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Editor

Chest Drains in Daily Clinical Practice

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To Gerlinde and Julia

Preface

This book is addressed to all professions who have to deal with chest drains – not only physicians of any specialisation but also nurses. It is my strong conviction that – with the exception of very few – all who work in somatic acute and emergency medicine should be able to manage chest drains and chest drain systems properly!

This is so important because a chest drain managed in the wrong way can be truly dangerous or even life threatening for the patient.

According to my knowledge, so far there is no such an elaborated book dealing with chest drains and chest drain systems covering all issues – beginning with anatomy and ending up with pain management and physiotherapy. That's why I am very grateful that the publishing company Springer made this project possible. I also want to thank my co-authors, who made it happened and helped publish this book just on schedule due to their tremendous work. My special thanks concerning this English edition of the text book go to Dr. Sarah Counts from Yale University who transformed my "school English" into a readable textbook!

Those who will read the entire book will mention that there are some reiterations concerning one or more chapters. This is intended! On the one hand it may make sense to repeat important aspects from a didactic point of view. On the other hand, the more experienced reader will pick just the chapter they are interested in.

I am open to critics and would appreciate to receive critics because this is the only way to improve and which hopefully may lead to a second edition!

Konstanz, September 2016

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Chapter 1
Anatomy of the Chest Wall and the Pleura

Peter Ehrhardt

1.1 Introduction

The chest wall represents the outer covering of the chest and shelters the organs inside the thorax. Due to its mobility and the wall structure, which is comparable to a cage, it plays an active role in the function of breathing when the intrathoracic volume is changed. During inspiration the volume increases and during expiration it decreases, therefore generating a negative or a positive pressure respectively. According to the law of Boyle-Mariotte, gases move constantly as a result of pressure and volume.

The chest wall is construced as a cage with variable rods. The spaces within the rods are the intercostal spaces. This space has to be air tight, robust in regards to pressure, while also being adequately mobile for ventilation. This is possible with the help of the pleural space which is created by two sheets of pleura, the parietal and visceral layers. The pleural space allows the lung to slide during inspiration and expiration, keeping the lung expanded due to adhesive forces.

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1.2 The Compostion and Margins of the Chest Wall

The sternum and cartilage of ribs 1–10 represent the anterior chest wall. The posterior part consists of 12 thoracic vertebrae and the posterior aspects of ribs 1–12. Laterally the chest cavity consists of ribs 1–12.

The thoracic aperture is created by the first ribs, the first thoracic vertebra, the upper edge of the sternum, the nerves, and the blood vessels, which together with the trachea and esophagus compose the upper opening of the chest.

The lower chest aperture is much wider and is formed by the costal arch, the free ribs (11th and 12th), and the sternum. The costal arches form an angle called the *Angulus infrasternalis* (epigastric angle) that opens caudally. This varies according to age, sex, and body compostion. In infants and women it is typically wider as compared to men (70°).

The diaphragm seals the lower chest aperture. Due to the negative pressure inside the pleural space, it is sucked cranially creating a dome.

The space between two ribs is called the intercostal space. The space is strengthened with muscles and ligaments which prevent sinking during inspiration. This whole construction is called the chest wall.

Anatomical regions are defined by the chest wall's surface:

Ventral: *Regio pectoralis / mammaria, Regio infraclavicularis, Regio parasternalis, Regio hypchondriaca*

Lateral: *Regio axillaris*

Dorsal: *Regio suprascapularis, Regios scapularis, Regio infrascapularis*

Orientation during a clinical examination and/or therapeutic procedure can be done with the assistance of anatomical lines: (Figs. 1.1 and 1.8)

- *Linea sternalis*
- *Linea parasternalis*
- *Linea medioclavicularis (MCL)*
- *Linea axillaris anterior, media, posterior*
- *Linea scapularis*
- *Linea paravertebralis*

