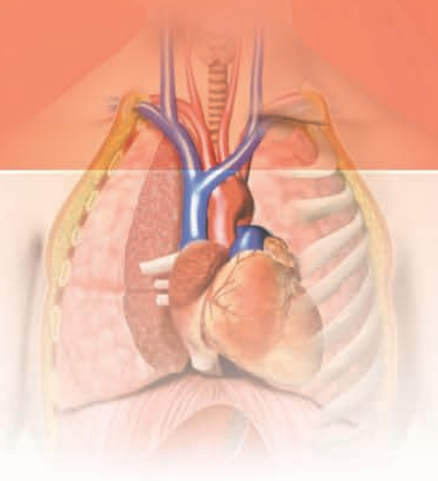

Chapter

39

Thoracic Wall

Competency: AN 21.1, 21.3 to 21.10

Objectives

- To list the structures forming the thoracic cage and to list the structure passing through its superior aperture
- To describe the anatomy of the sternum and to list the importance of sternal angle
- To classify the ribs into typical and atypical and discuss the features of a typical rib, first and second rib
- To name the joints of the thoracic cage, their type and movements allowed by them.
- To list the muscles of the intercostal space and to discuss their attachments, nerve supply and functions
- To discuss the anatomy of the respiration
- To define a typical intercostal space and to describe the course, branches, distribution and applied anatomy of the typical intercostal nerve
- To describe the origin, termination, branches and applied anatomy of the internal thoracic artery
- To discuss the arteries and veins in the intercostal space

The thorax includes the primary organs of the respiratory and cardiovascular system. It can be studied under thoracic wall and thoracic cavity. The thoracic cavity has a central compartment called mediastinum and pulmonary cavities on either side housing the lungs. Though mammary glands are located in the thorax, it is discussed in pectoral region of the upper limb. The thoracic wall includes thoracic cage (thoracic skeleton), muscles between the ribs, skin and fascia. The same structures covering the posterior aspect are discussed in Chapter 37.

THORACIC CAGE

The vital organs of the thorax (heart and lungs) are well protected inside the bony thoracic cage (Fig. 39.1A and B). It has following boundaries.

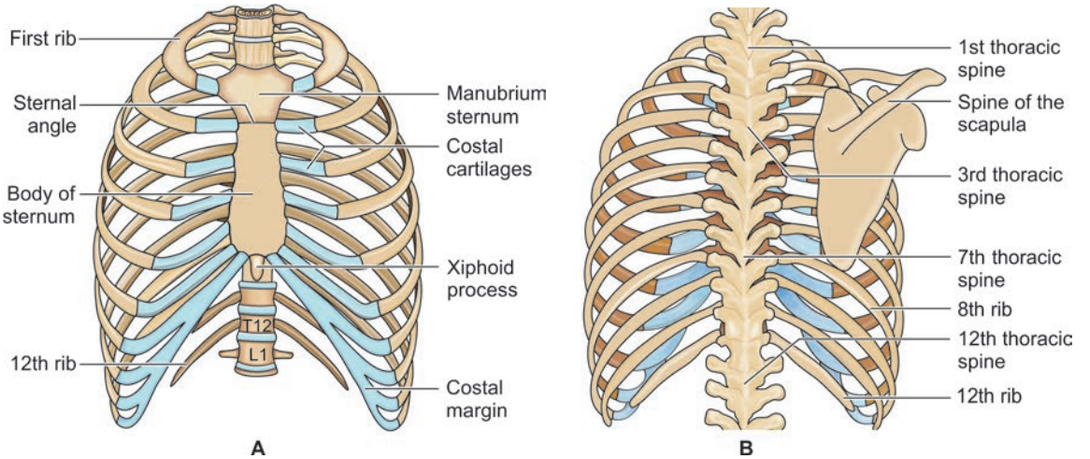

Fig. 39.1: Thoracic cage. **A:** Anterior view; **B:** Posterior view

Anteriorly: It is formed by the sternum.

On either side: The ribs and their costal cartilages.

Posteriorly: The thoracic vertebral bodies with intervertebral discs between them.

The cavity of the thoracic cage resembles a truncated cone which is narrow above and wider below. The upper end continues with the neck while the lower end is completely separated from the abdominal cavity by a dome-shaped muscular partition called diaphragm. Though the skeletal framework of the thoracic cage provides rigidity, its joints and flexibility of the ribs allow it to absorb many external blows and compressions. It is designed in such a way that it can alter the volume of thoracic cavity for respiration.

