THORACIC DRAINAGE
A STEP-BY-STEP GUIDE

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2 ANATOMY OF THE CHEST

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Chest drainage requires good functional knowledge of thoracic anatomy. Physicians must be versed not only in systematic anatomy (taught in undergraduate programs at medical faculties) but also in topographic anatomy. This chapter provides a brief overview of the basic anatomy of the chest and thoracic organs.

2.1 THORACIC CAGE

The thoracic cage encloses an airtight yet expandable cone-shaped cavity that functions as a case for vital organs.

The bones of the chest consist of the sternum and the twelve thoracic vertebrae, which are connected to the ribs by the costal cartilages. The upper part of the thoracic cage is enclosed by the clavicles and, on the lateral and dorsolateral sides, by the scapula and the humerus. The upper chest aperture is bounded by the manubrium of the sternum, the first ribs and the first vertebra, and the lower chest aperture is defined by the 12^{th} vertebra and 12^{th} rib posteriorly and laterally and ventrally by cartilages of the 7^{th} to the 12^{th} ribs and the xiphisternal joint (Fig. 2.1).

The lower chest aperture is covered by the muscular portion of the diaphragm and the central tendon of the diaphragm (tendinous part of the diaphragm).

CHEST ANATOMY FOR PRACTICE

» Basic knowledge of chest anatomy is necessary for the performance of chest drainage.

» Knowledge of the placement of organs and the routes of vessels will allow physicians to avoid undesirable or even fatal complications.

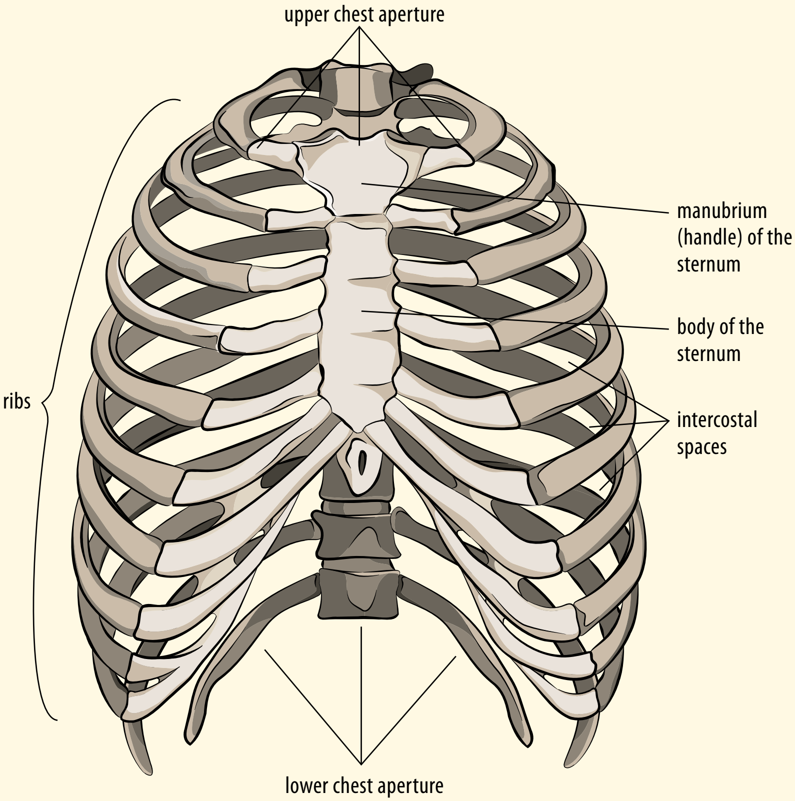

Fig. 2.1 Rib cage skeleton

The attachments of the muscle fascicles divide the diaphragm into sternal, costal and lumbar parts. The aorta, thoracic duct, esophagus and vagus nerve run through the muscle fascicles of the diaphragm. The inferior vena cava passes through the posterior tendinous part. The diaphragm is the main muscle contributing to breathing mechanics, accounting for 5% of the change in intrathoracic volume during normal breathing. Excursion of the diaphragm ranges from 1.5–7 cm, depending on the breathing depth.