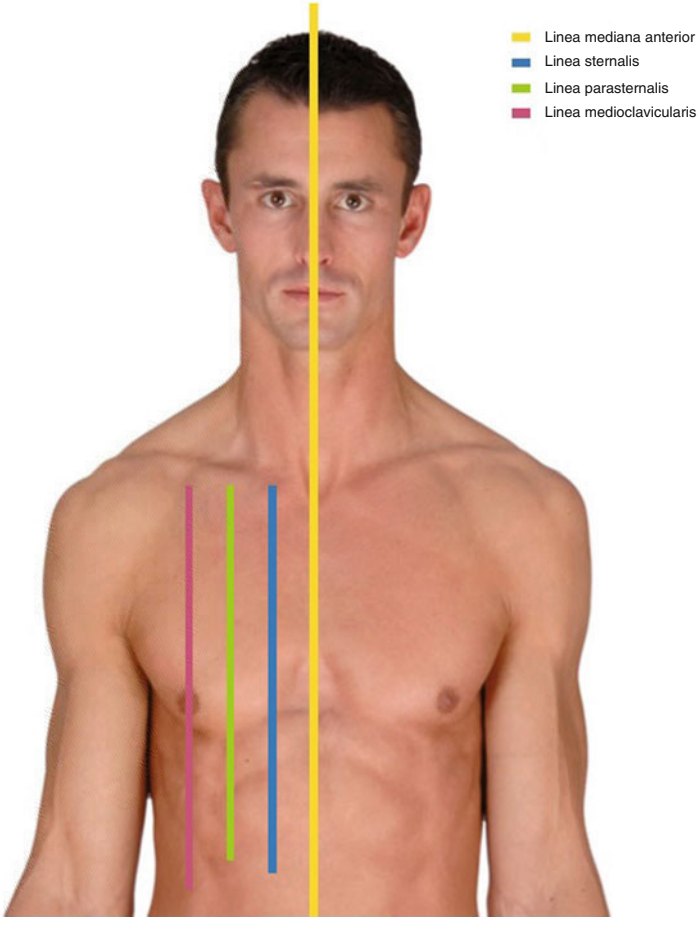


FIGURE 1.1 Anatomical lines of the anterior chest wall (Tilmann BN (2010), Ventrale Rumpfwand. In: Anatomie, Springer-Verlag Berlin Heidelberg, S. 816, Abb. 21.1)

Certain ribs and intercostal spaces can be located by palpating these structures.

The margin between the corpus and manubrium sterni is called the angulus sterni (Ludovici or sternal angle) which is visible and located next to the second rib. The first ribs cannot

be palpated as they are covered by the clavicles. The second ribs and below can be identified.

1.3 Bony Components and Joints

The sternum consists of the manubrium sterni, the corpus sterni, and the processus xiphoideus. The manubrium is linked with the clavicles on each side and also with the first ribs with the help of cartilagenous joints, called synchondroses. Ribs 2–7 articulate laterally at the corpus sterni. The xiphoid is not attached to any ribs.

In general, the ribs in humans are numbered the same as their corresponding vertebral bodies. There are 12 pairs of ribs with some of them rudimentary and fused with the vertebral bodies in so called rib stumps.

The ribs are divided into real ribs (costae verae, 1–7) that have sternal joints, false ribs (costae spuriae, 8–10) with cartilagenous joints to the costal arch (arcus costalis), and free ribs (costae fluctuantes, 11–12) that end in the soft tissue of the lateral chest wall. The 12th rib is not always present.

The head of the rib (caput costae) articulates laterally with the vertebral body and there is a second articulation between the transverse process and the vertebral body. The rib neck is located between these articulations and acts as the longitudinal axis for rib movement. The neck of the rib is followed by the body of the rib (collum costae), turning anteriorly at an angle (angulus costae). Anteriorly all bony tissue is followed by cartilage which represents the elastic link with the sternum (Fig. 1.2).

The ribs move upwards during inspiration around their rib neck and downwards during expiration. This volume increase and decrease is due to changes in both the sagital and transverse directions. The mobility of the chest is guaranteed by the joints between the vertebral bodies and ribs as well as by the interactions between the cartilage, sternum, and costal arch.

The costosternal complex moves cranially and ventrally (sagittal extension). The lower ribs move towards cranially and laterally to increase the diameter of the chest in the transverse direction (Fig. 1.3).

