THORACIC DRAINAGE
A STEP-BY-STEP GUIDE

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THORACIC DRAINAGE
A STEP-BY-STEP GUIDE

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To all those who would like to know more and try more

PREFACE AND ACKNOWLEDGEMENTS

The idea of writing a book on chest drainage was born several years ago, at a time when an interest in chest draining began to grow among pulmonologists and intensivists. Together with my colleague, Pavla Žáčková, M.D., we have sought to present our many years of experience with various types of drains in many pulmonary and pleural diseases in this book. We believe that this book will serve as a practical source of advice and as a guide for physicians who need and want to use the chest drainage procedure in the complex care of their patients.

Because I am aware of the difficulty of this topic, I conceived this book as a detailed instruction manual, as expressed by its subtitle – *step by step guide*.

I asked one of the leading Czech thoracic surgeons, Jan Čermák, M.D., my former kind teacher and friend, to write a review of this book. For me, Dr. Čermák has always been an infinite source of information including but not limited to the information on thoracic surgery, and I have always esteemed his opinion. I would like to express my great thanks to him for contributing to the professional level of this book.

I would also like to thank all those engaged in the creation of this book. First, I would like to thank my co-author and friend, Pavla Žáčková, M.D., who also reflected her extensive practical experience with the diagnosis and treatment of pleural complications in this book. I would also like to express my thanks to my colleague Peter, who took on the role of a model for drawing sites suitable for drainage. Last, I would like to give my thanks to Jan Hugo, M.D., editor-in-chief, Markéta Fidlerová, director, and graphic artists of Maxdorf Publishing for their outstanding work.

Prague, April 2016 Martina Vašáková

CONTENTS

LIST OF ABBREVIATIONS

APTT ....activated partial thromboplastin time
ARDS ....acute respiratory distress syndrome
BP ....bronchopleural fistula
COPD ....chronic obstructive pulmonary disease
CT.................................computed tomography
ICU ....intensive care unit
INR................................international normalization ratio
LDH...............................lactate dehydrogenase
PEEP ....artificial lung ventilation with high positive-end expiratory pressure
PNO ....pneumothorax
PSP ....primary spontaneous pneumothorax
SSP ....secondary spontaneous pneumothorax
TAG ....triacylglycerol
TP ....total protein
USG...............................ultrasonography (examination)
VATS..............................video-assisted thoracoscopic surgery

INTRODUCTION

Martina Vašáková

In a number of medical disciplines, chest drainage is a necessary invasive procedure that may resolve pathological processes in pleural cavities without requiring any major surgical intervention. For historical reasons, chest drainage has been performed primarily by general or thoracic surgeons and occasionally by radiologists. However, recently, there has been a growing trend of chest drainage also being performed by pulmonologists and by intensive and resuscitation care specialists. At the Department of Pulmonology of Thomayer Hospital in Prague, chest drainage is an integral method used in the treatment of pleural diseases. A number of arguments support chest drainage also being performed by pulmonologists or intensivists, as appropriate:

1. The physician is very familiar with the patient's disease status, as the physician is the one providing complex care.
2. Based on the clinical and radiological presentation and development of the disease, the physician is capable of considering the indications for chest drainage.
3. Chest drainage is performed by the physician him- or herself.
4. The physician continues providing care to the patient and can thus evaluate any alterations in the clinical condition and any effect of the chest drainage or modify the chest drainage as needed.

However, several conditions must be met to provide chest drainage at the department:

1. Proper facilities and equipment: an operating room and hospital ward equipment, including active suction systems
2. Trained medical and nursing personnel
3. Availability of imaging methods (skiagraphy, computed tomography, sonography)
4. Communication with a thoracic surgeon in the event of potential complications or insufficient effect of the chest drainage.

This book should serve as a source of advice and a guide for all who perform or would like to perform chest drainage. This book contains practical advice ranging from chest drainage indications to potential complications, with instructions for how to address each situation. This book was written based on many years of experience gained by the authors while working at departments engaged in the diagnosis and therapy of pleural diseases, namely, at the Department of Pulmonology and Thoracic Surgery, University Hospital Bulovka (Prague), and at the Specialized Therapeutic Institute of Tuberculosis and Respiratory Diseases in Prosečnice, which later became a part of the Department of Pulmonology of the Thomayer Hospital, Prague.