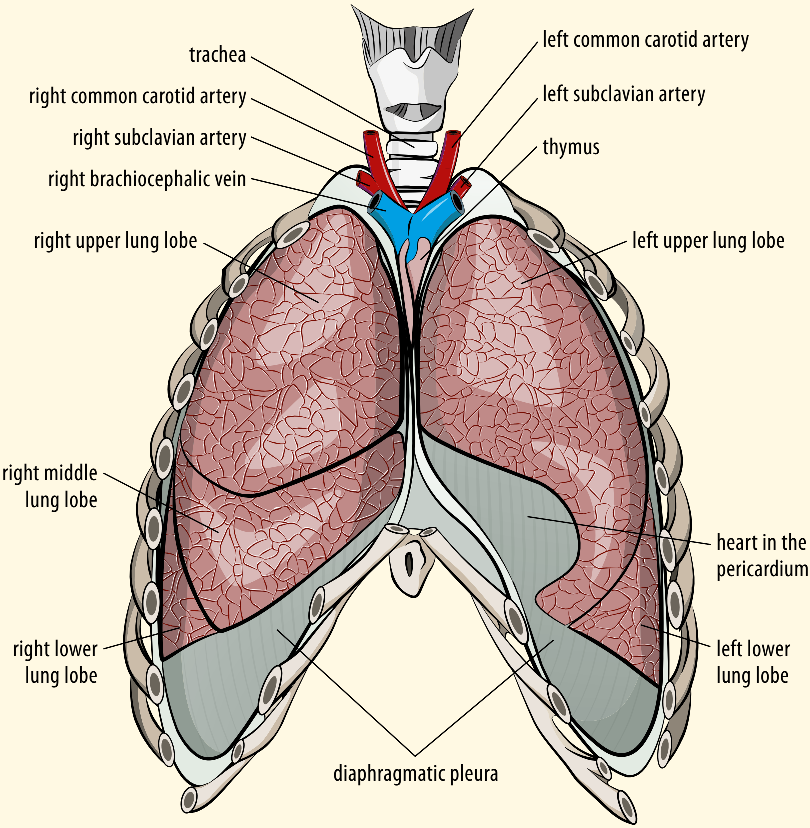

Fig. 2.2 Position of intrathoracic organs

2.1.1 Thoracic Cage Organs

The thoracic cage encloses two pleural cavities, which are separated by the mediastinum. The pleural cavities contain the lungs, which are divided into individual lobes: three on the right and two on the left. The pleural cavities are lined with parietal pleura, which changes in the

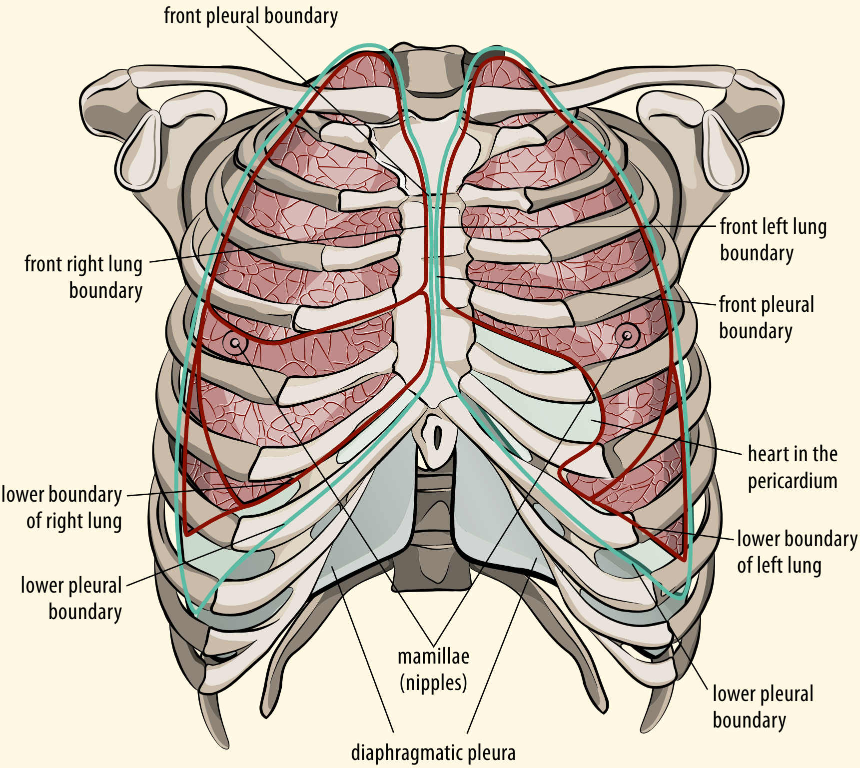

Fig. 2.3 Ventral view of the lung lobes

mediastinal area into the mediastinal pleura and subsequently, in the area of the lung hilum into the pleura covering the entire lung. Under normal conditions, the mediastinum contains only a small amount of fluid, which lubricates the pleural membranes during breathing. When breathing normally, the pressure in the pleural cavity ranges from –4 to –10 cmH_2O (–0.4 to –1 kPa). Dramatic changes then occur during