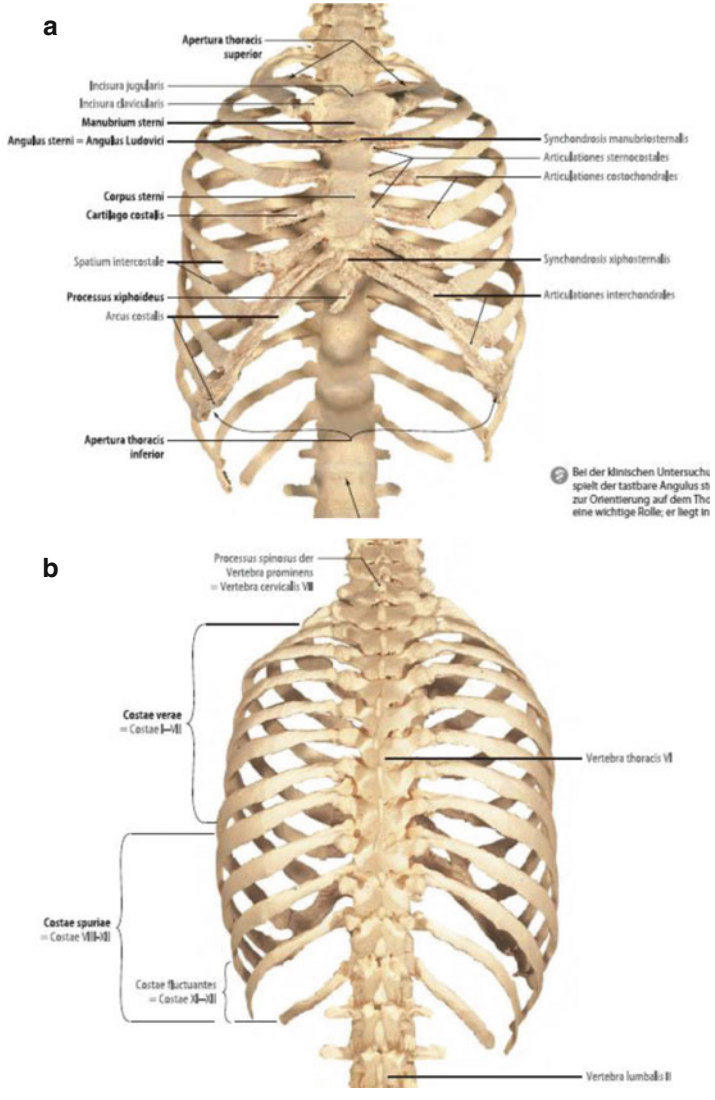


FIGURE 1.2 Bony chest (**a**) view from anterior, (**b**) view from posterior (Tilmann BN (2005), Rumpfskelett In: Atlas der Anatomie, Springer-Verlag Berlin Heidelberg, S. 187/188, Abb. 4.1, 4.2. (jeweils oberer Abschnitt ohne Becken))

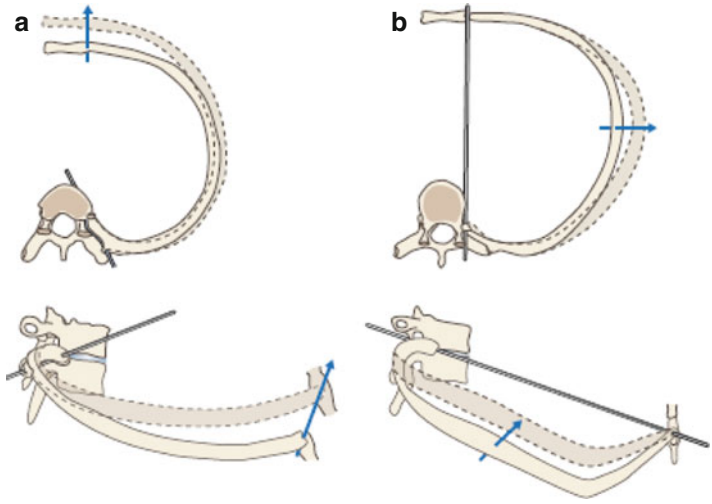


Figure 1.3 Movement of the ribs during inspiration and expiration (van Gestel A et al. (2010), Atembewegungsapparat. In: Physiotherapie bei chronischen Atemwegs- und Lungenerkrankungen, Springer-Verlag Berlin Heidelberg, S. 17, Abb. 2.2)

At the lower edge of the rib, the sulcus costaeis is located where the intercostal vessels and the intercostal nerve run. The intercostal muscles are attached to the edges of the ribs (Fig. 1.9).

