICAL FEATURES**

Classic symptoms of primary spontaneous pneumothorax are sudden onset of dyspnea and ipsilateral, pleuritic chest pain. The pleuritic component of the pneumothorax may resolve within the first 24 hours. Profound dyspnea is rare, unless the patient has poor reserve due to underlying parenchymal disease or develops a tension pneumothorax. Sinus tachycardia is the most common physical finding. Because many pneumothoraces are small, other classic findings like ipsilateral decreased breath sounds, hyperresonance to percussion, and decreased or absent tactile fremitus are absent. In traumatic pneumothorax, the positive predictive value of ipsilateral decreased breath sounds is 86% to 97% for the diagnosis. Cough and exertional complaints are not common signs or symptoms. Except for trauma, physical exam alone is not sensitive enough to exclude the diagnosis.

The clinical hallmarks of tension pneumothorax are tracheal deviation away from the involved side, hyperresonance of the affected side, hypotension, and significant dyspnea.

**DIAGNOSIS**

Pneumothorax is an important differential consideration in patients with chest pain, especially in those with underlying lung disease. Patients with pleurisy, pleural effusions, infiltrates, or shingles can present with pain similar to those with pneumothorax.

**IMAGING**

Chest X-Ray

A standard erect posteroanterior chest radiograph is the usual initial test and demonstrates loss of lung markings in the periphery and a pleural line that runs parallel to the chest wall (Figure 68-1). Ensure that the line does not extend outside of the chest cavity, suggesting a confluence of shadows or skin line. A lateral radiograph will identify a pneumothorax in an additional 14% of cases. An expiratory radiograph does not identify many additional pneumothoraces. The sensitivity of anteroposterior chest radiography, when compared with CT, was 75.5% (95% confidence interval, 61.7% to 86.2%), with a specificity of 100% (95%
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In critically ill patients, when they cannot be moved to an erect position, look for the **deep sulcus sign**, a deep lateral costophrenic angle, on the affected side.

**FIGURE 68-1.**
Spontaneous hemopneumothorax. Upright chest radiograph of a 19-year-old male college student with spontaneous hemopneumothorax. Note the large air-fluid level in the inferior portion of the right hemithorax in addition to the complete collapse of the entire right lung.

Large bullae in patients with chronic obstructive pulmonary disease may look like a pneumothorax, although a pneumothorax pleural line will run parallel with the chest wall, whereas bullae will have a medially concave appearance. Pneumothoraces usually cross more than one lung segment, whereas bullae are limited to a single lobe. A chest CT can differentiate the two. A thoracostomy with the chest tube inserted into a bulla mistaken for a pneumothorax results in a large pneumothorax, associated bronchopulmonary fistula, and its complications. Pleural adhesions cement the visceral and parietal pleura together, changing the appearance of the pneumothorax.

**Pneumothorax size** may be calculated by the Light index or Collins or Rhea methods, but most published formulae show only a modest correlation to actual pneumothorax size. The American College of Chest Physicians supports a method of measurement from the apex of the lung to the cupula of the thoracic cavity on an upright posteroanterior film. A measurement of less than 3 cm in this cephalad area is considered a small pneumothorax. Another method is to measure the interpleural distance at the level of the hilum; in this area, a distance of 2 cm correlates with a pneumothorax of approximately 50% by volume.
The British Thoracic Society defines a small pneumothorax as one with a <2-cm rim between the lung edge and chest wall and a large pneumothorax as one with a ≥2-cm rim.18

US

US detects traumatic pneumothorax, with a reported sensitivity of 98.1% (95% confidence interval, 89.9% to 99.9%) and specificity of 99.2% (95% confidence interval, 95.6% to 99.9%).13 The movement of the lung (ocean) against the stationary chest wall (shore) is often referred to as the "seashore." In a normal lung, there is commonly a sonographic reverberation distal to the pleura that looks like a comet tail and a sliding sign of the movement of the visceral pleura along the parietal pleura (Figure 68-2). In the presence of intrapleural air, pleural adhesions, effusions, and parenchymal disease, small pneumothoraces may be loculated, and therefore, the sliding sign and the comet tail reverberation are lost, limiting the specificity for pneumothorax.14,15

FIGURE 68-2.
US with M-mode and B-mode imaging of normal (A) and abnormal (B) pleura. [Image used with permission of Casey Glass, MD, Wake Forest School of Medicine.]