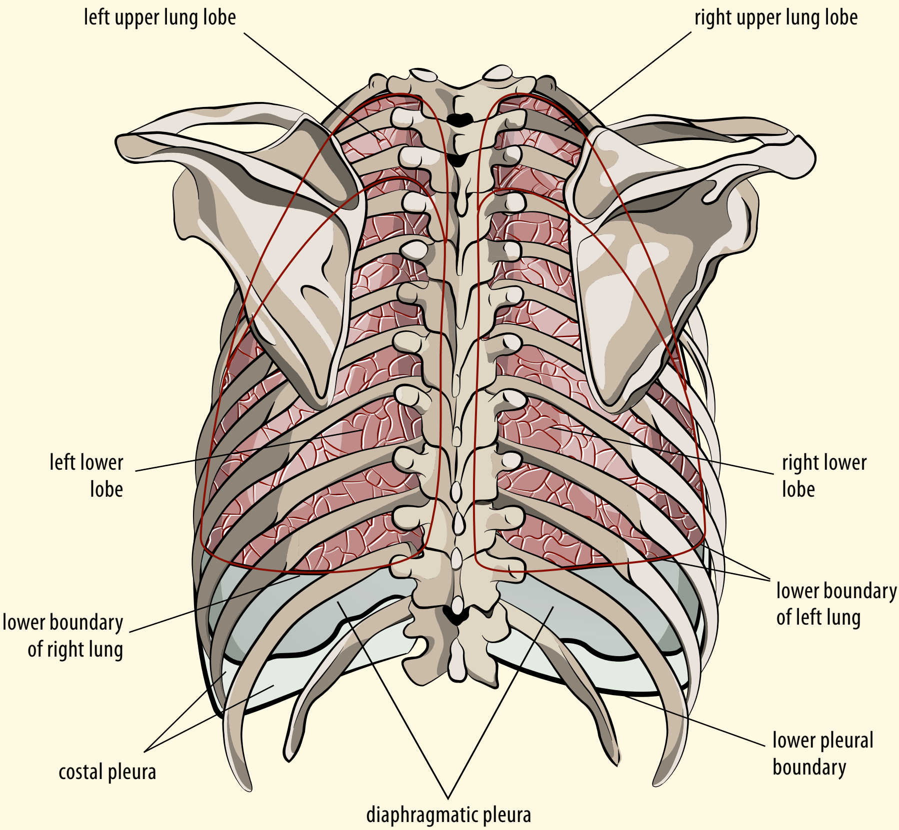

Fig. 2.4 Dorsal view of the lung lobes

heavy breathing, when the pressures during inspiration and expiration may increase up to –60 cmH_2O (–5.9 kPa) and up to +30 cmH_2O (2.9 kPa), respectively. The mediastinum contains the heart and great vessels, the main air passages, the esophagus, nerve plexuses, the thoracic duct, lymph nodes and the thymus (Fig. 2.2–2.4).

3 INDICATIONS AND CONTRAINDICATIONS FOR CHEST DRAINAGE

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Chest drainage permits the evacuation of pathological contents from the pleural cavity. The clinical need for chest drainage stems from the necessity to restore normal pressure conditions in the pleural cavity and re-expand the lung, normalizing respiratory mechanics.

Chest drainage procedures must be individualized, both in terms of the timing of drain placement and the location of the drain.

This chapter provides a brief overview of the indications and contraindications for chest drainage.

3.1 OVERVIEW OF CHEST DRAINAGE INDICATIONS

Tables 3.1 and 3.2 provide an overview of chest drainage indications.

3.1.1 Pneumothorax

3.1.1.1 PNEUMOTHORAX – BASIC TERMINOLOGY

Definition: pneumothorax (PNO) may be defined as the presence of air in the pleural space. Air may enter the pleural space either spontaneously, traumatically or iatrogenically.