1 HISTORY OF CHEST DRAINAGE

Martina Vašáková

As a surgical treatment method, chest drainage was introduced in the very early days of the history of surgery. Open chest drainage was first mentioned in Hippocrates's records from 460–337 BC. At that time, drainage of the pleural cavity was performed using reed stalks, and the first recorded indication for chest drainage was empyema. At the start of the early modern era, we can find references to the use of lead tubes as drains, and the 19th century saw the first application of rubber tubes with side apertures (1859 Chassaignac). In the second half of the 19th century, glass tubes were also used (1865 Koeberle). In addition to these tubes, drainage was performed using fabric inserts to induce a "suction" effect, and these inserts were placed either separately or inserted into tube drains (1882 Kehr). However, this strategy proved to be problematic due to the frequent contamination of these drains with bacterial flora, which surgeons attempted to avoid by disinfecting drains and wounds according to Lister's principles and using 5% carbolic acid (phenol). In 1867, Hillier was the first to extract pus from the chest using an underwater seal. In 1875, the Hamburg intern Gotthard Bülau was the first to use single-use closed gravity drainage in a water-seal bottle in the case of a 35-year-old patient suffering from pleuropneumonia. The case report was published in 1891. At almost the same time, the same drainage system was used by Playfair (England) and Potain (France). Hewett was the first to describe continuous chest drainage with a water seal. In 1895, Kellog described negative pressure drainage (i.e., suction drainage) based on Boyle-Mariotte's law. Three years later, Heaton introduced negative pressure drainage through suction. Subsequently, no new materials for chest drains were introduced until 1920, with the introduction of red rubber tubes. Plastic drains were invented in 1961 and released on the market by Sherwood Medical.

Drains were prophylactically used in chest surgery for the first time in 1922 by Lilienthal. Previously, drains were not routinely placed in the pleural cavity postoperatively, as this was regarded as an admission of surgical failure.

The first mention of chest drainage after an injury dates back to the 14th century, when Guy de Chauliac performed a thoracostomy without the use of anesthetics. In his 18th-century treatises, Boerhaave recommended the insertion of a flexible drain with a blunt end and side apertures in cases of hemothorax. In reality, closed chest drainage was not established as an alternative solution to thoracentesis for chest injuries until the end of World War I. The first improvised flutter valves to prevent air from penetrating the chest area were also used in World War I, although water-seal drainage was no longer applied and previous experience with this type of seal was infrequent and had apparently been forgotten. During World War II, chest drainage at the 8th intercostal space was used as a follow-up intervention after thoracotomies in cases of chest trauma. However, thoracentesis alone was recommended for blunt chest injuries associated with fluid in the pleural cavity; chest drainage was only used in cases of persistent air leakage and then only temporarily (48 hours). In the 1950s, Maloney and Gray introduced new methods of extracting pathological content from the pleural cavity into the standard treatment of chest injuries in civilians, including closed thoracotomy, thoracotomy with drainage, closed drainage and thoracostomy. These methods were considered equally as effective as thoracentesis. The main indication for such treatments was penetrating chest trauma. Consequently, chest drainage again became increasingly used in military medicine, including during the Korean War. Nevertheless, the use of chest drainage still had its opponents, who clearly favored repeated thoracenteses, even in patients with hemothorax (up to 60 thoracenteses in 2 months in a single patient were recorded by King). However, as early as 1963, a publication by Felton clearly recommended chest drainage as a method of treatment in cases of pneumothorax and hemothorax, whereas thoracentesis was only suggested as a method for acute relief of tension pneumothorax. In the same year, Heimlich introduced a valve that prevented air from entering the chest cavity and allowed for drainage of pathological discharge from the pleural cavity. This valve was an enhanced version of the improvised flutter valves used in World War I. In the late 20th century, chest drainage thus became a fully accepted standard method and was recognized in the treatment of pathological conditions in the pleural cavity, ranging from chest traumas, post-operative conditions, pleural effusion and pneumothorax to malignant pleural conditions. Chest drainage is mostly the domain of thoracic or general surgeons, although several indications and technical aspects of chest drainage have lately become the concern of internists and chest physicians as well as intensive and resuscitation care specialists.