1.4 Muscles of the Chest Wall

The lung itself does not have any muscles and therefore the muscles of the chest wall and diaphragm are responsible for the movements that let us breathe. Some of the chest wall muscles can be used as helpful anatomical landmarks.

At the neck, the chest is attached by the three scalene muscles, the intercostal muscles, and the muscles eminating from ribs 1 and 2 to the vertebral bodies (1–7). They are responsible for the flexion of the upper spine anteriorly and for lifting the ribs during inspiration (Fig. 1.4).

The Pectoralis major muscle covers the upper and lateral part of the chestwall like a shelf and creates the outline of the

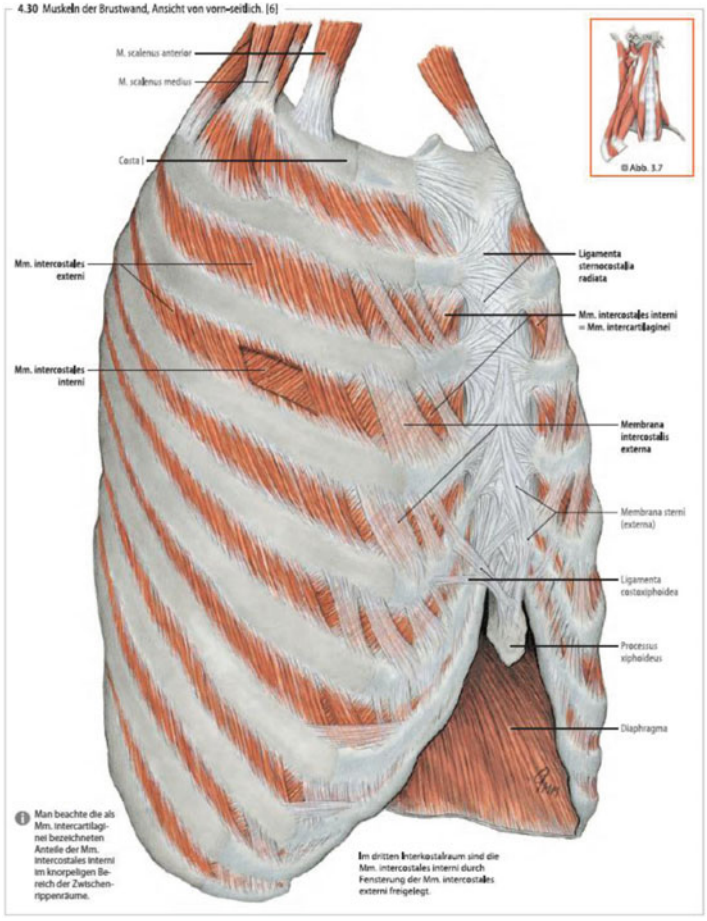


Figure 1.4 Chestwall muscles, view from anterolateral (Tilmann BN (2005), Muskeln der Brustwand. In: Atlas der Anatomie, Springer-Verlag Berlin Heidelberg, S. 204, Abb. 4.30 (jeweils oberer Abschnitt ohne Becken))

chestwall. It originates from the medial clavicle, the sternum, the cartilages of ribs 5–7, as well as from the rectus sheath, and inserts at the tuberculum majus humeri. The lower edge of the muscle creates the anterior axillary plication. This muscle causes a strong adduction and rotation of the arm and its lower portion acts as an auxillary breathing muscle.

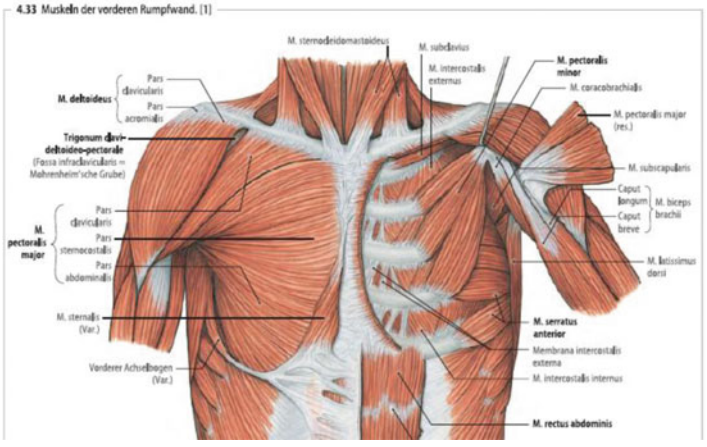


FIGURE 1.5 Muscles of the anterior chestwall (Tilmann BN (2005), Muskeln der Brustwand. In: Atlas der Anatomie, Springer-Verlag Berlin Heidelberg, S. 207, Abb. 4.33 (oberer Abschnitt))