Inlet of the Thoracic Cage

Clinically it is referred as **outlet of the thorax**. When viewed from above it appears to be kidney shaped with transverse diameter ranging between 10 to 12 cm while anteroposterior diameter is only 5 cm. The inlet is not horizontal instead obliquely placed with an angle of 45°. This means the anterior wall is situated in front and below while posterior wall is situated behind and above (Fig. 39.2).

Boundaries

Anteriorly: Upper border of the manubrium sternum.

Posteriorly: Upper border of the body of first thoracic vertebra.

On each side: First rib and its cartilage.

The inlet is related to apex of the lungs covered by cervical pleura and suprapleural membrane (Sibson's fascia).

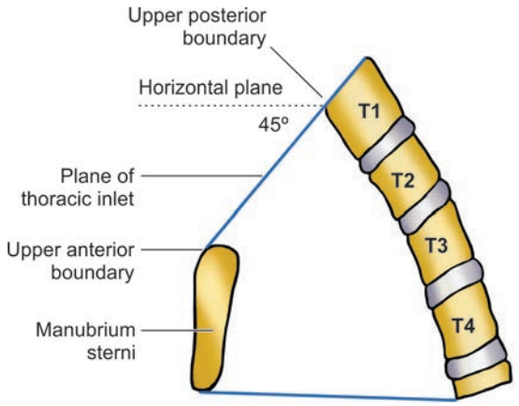

Fig. 39.2: Inlet of the thorax (lateral view)

Following are the important structures passing through the inlet of the thorax:

In the midline: Sternothyroid and sternohyoid muscles, inferior thyroid veins, trachea and the oesophagus.

On the right side of the midline: Brachiocephalic artery, right brachiocephalic vein.

On the left side of the midline: Left common carotid artery, left brachiocephalic vein, left recurrent laryngeal nerve and thoracic duct (Fig. 39.3).

Outlet of the thorax (inferior thoracic aperture): It is irregular in outline, and it is closed by the diaphragm. It is also oblique so that the posterior thoracic wall is longer than anterior.

STERNUM

Sternum is a flat bone, present in front of the thoracic cage. It presents the following parts from above

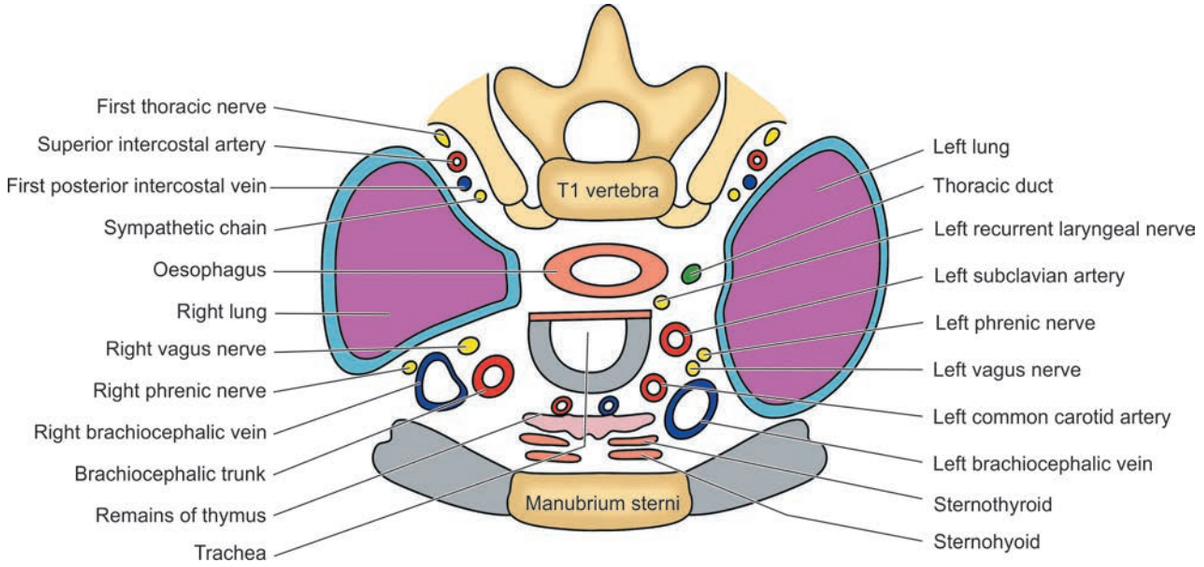

Fig. 39.3: Inlet of the thorax

downwards: Manubrium, body and xiphoid process (Fig. 39.4A and B).