CLINICAL IMPORTANCE OF CHEST DRAINAGE

- Evacuation of pathological content from the pleural cavity.
- Restoration of normal pressure conditions in the pleural cavity and achievement of lung re-expansion to normalize breathing mechanics.

Table 3.1 Absolute chest drainage indications

• Pneumothorax in each artificially ventilated patient
• Tension pneumothorax
• Extensive primary spontaneous pneumothorax
• Secondary spontaneous pneumothorax
• Extensive or loculated complicated parapneumonic effusion
• Extensive or loculated complicated effusion of a different etiology, including tuberculosis
• Chest empyema
• Post-operative fluidothorax and pneumofluidothorax
• Hemothorax
• Traumatic and post-operative chylothorax

Table 3.2 Relative chest drainage indications

• Recurring malignant or paramalignant effusion in a patient whose overall condition allows for talc pleurodesis
• Voluminous effusions accompanying internal diseases that are not controllable using conservative therapy, if pleurodesis is planned
• Non-traumatic and idiopathic chylothorax

Glossary

- *Primary spontaneous pneumothorax* (PSP) occurs in patients without any pre-existing lung disease.
- *Secondary spontaneous pneumothorax* (SSP) occurs in relation to an existing lung disease.
- *Traumatic pneumothorax* results from a penetrating or non-penetrating injury to the chest or abdomen.
- *Iatrogenic pneumothorax* is probably the most common type of pneumothorax. The main causes are thoracentesis, central venous catheter insertion, pleural biopsy, transparietal or transbronchial biopsy of the lung tissue or intrathoracic lymph nodes, artificial ventilation with high positive-end expiratory pressure (PEEP) and thoracic surgical interventions.

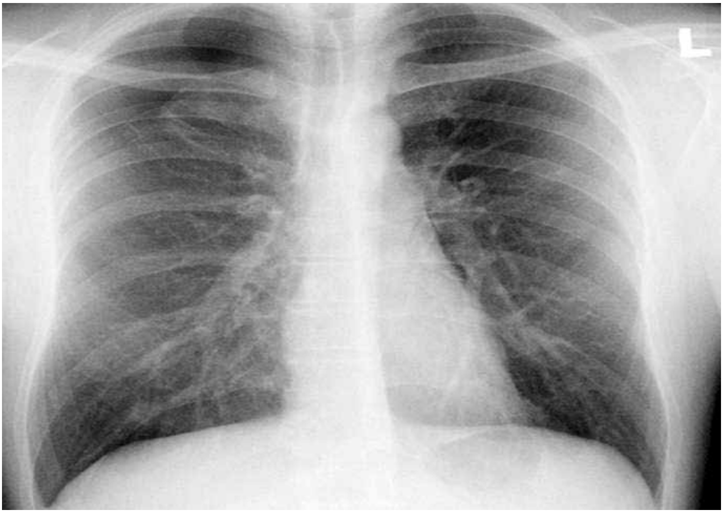

Fig. 3.1 Right-sided primary spontaneous partial pneumothorax, conservative treatment indicated

- *Occult pneumothorax* is defined as a pneumothorax that only visible on CT scans and is not noticeable on a standard chest X-ray. This condition most often occurs because of trauma and, depending on the extent, it may cause severe dyspnea accompanied by respiratory failure.

3.1.1.2 FACTORS INFLUENCING THE INDICATION FOR CHEST DRAINAGE

- *The extent of pneumothorax* is evaluated according to Noppen:
  - ~ In a small pneumothorax, the lung is only partially separated from the thoracic wall and may be treated conservatively with short-term observation and possible discharge. If the patient is hospitalized, oxygen therapy is appropriate (Fig. 3.1, 3.2).
  - ~ In a large pneumothorax, the lung is completely separated from the thoracic wall, and chest drainage is indicated (Fig. 3.3, 3.4).
- *The causes of pneumothorax include PSP, SSP, trauma, or iatrogenic injury.*
- *The clinical symptoms* include dyspnea and pain.