The Pectoralis minor muscle is completely covered by the Pectoralis major muscle. It derives from the ribs 3–5 and connects to the processus coracoideus of the shoulder. This muscle pulls the shoulder anteriorly and downwards and also lifts the chest as an auxillary breathing muscle (Fig. 1.5).

The intercostal muscles consist of two layers of short muscles between the ribs oriented in different directions. The more external layer is made of the *intercostales externi* muscle which is oriented craniolaterally to mediocaudally from the lower edge of the upper rib to the upper edge of the rib below. The *intercostales interni* muscle is located underneath oriented opposite of the externi and therefore from craniomedial to laterocaudal. Both muscles help to maintain the appropriate tension of the rib cage. The outer muscles lift the chest up (inspiration) and the inner ones lower it and strengthen expiration.

A soft tissue layer allows room for the intercostal vessels and nerve and separates the *intercostales interni muscles* from the *intercostales intimi muscles.* These muscle fibers are oriented in the same direction. The *intercostales interni*

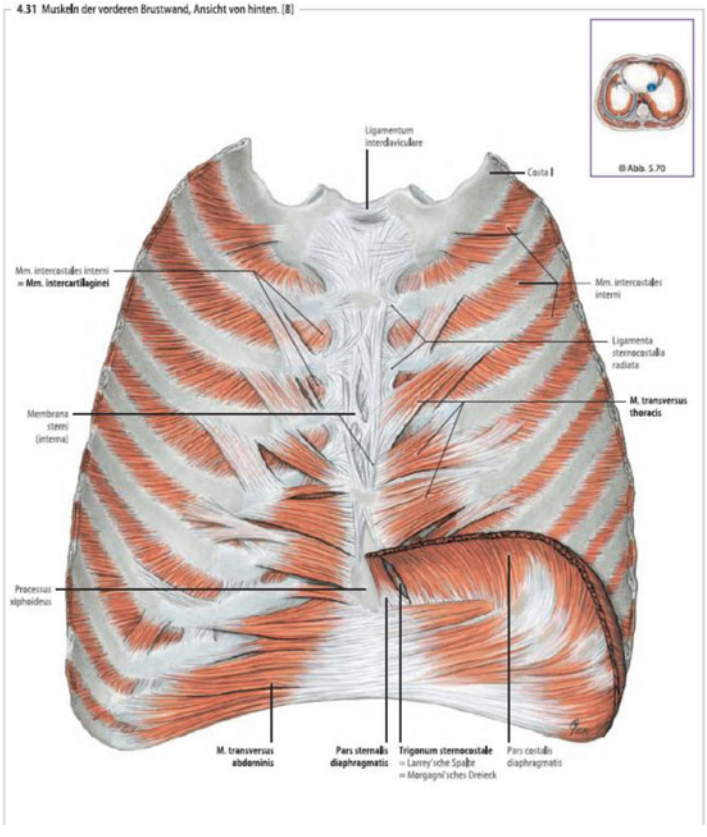
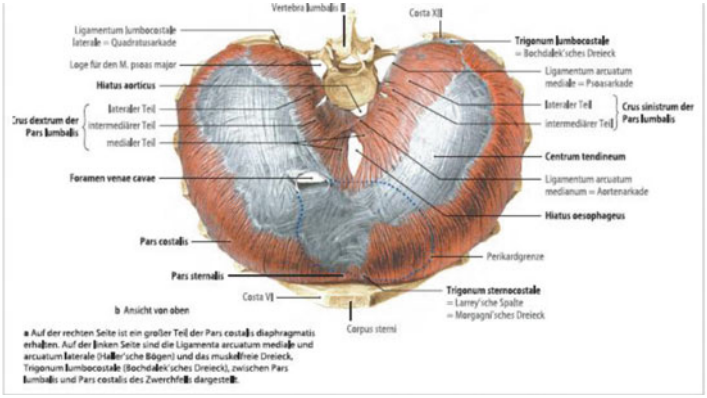


FIGURE 1.6 Muscles of the anterior chest wall – view from behind (Tilmann BN (2005), Muskeln der Brustwand. In: Atlas der Anatomie, Springer-Verlag Berlin Heidelberg, S. 205, Abb. 4.31)

muscles that create a longer layer of muscle going over the first and second rib are called *Subcostales muscles.*

Muscles running transversely from the inner surface of the sternum towards the ribs are called the *transversus thoracis muscles* (Fig. 1.6).

