Whether in the emergency room or in the exam: The pneumothorax, one of the most important differential diagnoses of acute chest pain, has considerable importance both in clinical practice as well as in medical studies. In particular, the pathophysiology should be fully understood by every single medical student. Continue reading and score in your next exam!

Definition of Pneumothorax

Open and closed pneumothorax

A pneumothorax refers to a collection of air in the pleural space, the potential between the lungs. This normally air-free space is located between the two pleurae, the parietal pleura (lines the chest wall) and the visceral pleura (covers the lung directly from the outside). If there is a connection to the outside, either through the chest wall (e.g., resulting from a stab wound or other injury from the outside) or through a connection to the bronchial system, it is called an open pneumothorax. A closed pneumothorax has no such connection to the outside air.
Pathophysiology of Pneumothorax

Pneumothorax as the accumulation of air in the pleural space

The pressure in the pleural space in a physiological resting expiratory position is approximately -0.5 kPa, which is a negative pressure. This negative pressure in the pleural space prevents the elastic and contractile elements of the lungs from contracting to a point where they shrink up completely.

However, if air enters the pleural space, the negative pressure is released and the elastic forces outweigh it. In that case, the lung may collapse. This can be a full or partial collapse (apical or mantle pneumothorax).
Depending on the extent of the pneumothorax, the breathing can be severely affected due to the now present **restrictive ventilatory defect**. The so-called **tension pneumothorax** is particularly dangerous: It allows air into the pleural space through a one-way valve mechanism, but does not let it escape again. With every additional breath, air accumulates in the pleural space and eventually shifts the mediastinum due to the increasing pressure towards the other side. At the same time, it provokes the progressive loss of the function of the healthy lung and leads to an obstruction of the venous return (by a compression of the **venae cavae**) to the heart.

There is a risk of circulatory insufficiency!

**Note**: A tension pneumothorax is a life-threatening medical emergency!

### Etiology and Epidemiology of Pneumothorax

#### Traumatic pneumothorax and spontaneous pneumothorax

Depending on the cause of the pneumothorax, a distinction is made between traumatic and spontaneous pneumothorax.

<table>
<thead>
<tr>
<th>Traumatic Pneumothorax</th>
<th>Spontaneous Pneumothorax</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trauma</strong></td>
<td><strong>Primary (= Idiopathic)</strong></td>
</tr>
<tr>
<td>Blunt or sharp, penetrating injury</td>
<td>Lung surgery, CVC insertion, thoracentesis, etc.</td>
</tr>
</tbody>
</table>

A traumatic pneumothorax is the result of an accident (e.g., penetrating thoracic trauma, complicated rib fractures, etc.) or iatrogenic (e.g., after placing a central venous catheter, thoracentesis, or surgery to the lungs).

The **etiolog**y of the spontaneous pneumothorax can be further divided into an **idiopathic** (primary) and a **secondary spontaneous pneumothorax**. The idiopathic
tension pneumothorax is the most frequent variant and particularly affects young, tall, and athletic men between 20 and 40 years of age (ratio men : female = 6 : 1).

There is no known pre-existing condition of the respiratory organs, but smoking and a α1-antitrypsin deficiency are among the risk factors. It is assumed that in most cases, the rupture of a sub-pleural emphysema provokes a trauma of the parietal pleura and therefore releases air into the pleural space. Such emphysema usually rupture in the apical area of the lungs.

A secondary spontaneous pneumothorax occurs in individuals with a known pre-existing lung condition, when an increased existence of emphysema, caverns, or bronchiectases cause the pneumothorax. These include especially the COPD (in over 50 % of cases), cystic fibrosis and pulmonary emphysema. Middle-aged and older patients are most affected and the gender ratio is male : female = 3 : 1.

Clinical Signs and Symptoms of Pneumothorax

From dyspnea to circulatory shock with pneumothoraces

Small pneumothoraces can be symptom-free and remain undetected.

A symptomatic idiopathic spontaneous pneumothorax, however, often manifests in a very dramatic way: The patients experience a sudden sharp pain on the affected side, irritation of the throat, and possibly dyspnea. If a tension pneumothorax develops, the clinical condition of the patient deteriorates rapidly and presents a pronounced dyspnea and cyanosis, tachycardia, and hypotension — all the way up to a respiratory insufficiency and circulatory shock.