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Chest CT detects between 25% and 40% of pneumothoraces not visualized on a postprocedure chest radiograph. CT can detect other pathology such as pulmonary blebs. If a chest radiograph does not demonstrate pneumothorax but there is clinical suspicion for the condition (e.g., in symptomatic high-risk patients, those with underlying lung disease or positive-pressure ventilation, or after lung biopsy), obtain a chest CT (Figure 68-3).

FIGURE 68-3.
Secondary spontaneous pneumothorax. CT of a large, left-sided secondary spontaneous pneumothorax. Note diffuse bullous emphysema.
TREATMENT

The ED treatment goal is the elimination of intrapleural air. **Tension pneumothorax should be diagnosed clinically—before a radiograph—and immediately treated by needle decompression followed by tube thoracostomy.**

Treatment options are **oxygen**, observation, needle or catheter aspiration (either single or sequential aspirations), and tube thoracostomy (either small-size or standard chest tube) (see Tables 68-2 and 68-3). **Oxygen** administration (>28%) increases pleural air resorption three- to fourfold over the base 1.25% reabsorbed per day, by creating a nitrogen gas pressure gradient between the alveolus and trapped air.\(^{19,20,21}\) Without supplemental **oxygen**, a 25% pneumothorax would take approximately 20 days to resolve. Recommended dosing ranges from 3 L/min nasal cannula to 10 L/min by mask and should be guided by the patient’s status. Monitor for hypercapnia in patients with chronic obstructive pulmonary disease.

**Observation** is appropriate for small, stable pneumothoraces only. If this option is selected, observe the patient for at least 4 hours on supplemental **oxygen**, and then repeat the chest radiograph. If symptoms and chest radiograph improve, the patient should return in 24 hours for repeat examination. First-time spontaneous pneumothorax of <20% lung volume in a stable, healthy adult may be treated initially with **oxygen** therapy and observation.\(^{19,20,21,22,23,24}\)

**Aspiration or tube thoracostomy** is selected based on likelihood of recurrence and likelihood of spontaneous resolution. Pneumothoraces in patients with underlying pulmonary disease are likely to recur. Large pneumothoraces and those with an air leak are unlikely to resolve without drainage. Inability to return for care or to tolerate any pneumothorax increase (i.e., those with poor cardiopulmonary reserve) should prompt drainage.
When deciding to intervene procedurally on a pneumothorax, the stability of the patient, the degree of symptoms, the size and relative change in size over time, the cause of the pneumothorax, the degree of underlying lung disease, the likelihood of recurrence and resolution, and the need for positive-pressure ventilation are factors to consider. In situations when the patient is clinically stable (Table 68-2), various treatment approaches can be considered (Tables 68-3 and 68-4).

**TABLE 68-2**

**Criteria for Stable Patient with Pneumothorax**

- Respiratory rate <24 breaths/min
- No dyspnea at rest, speaks in full sentences
- Pulse >60 and <120 beats/min
- Normal blood pressure for patient
- Room air oxygen saturation >90%
- Absence of hemothorax
The term "catheter" is used for a thin flexible tube; the term "chest tube" is used for a more rigid, larger tube. French sizes represent tube or catheter diameter (1 French = \( \frac{1}{3} \)-mm diameter), and the larger the French number, the larger the device.

<table>
<thead>
<tr>
<th>Aspiration and Thoracostomy Devices*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single aspiration</td>
</tr>
<tr>
<td>Needle aspiration</td>
</tr>
<tr>
<td>Small-size catheter</td>
</tr>
<tr>
<td>Small-size chest tube</td>
</tr>
<tr>
<td>Pigtail catheter</td>
</tr>
<tr>
<td>Moderate-size chest tube</td>
</tr>
<tr>
<td>Large-size chest tube</td>
</tr>
</tbody>
</table>

*The term "catheter" is used for a thin flexible tube; the term "chest tube" is used for a more rigid, larger tube. French sizes represent tube or catheter diameter (1 French = \( \frac{1}{3} \)-mm diameter), and the larger the French number, the larger the device.
# TABLE 68-4
## Treatment of Pneumothorax