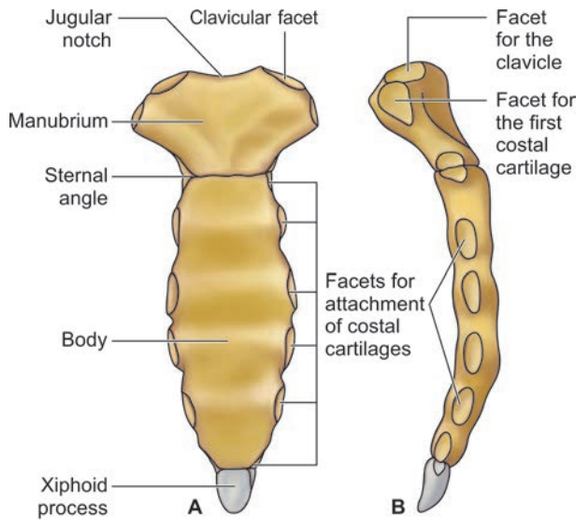

Fig. 39.4: Sternum. **A:** Anterior view; **B:** Lateral view

Manubrium: The manubrium is the upper part of the sternum. It articulates with the medial ends of clavicles and first costal cartilages. Its upper end is easily palpable and is called jugular notch (suprasternal notch). The anterior surface of the manubrium provides attachments to pectoralis major and sternocleidomastoid muscle. The upper part of the posterior surface provides attachments to sternohyoid and sternothyroid muscles. The posterior surface of the manubrium is related to the arch of the aorta.

Sternal angle (angle of Louis): It corresponds to the joint between manubrium and body of the sternum. It is an important landmark for the following reasons:

- The second costal cartilage can be felt at the sides of this angle. From this site one can count the ribs downwards.
- The ascending aorta ends, arch of the aorta begins and ends, and the thoracic aorta begins at this level.
- The trachea divides into two right and left principal bronchi.
- Azygos vein arches over the root of the right lung.
- The pulmonary trunk divides into right and left pulmonary arteries.
- The thoracic duct crosses from right to left side at this level.
- An imaginary horizontal plane passing through this level, demarcates superior mediastinum from the inferior mediastinum.

Body: The body is larger part of the sternum: On each side, it receives ribs through their costal cartilages (third to sixth ribs).

The anterior surface of the body provides attachment to pectoralis major on each side.

The lower part of the posterior surface provides attachments to sternocostalis muscle.

The posterior surface on the right half is directly related to anterior border of the right lung and pleura while the left half is related to the anterior border of the left lung and pleura in the upper part and pericardium and heart in the lower part. The posterior surface also provides attachments to sternopericardial ligament.

Xiphoid process: The xiphoid process is the most variable part of the sternum. It is a cartilaginous structure in young people but ossified in adults. Its joint with the body of the sternum (xiphisternal joint) laterally corresponds to 7th costal cartilage. Its anterior surface provides attachments to rectus abdominis, aponeurosis of external oblique abdominis and internal oblique abdominis muscles.

It is a midline marker for central tendon of diaphragm, inferior border of the heart and upper limit of the liver. Refer Chapter 38, for the development of the sternum and related anomalies.

Clinical Notes

Sternal puncture: A bone marrow sample can be obtained from sternum for hematological examination.

The fracture of the sternal body is usually a comminuted fracture (broken into several pieces), but displacement of the fragments is uncommon because of muscle attachments. Sternal fracture is common in road accidents, with its backward displacement, compressing aorta, heart or liver.

Sternum may be divided in the median plane (median sternotomy) for the surgeries of heart and its blood vessels. The flexibility of ribs and costal cartilages enables spreading of the halves of the sternum.

RIBS (COSTAE)

There are 12 pairs of ribs in the body. Each rib anteriorly articulates with the sternum, through its costal cartilage (first to seventh). The lower ribs articulate anteriorly with the higher costal cartilages (eighth to tenth). The anterior ends of the last two ribs are free and are called floating ribs (vertebral). Posteriorly each rib articulates with the thoracic vertebrae.

The third to ninth ribs present almost the same features, hence are referred as **typical ribs**. The 1st, 2nd, 10th, 11th and 12th ribs are atypical.

Typical Rib

Each typical rib has an anterior end, shaft and posterior end (Fig. 39.5).

a. **Anterior end:** It joins the corresponding costal cartilage by primary cartilaginous joint.
b. **Posterior end:** It presents head, neck and tubercle.