References

1. Čapov I, Wechsler J, et al. Drény a jejich využití v chirurgických oborech. Praha: Grada; 2001. p. 15–84.
2. Monaghan SF, Swan KG. Our Surgical Heritage. Tube Thoracostomy: The Struggle to the "Standard of Care". Ann Thorac Surg. 2008;86:2019–22.

2 ANATOMY OF THE CHEST

Martina Vašáková

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 12th vertebra and 12th rib posteriorly and laterally and ventrally by cartilages of the 7th to the 12th 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.

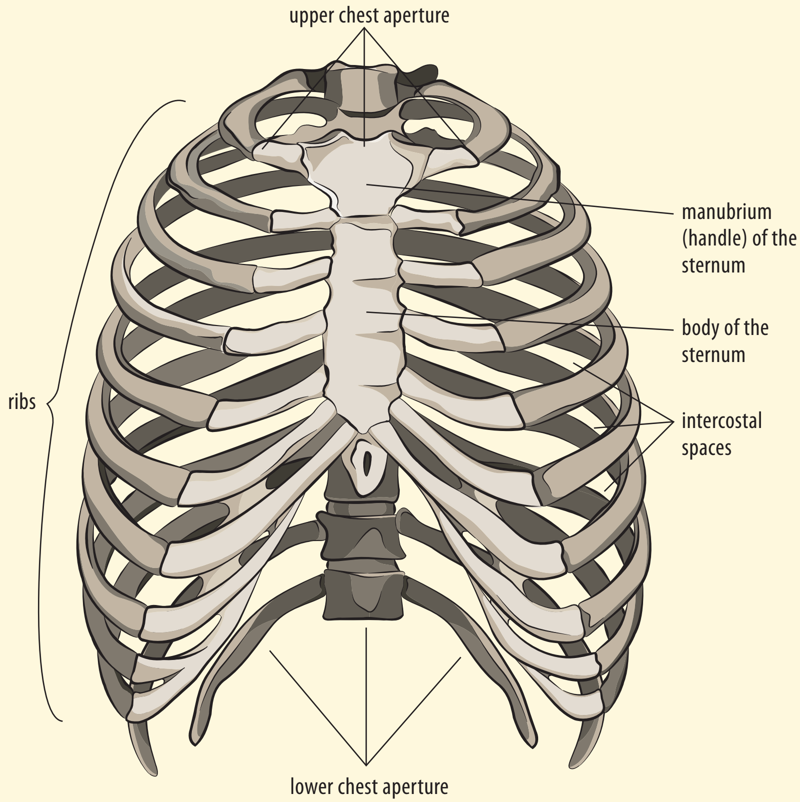

Fig. 2.1 Rib cage skeleton

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.