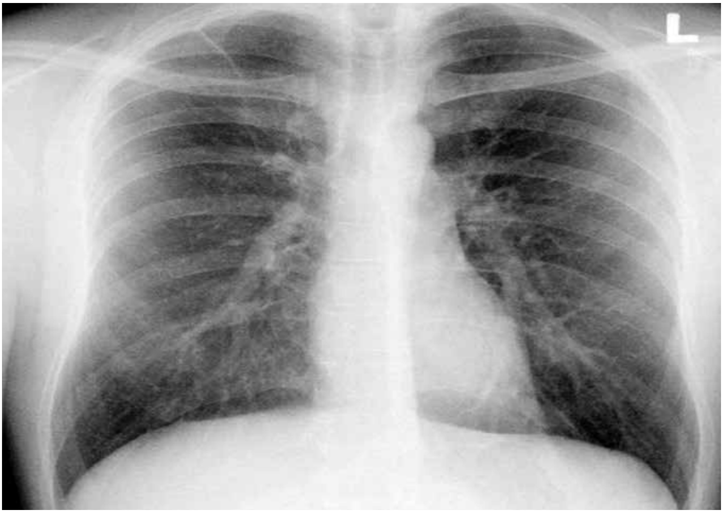

Fig. 3.2 Spontaneous pneumothorax resorption, right lung fully expanded

3.1.1.3 INDICATIONS FOR CHEST DRAINAGE

- Pneumothorax *in any artificially ventilated patient*

CAVE: a short-term discontinuation of ventilation is required when inserting the chest tube to avoid injury to the lung

- *Tension* pneumothorax (Fig. 3.5)
- *Extensive primary spontaneous* pneumothorax (Fig. 3.6)

According to the British Thoracic Society, simple evacuation of air from the lung using needle aspiration is recommended as the first therapeutic step, while only persistent pneumothorax or recurring

NOTE

» When inserting the tube in artificially ventilated patients, ventilation must be interrupted for the required period of time.

Fig. 3.9 CT finding showing the location of occult pneumothorax

Fig. 3.10 Targeted drainage of a partial pneumothorax according to CT findings

pneumothorax after aspiration is considered an indication for chest drainage. In our practice, we prefer chest drainage as the first therapeutic measure. Based on our experience, extensive primary spontaneous pneumothorax is usually associated with a larger defect in the lung tissue. Simple aspiration is usually insufficient, and an early recurrence of pneumothorax can occur.

- *Secondary spontaneous* pneumothorax (Fig. 3.7), with the exception of asymptomatic patients with very small pneumothoraces.
- *Traumatic, iatrogenic and occult* pneumothorax.

Indications for chest drainage depend on the extent of the pneumothorax and the presence of clinical symptomatology, including dyspnea and pain (Fig. 3.8–3.10).

3.1.1.4 MAIN INDICATIONS FOR A SURGICAL SOLUTION

Surgery is indicated when chest drainage is ineffective, which is demonstrated by the following situations:

- air leakage for longer than 5–7 days
- lung does not re-expand within 5–7 days
- contralateral pneumothorax during a pneumothorax treated with drainage
- first episode of pneumothorax in high-risk patients
- recurrent pneumothorax

3.1.2 Pleural Effusion

3.1.2.1 PLEURAL EFFUSION – BASIC TERMINOLOGY

Definition: pleural effusion refers to conditions characterized by the presence of a fluid of pathological volume and/or pathological character in the pleural cavity.

Glossary

- *Transudate* is a clear, straw-colored odorless discharge with a low volume of total protein (lower than 30 g/l) or a ratio of serum/effusion of less than 0.5. In cases of diagnostic difficulties, it is worth determining the albumin gradient (serum albumin minus effusion albumin at more than 12 g/l). The specific weight of a transudate

TRANSUDATE VS. EXUDATE

Light's criteria – a pleural effusion is likely exudative if at least one of the following occurs:

» the ratio of pleural fluid protein to serum protein is > 0.5

» the ratio of pleural fluid LDH and serum LDH is > 0.6; or

» the LDH level of the pleural fluid is > two-thirds of the upper limit of the laboratory's normal range of serum LDH

Gradients – if the clinical presentation indicates a transudate and the difference in the value of the albumin in the serum and the albumin in the pleural fluid exceeds 12 g, an exudate may usually be excluded.

should not exceed 1015 g/l, and the pH should exceed 7.3. The glucose concentration of a transudate correlates with the blood glucose value, and the most common causes of transudate are heart failure, liver cirrhosis or nephrotic syndrome.