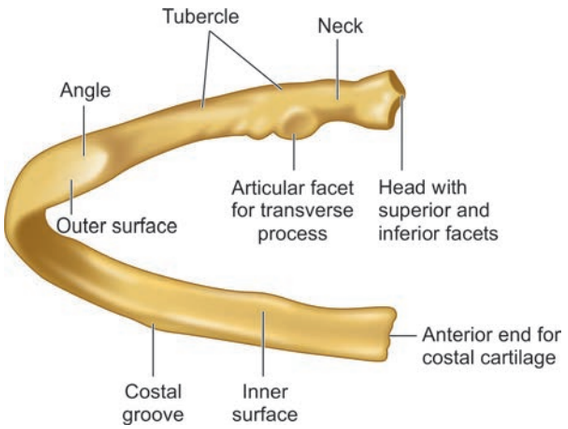

Fig. 39.5: Typical rib

Head: It comprises two facets. The lower facet of the head articulates with body of the numerically corresponding vertebra (plane synovial joint). The upper facet of the head articulates with body of the vertebra above (plane synovial joint). The two facets are separated by a crest, which corresponds to the intervertebral disc.

Neck: It is the narrow succeeding part of the head. It lies in front of the transverse process of the corresponding vertebra.

Tubercle: It is the rough portion between neck and shaft. It has medial articular and lateral nonarticular parts. The medial articular part articulates with transverse process of corresponding vertebra by a plane synovial joint (costotransverse joint). The lateral part provides attachment to lateral costotransverse ligament.

Shaft: It is the elongated flat part of the rib. It presents angulation about 5 to 6 cm lateral to the tubercle. The shaft is also twisted so that it is inner surface faces upwards behind the angle and faces downwards in front of the angle. The shaft presents upper and lower borders, outer and inner surfaces. The upper margin is smooth and rounded while lower border is sharp. From second to the tenth ribs, the distance between angle and tubercle increases. Medial to the angle, the outer surface gives attachment to levator costae and covered by erector spinae. The outer surface near the sternal end presents an indistinct line which separates the attachments of the external oblique and serratus anterior (or latissimus dorsi in case of the ninth and tenth ribs).

The external intercostal muscle is attached to inferior border. The superior border has two lips, the outer lip receives attachments of external intercostal while the inner lip receives internals intercostal muscles. The floor of the costal groove provides attachment to internal intercostal muscles. The innermost intercostal muscles are attached to inner surfaces of the shaft.

Costal groove: The lower part of the inner surface presents a costal groove, which is occupied by posterior intercostal vein, posterior intercostal artery and intercostal nerve from above downwards. You can remember these arrangements using a mnemonic VAN (Vein, Artery and Nerve). ☺

First Rib

- It is the shortest, broadest and most curved among all the ribs (Fig. 39.6A).
- The head presents only one facet for the body of first thoracic vertebra.
- The neck is rounded and directed laterally. Following important structures are related in front of the neck of the first rib from medial to lateral side.
  a. Sympathetic chain
  b. First posterior intercostal vein
  c. Superior intercostal artery
  d. Ventral ramus of the first thoracic nerve
  (You can recall these structures using a mnemonic —chain pulling a VAN) ☺

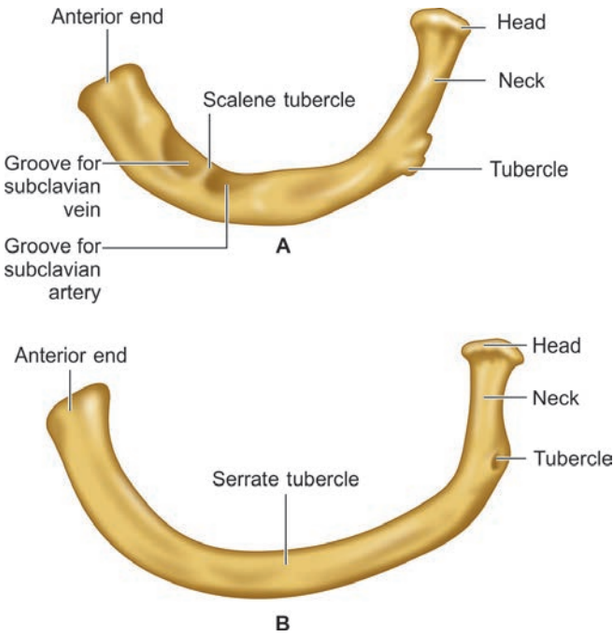

Fig. 39.6: Atypical ribs; **A:** First rib (superior view); **B:** Second rib (superior view)