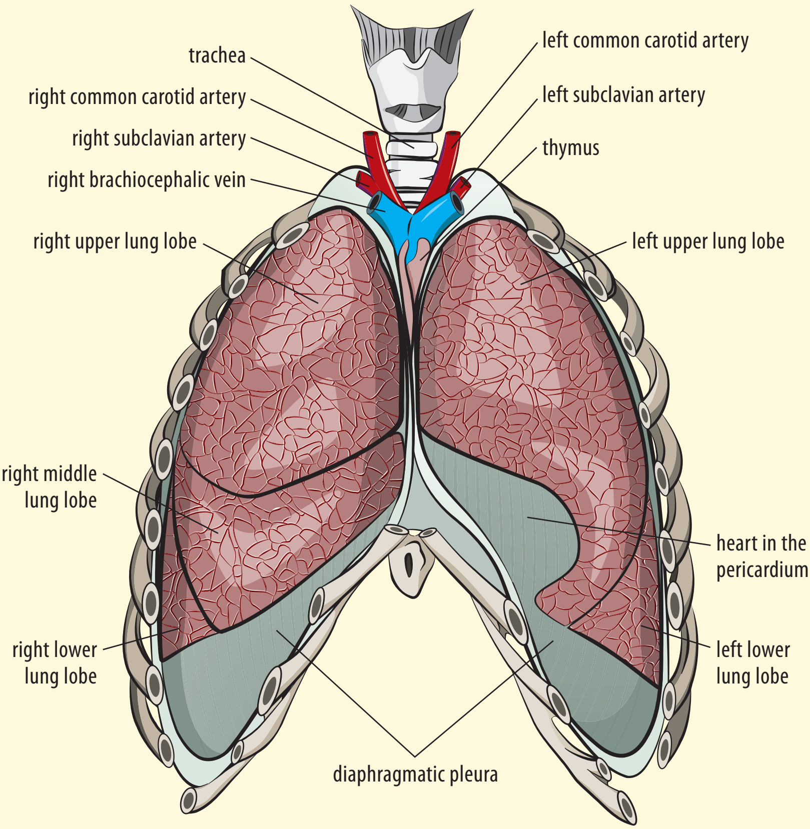

Fig. 2.2 Position of intrathoracic organs

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

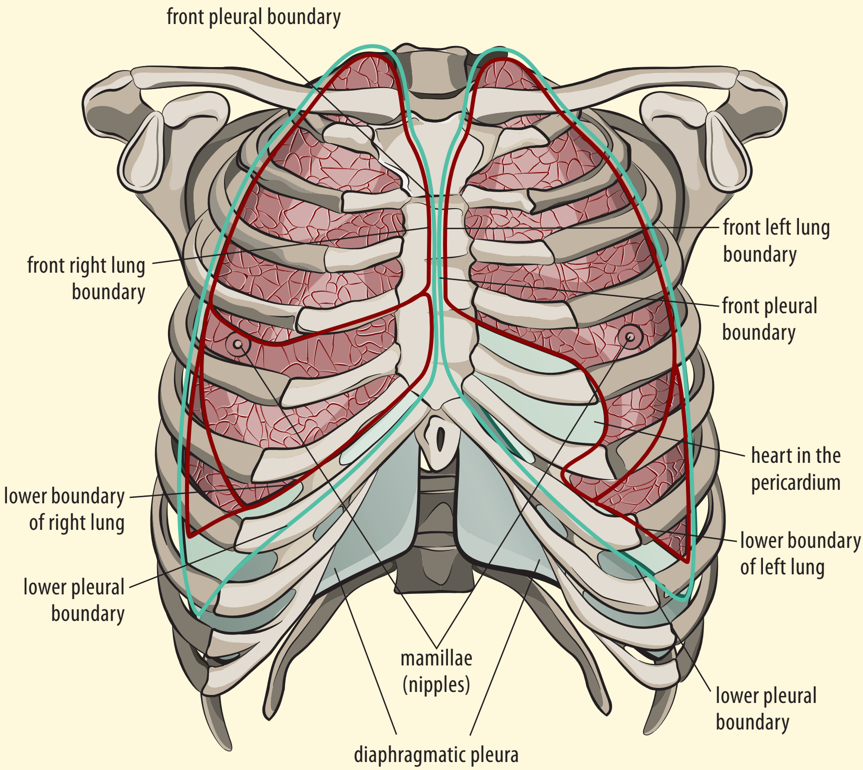

Fig. 2.3 Ventral view of the lung lobes

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

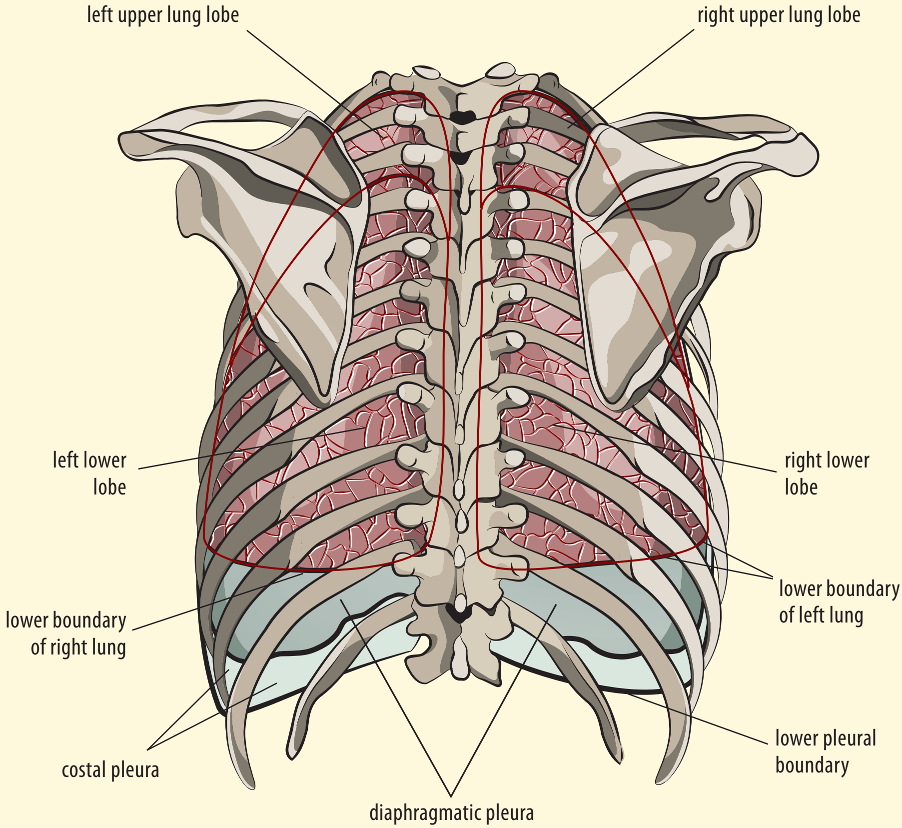

Fig. 2.4 Dorsal view of the lung lobes

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).

2.2 THORACIC WALL

The thoracic wall consists of 3 layers.

The surface consists of the skin and subcutaneous tissue, which contain surface blood vessels, subcutaneous lymphatic vessels and nerves.

The middle layer is composed of 3 major muscle groups (Fig. 2.5), which can be divided as follows:

- anterior group: pectoralis major and minor muscles
- lateral group: serratus anterior muscle
- posterior group: trapezius, latissimus dorsi, iliocostalis, and scapular muscles