- *Exudate* is a macroscopically slightly turbid discharge of varied coloring with a high content of total protein (TP effusion/serum > 0.5), a pH below 7.2, and a high concentration of lactate dehydrogenase (LDH) in the effusion; the concentration of LDH in an exudative effusion should exceed 2/3 of the serum value (Light's criteria). The etiology of the exudate can either be infectious (inflammation of various primary locations, tuberculosis, etc.) or non-infectious (malignant and paramalignant effusion, pulmonary embolism, systemic diseases, uremia, or postpericardiotomy syndrome).
- *Inflammatory effusion* is caused by an infection of the pleural cavity due to direct transmission of the infection into the pleural cavity from the surrounding organs, such as the lungs, mediastinum, upper respiratory tract, subphrenic space, paracolic area, or bones (osteomyelitis). Thus, lung inflammation produces a complicated parapneumonic effusion (the most common type of exudate). Infection of the pleural cavity may be caused by direct penetration by trauma or iatrogenic insult (puncture, drainage, surgery). Infection via hematogenous spread is also possible.

3.1.2.2 CHEST DRAINAGE INDICATIONS

- *Free-flowing* pleural effusion, the extent of which exceeds *one half of the hemithorax* (Fig. 3.11, 3.12)
- *Encapsulated* or multilocular effusion (Fig. 3.13–3.16)
- *Non-standard biochemical parameters* of the effusion, including pH < 7.2, a drop in glucose concentration or a rise in the concentration of LDH

A drop in pH is associated with a drop in the glucose concentrations, which are subject to metabolism by bacteria-destroying granulocytes. The LDH level should always be compared with the value obtained for serum LDH. The "standard" value can differ significantly among institutions. At our institution, the upper limit of the normal range for serum LDH is 3.75 µkat/l (218 U/l). An LDH level in the effusion 3× higher than the upper limit of the standard is considered high.

- *Complicated* parapneumonic effusion (Fig. 3.17, 3.18)
- *Other effusions of inflammatory etiology* (transmission of the infection from the upper respiratory tract or the mediastinum, osteomyelitis, spread from the subphrenic or paracolic spaces)
- *Chest empyema* (Fig. 3.19, 3.20)
- *Tuberculous* pleural effusion (Fig. 3.21–3.23)
- *Post-operative* pleural effusion or pleural effusion with a pneumothorax (collapsed lung) (Fig. 3.24, 3.25)
- *Malignant or paramalignant* effusion, unless the patient is in the terminal stage of the primary disease and the overall condition allows for talc pleurodesis (Fig. 3.26, 3.27)
- *Voluminous* effusions accompanying *internal diseases* that cannot be managed with conservative therapy
- *Chylothorax:* non-traumatic, traumatic or idiopathic (Fig. 3.28, 3.29)
- *Hemothorax* (Fig. 3.30–3.34)

NOTE

» High contents of LDH in exudate usually indicates the occurrence of empyema.

Fig. 3.21 Left-sided tuberculous chest empyema with parenchymal-pleural fistula

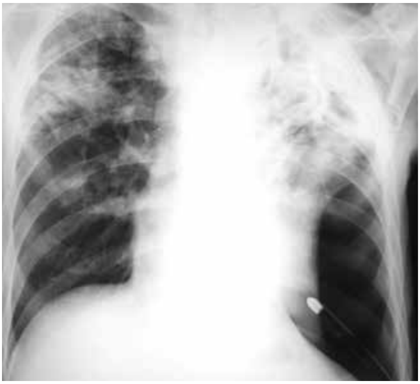

Fig. 3.22 Targeted drainage of the empyema cavity with massive air leakage through the drain; evacuation of the discharge is not followed by lung expansion

Fig. 3.23 Long-term chest drainage; after the parenchymal-pleural fistula heals, the lung expands. Retraction of the left hemothorax, substantial residue after healing

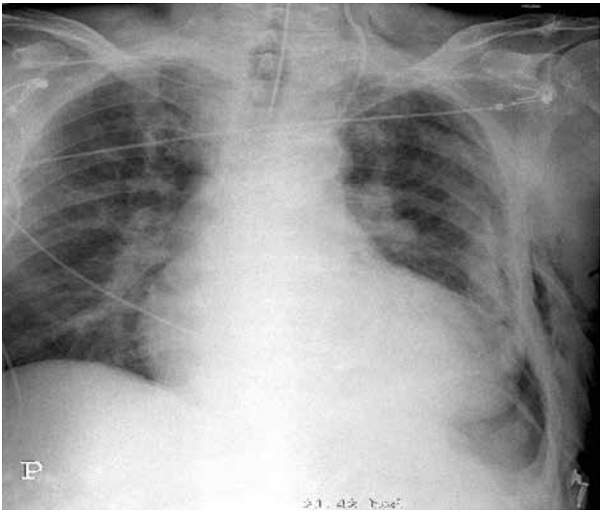

Fig. 3.34 X-ray of the chest immediately after surgery; the source of bleeding was an injury to the intercostal artery