<table>
<thead>
<tr>
<th>Condition</th>
<th>Treatment Options</th>
</tr>
</thead>
</table>
| Small primary pneumothorax (<20% or 3 cm apex-cupula and asymptomatic)   | Observation for >3 h on oxygen, repeat chest x-ray, discharge if no symptoms, and return for check if symptoms recur or in 24 h  
Or  
Small-size catheter aspiration with immediate catheter removal, then observe for >3 h, discharge if no symptoms, and return for check if symptoms recur or in 24 h  
Or  
Small-size catheter aspiration or small-size chest tube insertion, Heimlich valve, or water seal and admission |
| Small secondary pneumothorax                                             | Small-size catheter or small-size chest tube insertion, Heimlich valve, or water seal and admission                                                                                                                |
| Large pneumothorax, either primary or secondary, or bilateral pneumothoraces | Moderate-size chest tube and admission; large-size chest tube if fluid or hemothorax present; water seal and admission                                                                                           |
| Tension pneumothorax                                                     | Immediate needle decompression followed by moderate or large-size chest tube insertion, water seal drainage, and admission; immediate chest tube placement ideal                                                 |

The selection of catheter or chest tube size is based on the flow rate of air that the device can accommodate. Select large-bore tubes for anticipated big leaks, as from mechanical ventilation. Tension pneumothorax can develop if a large air leak develops, and small-bore tubes or catheters cannot handle the air flow. Every chest tube has a proximal hole, called the sentinel eye, which is visible radiographically and helps ensure that all drainage holes are inside the pleural cavity. Table 68-3 provides definitions for terms and various devices used to treat pneumothorax.\textsuperscript{26,27,28,29,30}

## NEEDLE DECOMPRESSION

To decompress, wear protective clothing or at least a mask to prevent material from squirting onto the operator. Use a 14-gauge needle for adults and an 18-gauge needle for children. Select a needle at least 2 inches (5 cm) long to penetrate the pleural cavity. Two locations are recommended: into the second or third intercostal space just above the rib (to avoid the intercostal artery) at the midclavicular line, or in the fourth or fifth intercostal space just above the rib and at the anterior axillary line (Figure 68-4). One small
postmortem study analyzing both approaches reported only a 59% success rate in entering the pleural cavity.\textsuperscript{31} If the needle is inserted medial to the midclavicular line, mediastinal vessels can be injured. A finger cot cut at its distal end can then be placed over the needle to fabricate a one-way valve. The Heimlich valve is still occasionally used for ambulatory treatment of pneumothorax, and serious complications with its use are rare.\textsuperscript{32}

**FIGURE 68.4.**

\begin{center}
\includegraphics[width=\textwidth]{figure68.4.png}
\end{center}

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**NEEDLE OR CATHETER ASPIRATION**

Needle or catheter aspiration is as effective as thoracostomy for treating the first episode of small primary or secondary spontaneous pneumothorax,\textsuperscript{25} with success ranging from 37% to 75%, or higher in those with primary spontaneous pneumothorax.\textsuperscript{26} Techniques include simple one-time aspiration with a large-gauge needle or a small-bore catheter, repeated aspirations through a small-size catheter, or chest tube attached to
a one-way valve or water seal drainage. The catheter technique has the advantages of both aspiration and chest tube placement.  

**Small-Size Catheters**

The catheter technique involves placing a small catheter either into the second anterior intercostal space in the midclavicular line or laterally at the fourth or fifth intercostal space in the anterior axillary line after local anesthesia and sterile preparation. Attach a three-way stopcock, and use a 60-mL syringe to aspirate the pleural space until resistance is met, often triggering a cough. Close the stopcock, secure the tube, and obtain a follow-up chest radiograph to ensure lung reexpansion. Aspiration of more than 4 L suggests continued air leak and failure of simple aspiration. Failure of the lung to fully expand warrants another aspiration attempt or formal tube thoracostomy and admission.

**Pigtail Catheters Using Seldinger Technique**

Advantages of this technique are a smaller incision, less tissue dissection, and smaller scar.

Insert the needle into the pleural space, making sure placement is in the "triangle of safety" (Figure 68-5). Aspirate fluid or air to verify location in the pleural space, and advance a guidewire through the needle. Place a dilator over the guidewire until the pleural space is entered. Remove the dilator and place the chest tube over the wire into the pleural space. Remove the stylet, secure the tube, and attach to suction.

**FIGURE 68-5.**
Safe location of chest tube, within a triangle bordered by the fifth intercostal space, pectoralis major, and latissimus dorsi.
Tube Thoracostomy

Chest tube thoracostomy is used to treat a large pneumothorax, recurrent or bilateral pneumothorax, or coexistent hemothorax, or if there are abnormal vital signs or dyspnea. A chest tube is used in small spontaneous secondary pneumothoraces where large air leak is anticipated or noted. Standard chest tube thoracostomy with underwater seal drainage is the most commonly used approach, with a low complication rate and a success rate of 95%.²⁴,²⁵ Most guidelines suggest a small 10- to 14-French chest tube for nontrauma, reserving larger 14- to 22-French chest tubes if a large air leak is probable, such as from mechanical ventilation or with underlying pulmonary disease.