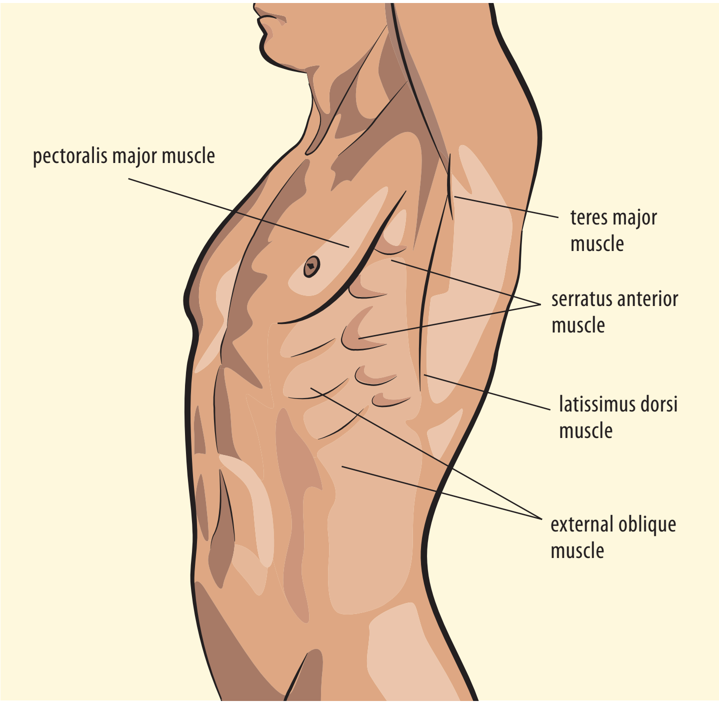

Fig. 2.5 View of chest muscles on the body surface

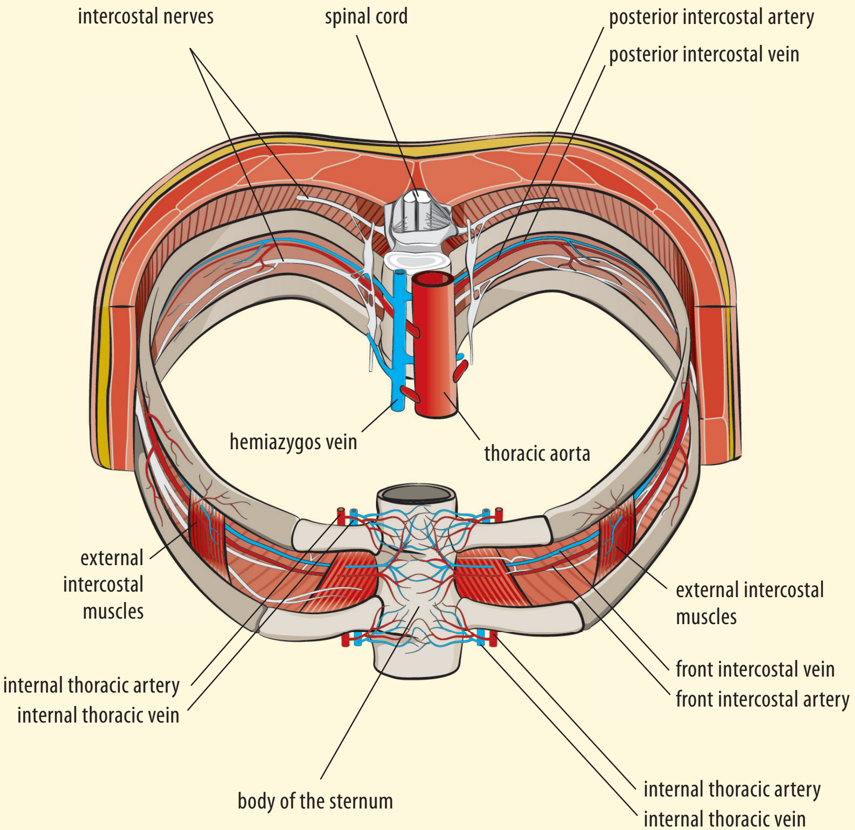

Fig. 2.6 Thoracic wall section. Diagram of muscles, blood vessels and nerves of the thoracic wall

The deep layer is composed of the ribs, sternum, thoracic vertebrae, scapulae and intercostal spaces with muscles, vessels and nerves. The deepest layer of the thoracic wall is covered with endothoracic fascia and parietal pleura.

There are eleven intercostal spaces, the first of which is situated between the 1st and 2nd ribs (Fig. 2.6).

2.2.1 Blood Vessels of the Thoracic Wall

Blood and nervous supply to the thoracic wall are provided by the intercostal vessels, as well as vessels and nerves originating from the throat and axilla. The intercostal arteries and the posterior intercostal arteries are ten rather thick arteries arising from the thoracic aorta (posterior intercostal arteries III–XII). Two cranial arteries then arise from the costocervical trunk (posterior intercostal arteries I–II). Eleven pairs of intercostal arteries pass through the 1st to the 11th intercostal spaces, and the final, twelfth pair of arteries, or the subcostal arteries, runs under the 12th rib. At the head of the rib, the posterior intercostal artery emits a thin posterior branch to the deep back muscles and then continues as a proper thick posterior intercostal artery along the anterior surface of the internal intercostal muscle. At the costal angle, this artery divides into a thicker upper branch, which represents the actual continuation of the intercostal artery and embeds itself in the costal groove, and a thinner collateral (supracostal) branch that runs along the upper edge of the lower rib. From the rib angles, both branches pass between the internal and innermost intercostal muscles and anastomose with intercostal branches of the internal thoracic artery, which is a branch of the subclavian artery. The first posterior intercostal artery anastomoses with the supreme intercostal artery. Branches 7–12 of the intercostal artery pass over the rib arch and enter the muscles of the abdominal wall, where they anastomose with the branches of the superior and inferior epigastric arteries.