Bleeding into the pleural cavity is an absolute indication for chest drainage with the aim of complete blood evacuation, which may lead to hemostasis by apposition of the parietal and visceral pleura. Drainage of a hemothorax prevents the development of pleural empyema, which is a frequent complication because blood is an excellent growth medium. Drainage also prevents the subsequent development of a ventilation disorder caused by fibrothorax and allows for the precise measurement of losses. Thus, drainage can provide timely information about whether surgery is indicated (a total loss of over 1500 ml, or 250 ml/h for 4 hours).

NOTE

» Bleeding into the pleural cavity is an absolute indication for chest drainage aimed at stopping the bleeding, preventing the occurrence of empyema, and providing a timely indication of surgical intervention.

3.2 CONTRAINDICATIONS TO CHEST DRAINAGE

3.2.1 Absolute Contraindications to Chest Drain Insertion

- *Adhesion between the visceral and parietal pleura* causing *disappearance of the pleural space,* which can be caused by previous trauma to the chest or iatrogenic causes such as pleurodesis or thoracic surgery.
- *Physician lacking sufficient experience* in chest drain insertion.

Chest drainage requires sufficient experience, knowledge of the anatomy of the chest area and pleural cavity, the ability to correctly interpret radiological findings, spatial intelligence and manual skill. It is essential for a physician who is new to chest drainage to perform at least 10 interventions (procedures) under the supervision of an experienced physician (tutor).

3.2.2 Relative Contraindications to Chest Drain Insertion

- *Coagulation disorders caused by medication* – coumarin derivative treatment, anti-aggregation treatment (clopidogrel), heparinization, e.g., in patients on extracorporeal circulation or hemodialysis.
- *Coagulation disorders caused by hematologic disease*, thrombocytopenia, or thrombocytopathy.

Patients who require urgent chest drainage should be prophylactically given frozen plasma or platelet transfusions.

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4 TYPES OF CHEST DRAINAGE

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There are two basic types of chest drainage: open (pleuro- and thoracostomy) and closed chest drainage. Open chest drainage is the domain of thoracic surgeons. The following text only considers closed chest drainage.

The process of chest drainage consists of identifying the correct indications and timing for the procedure, performing a technically precise insertion of a properly sized chest tube, and choosing an appropriate method to extract the pathological contents of the pleural cavity.

IMPORTANT

» There are several methods for draining air, blood, or discharge from the pleural cavity. To correctly determine the indications, we must be familiar with the drainage system principles.

4.1 BASIC CHEST DRAINAGE METHODS

The main distinction between gravity-type drainage systems and suction-based techniques is the method by which the pathological content is extracted from the pleural cavity. The basic type of chest drainage is the extraction of discharge and air under a water seal, which is performed using a single drainage bottle fitted with a water seal, according to Bülau.

4.1.1 Bülau's Gravity Drainage

Gravity drainage represents the simplest drainage system in which a chest tube is usually attached directly after being inserted into the pleural cavity. This system consists of a single closed bottle and one afferent (discharge) tube that opens below the level of the fluid