The lower border of the chest cavity made up of the diaphragm which originates from the lower chest aperture and the vertebral bodies 1–4 of the lumbar column. The



a Auf der rechten Seite ist ein großer Teil der Pars costalis diaphragmatis erhalten. Auf der linken Seite sind die Ligamenta arcuatum mediale und arcuatum laterale (Haller'sche Bögen) und das muskelfreie Dreieck, Trigonum lumbocostale (Bochdalek'sches Dreieck), zwischen Pars lumbalis und Pars costalis des Zwerchfells dargestellt.

FIGURE 1.7 Diaphragm, view from above (Tilmann BN (2005), Hintere Rumpfwand. In: Atlas der Anatomie, Springer-Verlag Berlin Heidelberg, S. 212, Abb. 4.40b)

diaphragm is a muscle measuring 3–5 mm thick which creates a dome with a tendon in the center. In regard to surface area it is the largest muscle in the human body. Due to the elastic recoil of the lung which is transferred throughout the pleural cavity, the diaphragm lifts upwards creating the diaphragmatic dome which is slightly higher on the right side. The top of the dome can vary about 6–7 cm from inspiration to expiration respectively. Contraction of the diaphragmatic muscle causes it to flatten and thus increases the volume of the chest cavity (Fig. 1.7).

1.5 Topography of the Chest Cavity

The pleura is a serous skin that consists of mesothelium, a squamous epithelium (one layer), and the lamina propria. The pleura covers the lung and chest wall. There are two layers called the visceral pleura and the parietal pleura which are separated by a capillary gap filled up with 2–4 ml of fluid. This configuration allows the lung to slide up and down and, despite the elastic recoil, keeps the lung expanded.

In the pleural cavity there is a negative pressure due to the elastic recoil of the lung fighting against the adhesive forces generated by the pleural fluid. These forces during inspiration pull the lung to follow the chest wall.

The visceral pleura covers the entire lung with the exception of the hilar region. The parietal pleura covers the inner chest wall similar to wallpaper. The regions where the parietal pleura covers the mediastinum, chest wall, or diaphragm are correspondingly named *Pars mediastinalis, Pars costalis* and *Pars diaphragmatica.* Both of the pleural cavities are closed spaces completely filled with the lungs without any connection to each other, the atmosphere, or the other lung. The shape of the pleural cavity is determined by the lordosis of the vertebral column. The domes of the diaphragm create an optimal shape for expansion of the volume of the chest cavity during inspiration. In the middle, the two pleural cavities are separated by the mediastinum anteriorly and vertebral collum posteriorly. At the middle aspect of the sternum, the two pleural cavities are separated by the parietal pleura which are separated by the parietal pleura and are in contact with each other.

Cranially the pleural cavity extends for 2–3 cm above the upper chest aperture (*Cupula pleurae*).

The pleura cavities have narrow spaces called *Recessus pleurales* where the lung can expand which are located anteriorly between the chest wall and sternum and laterally between diaphragm and chest wall. The *recessus costomediastinalis* on the left side between pericardium and chestwall is somewhat wider as compared to the right side. The *recessus costodiaphragmaticus* creates an additional deep semicircular space reaching nearly to the origin of the diaphragm (Fig. 1.8).

In the back, the recessus may extend up to 2 cm below the 12th rib therefore putting it in the neighborhood of the right lobe of the liver and on the left towards the stomach, spleen, and upper pole of the kidney (Fig. 1.8, Table 1.1). The margins of the lung shift during inspiration and expiration anteriorly for 1–2 cm and in the back for 5–6 cm. Normally the lower margin of the right lung is 1–2 cm above the lung margin on the left side.