PRACTICAL KNOWLEDGE OF THE BLOOD VESSELS OF THE THORACIC WALL

- Injury to the intercostal artery is a serious complication of chest drainage.
- The front and rear intercostal arteries run under the lower edge of the upper rib; therefore, the area above the upper edge of the lower rib is a relatively safe area for thoracentesis.
- However, atypical routes of intercostal arteries are not uncommon.

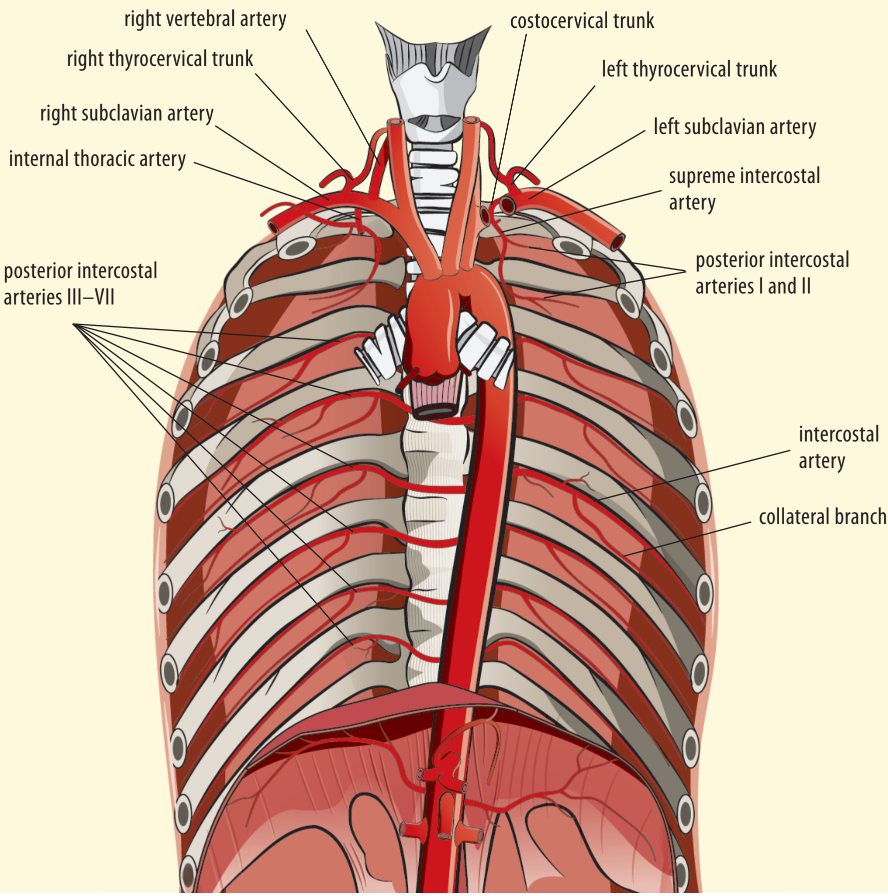

Fig. 2.7 Arterial blood supply to the thoracic wall

The intercostal arteries run in the intercostal space between the intercostal vein and nerve. The posterior intercostal artery, intercostal vein and intercostal nerve form the intercostal neurovascular bundle.

The anterior intercostal veins are located in the anterior sections of the upper nine to ten intercostal spaces and empty into the corresponding internal thoracic veins bilaterally. The posterior intercostal veins run in the rib groove parallel and superior to the intercostal vein and open on the right into the azygos vein and on the left into