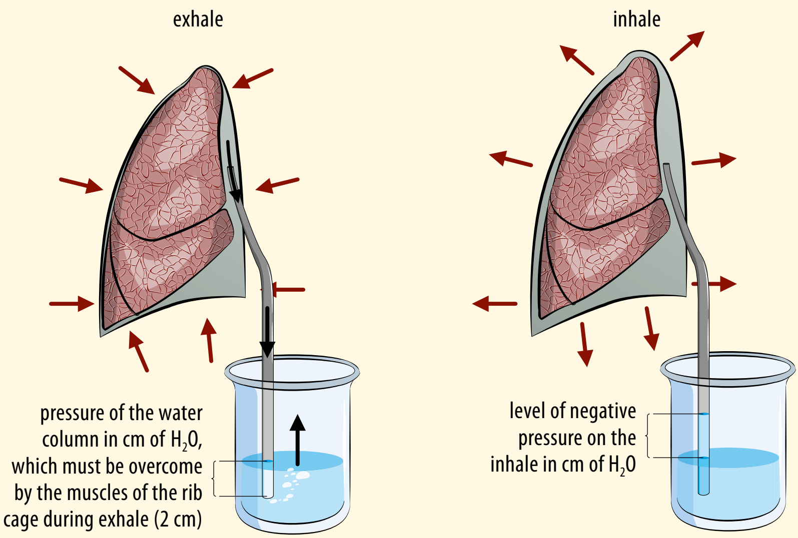

Fig. 4.1 Diagram of gravity chest drainage with a water seal

(disinfectant) in the bottle. This afferent tube is attached to the connection tubing of the chest drain. There is a short efferent tube that draws air and gas from the drainage bottle (Fig. 4.1–4.5).

The level of the disinfectant fluid in the drainage bottle is usually 5 cm above the bottom. However, it is more important to submerge the afferent tube at the correct depth in the disinfectant, which determines the pressure in the water column that must be overcome by the liquid or air leaving the chest. Thus, in practice, if the end of the discharge tubing is immersed 5 cm below the disinfectant, the muscles of the thoracic cage must exert a pressure in the pleural cavity of at least 5 cmH_2O during expiration to expel the pathological content from the pleural cavity into the bottle. During inspiration, however, the level of the disinfectant in the discharge tubing rises and is drawn in towards the chest. The level reached in the tube above the level of the disinfectant in the bottle corresponds directly to the value of the negative pressure in the pleural cavity, specified as the height of the water cylinder in centimeters. Therefore, if the fluid in the discharge tube rises by 5 cm above the level of the disinfectant in the bottle

Fig. 4.2 Gravity chest drainage

Fig. 4.3 A single-use drainage kit for gravity drainage under a water seal

Fig. 4.4 Basic drainage kit for correct chest drainage, re-sterilizable glass bottle with disinfectant, connecting tubing

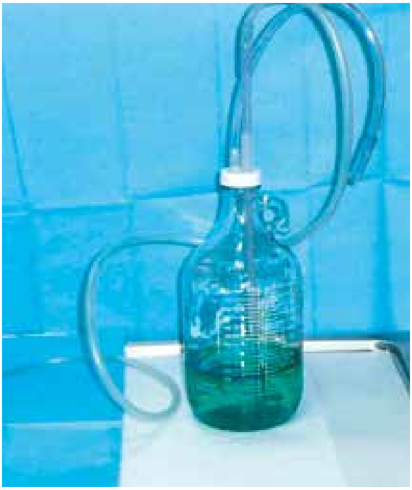

Fig. 4.5 Drainage kit ready to be connected to the chest tube

during inspiration, the negative pressure in the pleural cavity during inspiration is –5 cmH_2O (Fig. 4.1).

Drainage systems used for gravity water-seal drainage are available both in a glass re-sterilizable bottle with plastic connecting tubing and chest tubes of different lengths running through the bottle cap and in a disposable plastic bottle with a cap and connecting tubing (Fig. 4.2, 4.3).

4.1.1.1 ADVANTAGES

- This drainage system is simple, easy to understand, and has a low probability of error during handling.
- Pressure changes in the pleural cavity can be very well visualized based on the movement of the column of fluid in the discharge tube.
- Air leakage is clearly visible.
- This drainage system is convenient because it can be carried by the patient in a portable bag. The patient only has to be instructed not to place the bottle above the level of the chest and to keep it upright to prevent spillage of its contents.

4.1.1.2 DISADVANTAGES

- Drainage is based on gravity, and in cases of increased negative pressure in the pleural cavity (lower elasticity of the lung, extensive resections, lung edema, or obstruction of the large airways), gravity drainage is unable to extract the pathological contents from the pleural cavity.
- In cases of extremely negative pressure in the pleural cavity, fluid from the drainage bottle may be sucked in and enter the chest, often unexpectedly.

4.1.1.3 CONSIDERATIONS

- The discharge tube can only be submerged below the level of the disinfectant to a depth (usually 5 cm) that would not generate extensive pressure and prevent efficient evacuation of the pathological content from the pleural cavity.
- The discharge tube must not be submerged to a depth that is too shallow because in cases of increased negative pressure in the pleural cavity, a greater quantity of the fluid could be drawn into the

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