The technique of tube thoracostomy is described in the chapter 261, "Pulmonary Trauma."

There is no clear difference between simple aspiration and intercostal tube drainage in overall short- and long-term outcomes,²⁴ and simple aspiration is as safe and effective as tube thoracostomy for small-volume air leak primary spontaneous pneumothorax.²⁵

TREATMENT COMPLICATIONS
Complications of the pneumothorax itself can include those due to hypoxia, hypercapnia, and hypotension. Reexpansion lung injury is uncommon and seen more often when there is collapse of the lung for greater than 72 hours, a large pneumothorax, rapid reexpansion, or negative pleural pressure suction of greater than 20 cm. Most patients need no treatment for re-expansion injury aside from observation or oxygen, with virtually no adverse outcomes.

Intervention complications include intercostal vessel hemorrhage, lung parenchymal injury, empyema, and tube malfunction (development of an air leak or tension pneumothorax). Pleurodesis for recurrence prevention is used in those with first spontaneous pneumothorax with a persistent air leak, second ipsilateral spontaneous pneumothorax, first contralateral pneumothorax, bilateral spontaneous pneumothoraces, first episode of a secondary pneumothorax, or recurrent high-risk activities (flying or diving).

**SPECIAL CONSIDERATIONS**

**IATROGENIC PNEUMOTHORAX**

Iatrogenic pneumothorax is a subset of traumatic pneumothorax and occurs more often than spontaneous pneumothorax. Transthoracic needle procedures (needle biopsy and thoracentesis) account for approximately half of iatrogenic pneumothoraces, and subclavian vein catheterization accounts for one fourth. Given that one central venous line is placed every minute in the United States and that pneumothorax occurs after 0.5% to 3.0% of subclavian line attempts, iatrogenic pneumothorax is common, underdetected, and underreported. Factors associated with the increasing frequency of iatrogenic pneumothorax include the patient population, underlying disease, body habitus, and experience of the operator. US guidance for central venous catheter insertion for thoracentesis reduces the pneumothorax complication rate.

Although it is routine to obtain a chest radiograph after central line placement or transthoracic needle procedures, chest radiograph may not identify a pneumothorax if supine or if there is inadequate time for the pneumothorax to develop, with up to one third detected later.

Treatment for iatrogenic pneumothorax is generally the same as that for spontaneous pneumothorax. Patients with a small pneumothorax after a needle puncture and those not requiring positive-pressure ventilation can be observed or initially treated with simple catheter aspiration (with or without a Heimlich valve), which is adequate for 60% to 80% of patients. Long-term recurrence is not a concern with iatrogenic pneumothorax.

**AIR TRANSPORT WITH PNEUMOTHORAX**

Increased elevation causes an increase in gas volume (Boyle's law), increasing the risk for tension pneumothorax in air transport patients with pneumothorax, particularly when transported in fixed-wing vehicles (airplane) given the altitudes reached. High-altitude flying is not recommended for at least 7 to 14 days after pneumothorax resolution.
DIVING

Similarly, due to Boyle's law, development of a pneumothorax at depth may lead to a tension pneumothorax with ascent. Current guidelines suggest that a history of spontaneous pneumothorax is a contraindication to underwater diving unless treated by surgical pleurectomy and normal lung function exists.\(^{21}\)

DISPOSITION

Patients with a primary spontaneous pneumothorax who have been treated with observation or with catheter aspiration can be discharged if the pneumothorax does not increase in size over 3 to 6 hours and symptoms resolve or do not worsen. The remaining patients are observed longer or admitted, with that decision based on the size, therapy, and clinical condition.

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[PubMed: 17621614]


[PubMed: 11991872]


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[PubMed: 18166436]


[PubMed: 17189116]


[PubMed: 23411057]


[PubMed: 23766331]
[PubMed: 22071915]

[PubMed: 24227562]

[PubMed: 23561257]

[PubMed: 23515437]

**USEFUL WEB RESOURCES**

An American College of Chest Physicians Delphi Consensus Statement—  

British Thoracic Society guidelines for the management of spontaneous pneumothorax—  
http://thorax.bmj.com/cgi/content/full/58/suppl_2/ii39

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