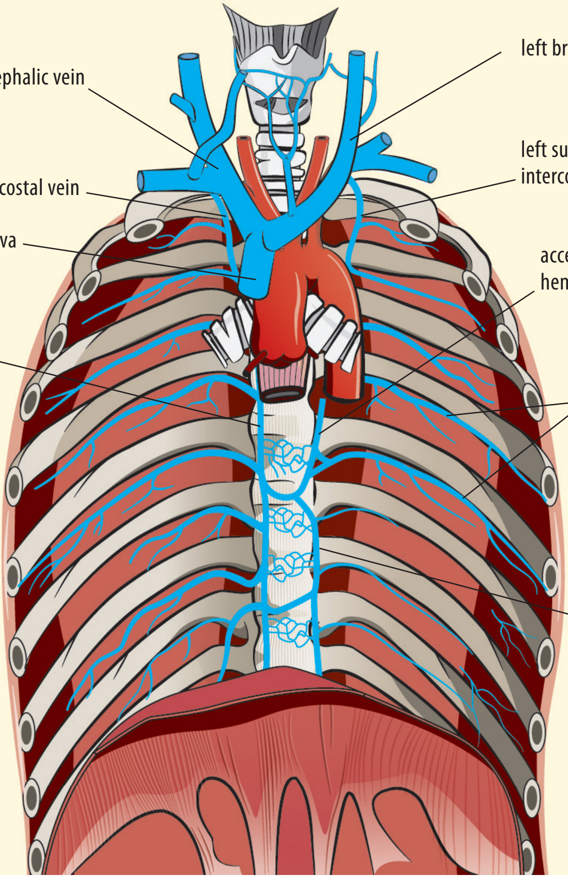

Fig. 2.8 Venous system of the thoracic wall

the hemiazygos vein. The intercostal vein that runs along the lower edge of the 12th rib is called the subcostal vein. The upper nine to ten posterior intercostal veins are connected in the anterior sections of the intercostal spaces with the anterior intercostal veins; the remaining posterior intercostal veins and the subcostal vein do not connect with the internal thoracic vein. Veins that drain the blood from the upper intercostal spaces merge and form the superior intercostal veins, both right and left, and the right superior intercostal vein also

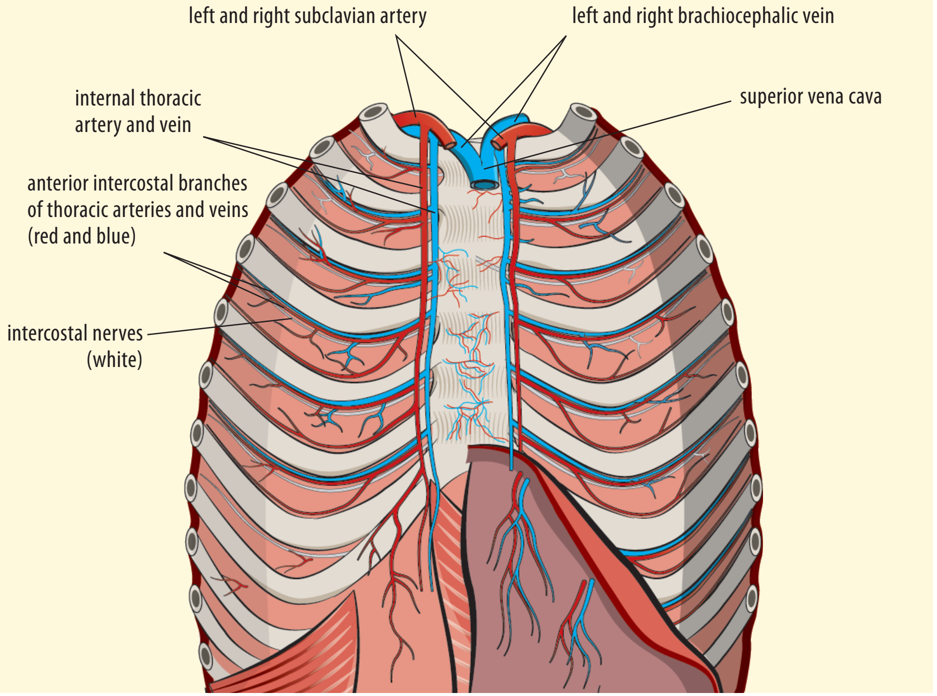

Fig. 2.9 Arteries, veins and nerves of the anterior thoracic wall (inner thoracic wall)

empties into the azygos vein through a left-sided venous portal into the left brachiocephalic vein. It should be noted that the route of the intercostal arteries is often abnormal and may be even tortuous, and the posterior intercostal artery may run through the intercostal space in the form of a sine curve. Injury to the posterior intercostal artery with subsequent bleeding is one of the most frequent indications for thoracic surgical intervention after thoracentesis or chest drainage (Fig. 2.7–2.9).