Diagnosis of Pneumothorax
Anamnesis and clinical examination of a pneumothorax

During the anamnesis, targeted questions can give first indications of a pneumothorax: Are there any known thoracic traumata? Have any surgical interventions been performed on the lungs? Have there been pneumothoraces before (recurrences are very common!)?

In the subsequent clinical examination, the following signs can be detected; they are also often a subject in medical exams:

- **Hyperresonant percussion** as well as a **decreased fremitus** on the affected side (these can also be detected without a stethoscope when performing first aid outside of a hospital!)
- Auscultation reveals **weakened breathing sounds** on the affected side
- Possibly, **asymmetric respiratory movements** ("lagging" of the affected side)

Here, as always, the comparison of left and right side in the percussion and auscultation is very important and indicatory!

**Chest radiography on two levels as a gold standard**

When the corresponding clinical symptoms are present, a mere auscultation cannot provide a sufficient evidentiary basis on which to rule out the suspected diagnosis: in cases of any reasonable suspicion of a pneumothorax, a **chest radiography on two levels** should always be taken.

**Note:** The chest X-ray should not be performed, as would be usual, during maximum inspiration, but during maximum expiration (this way, smaller pneumothoraces can be recognized more easily!)

In the radiographic image, the **pleura visceral** is distinguishable as a lung border in the form of a fine line. Adjoining this line in peripheral direction is an area of increased radiolucency (due to the air present in the pleural space). In case of uncertainty regarding whether it is perhaps an artifact or, for example, a projection of the scapula, it is necessary to ascertain whether the pulmonary vascular markings go beyond this fine line. If not, this indicates a pneumothorax.

To assess whether it is a tension pneumothorax, you should always look for a **mediastinal shift** (shift of the heart and/or trachea silhouette towards the healthy side).

In addition, a low standing diaphragm is often found on the affected side. In cases of traumatic pneumothoraces, it should be a matter of course to not overlook any associated injuries and to diagnose them (e.g., rib fractures, skin emphysema).
When in doubt, particularly small pneumothoraces can also be detected in a **CT scan**. Here, emphysema or other lung structural changes can also be depicted in more detail. Especially when considering a surgical intervention or assessing the likelihood of recurrence, a CT scan can offer more conclusive information. Yet due to the high radiation exposure, a chest CT will not be the first measure taken.

### Treatment of Pneumothorax

#### Controlled waiting or draining the pneumothorax?

The treatment depends on the size of the pneumothorax, the clinical symptomatology, and the frequency of the occurrence (Relapse? Initial manifestation?)

- If it is a first time idiopathic pneumothorax with just a few symptoms or a small pneumothorax (< 3 cm) after, e.g., a CVC insertion, it is recommended to wait for the air in the pleural space to become reabsorbed spontaneously during which time regular **radiological controls** have to be performed.
- If it is a pneumothorax with severe symptoms and/or size as well as in all cases of recurrence, a **pleural drainage** will have to be performed.

#### Monaldi’s or Bülau’s method for draining the pneumothorax?

Here, you can find an overview of the indications for the two most common drainage methods and their respective access routes:

<table>
<thead>
<tr>
<th>Indication</th>
<th>Monaldi’s Drainage</th>
<th>Bülau’s Drainage (siphon drainage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isolated pneumothorax</td>
<td><strong>Monaldi’s Drainage</strong></td>
<td>Pneumothorax in combination with a hemorthorax (blood must also be drained)</td>
</tr>
<tr>
<td>Pneumothorax in combination with a hemorthorax (blood must also be drained)</td>
<td>2nd (or 3rd) intercostal space (ICS), midclavicular line</td>
<td>5th or 6th ICS, front to middle axillary line (in men, this corresponds approximately to the height of the mamilla)</td>
</tr>
</tbody>
</table>
The drain has to be pushed towards the apex because the air in the pleural space will rise upwards. Sometimes, the lung will start to re-expand even without applying suction; if not, suction may be set at \(-20 \text{ mm Hg}\). In some rare cases however, if suction is applied too strong or too fast, this can cause so-called \textit{re-expansion edema}!

\textbf{Note:} Always insert the drain at the upper edge of the rib as the intercostal vessels run along the lower edge of the ribs and could otherwise be injured!

\section*{Surgical treatment of a pneumothorax}

Especially in cases with recurrences, secondary pneumothoraces, or when the pneumothorax is non-responsive to the drainage, a surgical intervention should be considered as a next step. This would consist in a \textit{thoracoscopy} performed under general anesthesia, where the subpleural bullae, the caverns, or bronchiectases are resected or atrophied in a \textit{minimally invasive} procedure, and the defects of the pleura are sewn over. In addition, the pleura are roughened (\textit{pleurodesis}) or \textit{talcum} is introduced into the pleural space to support the adhesion of the two pleural layers. After such an intervention, the risk of recurrence is estimated at only < 5 %!

\section*{Using the Heimlich flutter valve for a pneumothorax}

\begin{figure}[h]
\centering
\includegraphics[width=0.3\textwidth]{heimlich-valve.png}
\caption{Heimlich valve}
\end{figure}

In the event of a life-threatening tension pneumothorax, it is crucial to initiate \textit{emergency medical care} (elevated upper body, administration of oxygen) and to provide \textit{relief}. With a large-bore cannula, the 2nd ICS is aspirated at midclavicular point and an emergency valve inserted.

Best known is the so-called \textit{Heimlich flutter valve}. With this one-way valve, the air can now escape but no new air can enter. If in an acute situation the appropriate equipment is not available (e.g., as first responders outside of working hours), then instead of the Heimlich valve, a cut \textit{rubber finger cot} is attached to the puncture needle and can act as a one-way valve, bringing the needed relief by the same principle as the Heimlich valve.

\section*{Differential Diagnosis of Pneumothorax}

\section*{Chest pain as cardinal symptom: Pneumothorax as differential diagnosis}

In medical exams, it is a popular question to ask about “chest pain” as a cardinal symptom. You will need to be able to discuss the possible differential diagnoses — the pneumothorax is one of them.
Here are the three most important differential diagnoses of spontaneous pneumothorax at a glance:

<table>
<thead>
<tr>
<th>Differential diagnosis</th>
<th>Indicative diagnostics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pulmonary embolism</strong></td>
<td>Anamnesis (thrombosis? extended immobility? condition after surgery? etc.), ECG (right ventricular strain?), laboratory tests (D-Dimer!)</td>
</tr>
<tr>
<td><strong>Myocardial infarction</strong></td>
<td>Anamnesis (known CAD? other risk factors? pain character?), auscultation (over both lungs, a vesicular breathing sound should be noticeable!), ECG (ischaemic signs?), laboratory tests (cardiac enzymes)</td>
</tr>
<tr>
<td><strong>Pleuritis</strong></td>
<td>Anamnesis (breath-dependent pain?), auscultation (pleural rub?)</td>
</tr>
</tbody>
</table>

**Prevention of Pneumothorax**

The **high rate of recurrence** of a spontaneous pneumothorax (up to 50 %) can be best countered by the surgical procedure described above. In addition, the patient should be advised to refrain from scuba diving (rapid changes of pressure conditions). Air travels under normal pressure compensation only have to be re-evaluated in cases with very large emphysema.

**Review Questions**

Solutions can be found below the references.

1. Where is the best point of insertion for the drainage of a tension pneumothorax (Monaldi’s method)?

   A. 5. ICS, anterior axillary line  
   B. 5. ICS, posterior axillary line  
   C. 2. ICS, midclavicular line  
   D. 2. ICS, posterior axillary line  
   E. 2. ICS, anterior axillary line

2. While lifting a moving box, a 20-year-old tall man suddenly feels a stabbing right thoracic pain with a subsequently increasing dyspnea. Which of the following medical findings can most likely be expected upon arrival of the ambulance?

   A. Bradycardia  
   B. Decreased fremitus over the left lung  
   C. Dull resonance on percussion over the right lung  
   D. Jugular venous distension  
   E. Tightening of the left thoracic cavity

3. Which of the following anamnestic statements are not considered a risk factor for the development of an idiopathic spontaneous pneumothorax?

   A. Male gender  
   B. 20 - 40 years of age  
   C. Tall and slim stature  
   D. Smoking  
   E. Increased alcohol consumption
References


**Correct Answers**: 1C, 2D, 3E

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