- The clinical relevance of these relations is discussed in Chapter 41.
- The shaft has no twisting hence presents superior and inferior surfaces, outer and inner borders.
- The inner border and the upper surface present **scalene tubercle** for the insertion of scalenus anterior muscle. The inner border provides attachment to suprapleural membrane.
- The outer border is convex and receives attachment of first digitation of serratus anterior muscle.
- Its superior surface is grooved by subclavian vein in front of the scalene tubercle and subclavian artery behind the scalene tubercle.
- The anterior part of the superior surface provides attachment to subclavius muscle.
- The shaft has no costal groove.

Second Rib

- The second rib is also highly curved like first rib (Fig. 39.6B), but the length is twice that of the first rib.
- Shaft has no twisting and presents outer convex and inner concave surface.
- The head presents two articular facets for the bodies of 1st and 2nd thoracic vertebrae.
- It has a rough area on its upper surface called **serrate tubercle** providing attachment to serratus anterior muscle.
- A short costal groove is present on the posterior part of the inner surface.
- The posterior part of the upper border of the shaft receives insertion of scalenus posterior muscle.

Tenth Rib

The 10th rib has one facet—for articulation with its numerically corresponding vertebra.

11th and 12th Ribs

- There is no neck and tubercle.
- The head presents only one facet.
- Their anterior end is pointed.
- Costal groove and angle are absent in 12th rib, however in 11th rib it may be ill defined.

Clinical Notes

- The middle ribs are most commonly fractured from blows or from crushing injuries (automobile injuries). The weak point of the rib is near (anterior) its angle, however direct violence may fracture a rib anywhere. Fracture involving this site can penetrate the lungs or spleen. Fractures of the lower ribs may tear the diaphragm and result in diaphragmatic hernia. Rib fractures are painful.
- Ribs may be fractured occasionally during muscular strains (coughing).
- Rib dislocation can occur where costal cartilage articulates with sternum.
- Rib separation is the dislocation at the articulation between costal cartilage and ribs.
- In coarctation of aorta, X-ray shows notching of the ribs due to pressure by intercostal arteries.
- Supernumerary ribs: Presence of cervical or lumbar ribs is also known. Presence of cervical rib can lead to compression of neurovascular structures. Absence of 12th pair of ribs is also known.

Cervical Rib Syndrome/Scalenus Anterior Syndrome/Thoracic Outlet Syndrome

- Presence of cervical rib (Fig. 39.7) or a congenitally hypertrophied scalenus anterior muscle can compress the subclavian artery or lower trunk of the brachial plexus.
- Compression of the subclavian artery causes pallor and coldness of the upper limb and reduced radial pulse.
- Compression of the subclavian vein causes distension of the superficial vein, oedema and pain in the upper limb.
- Compression of the lower trunk of the brachial plexus causes numbness, tingling and pain along the medial border of the hand (C8 and T1) and little finger, wasting of small muscles of the hand.

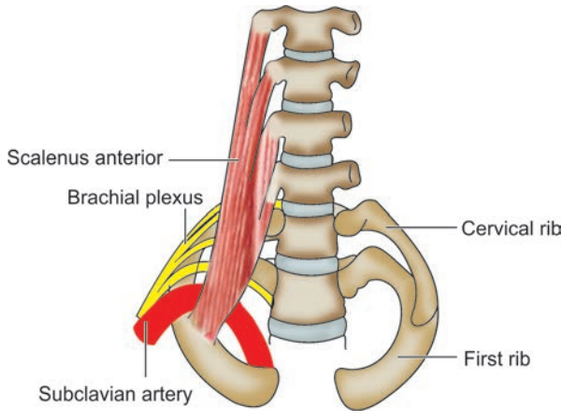

Fig. 39.7: Cervical rib

Costal Cartilages

The anterior ends of the ribs continue as costal cartilages, providing elasticity to thoracic wall. The cartilages increase in length through first seven and then gradually decrease. The first seven costal cartilages directly articulate with sternum. The eighth, ninth and tenth articulates with costal cartilages superior to them forming **costal margin.** The 11th

and 12th costal cartilages form caps on the anterior ends of the corresponding ribs.
Costal cartilages provide resilience to the thoracic cage and prevent fractures of ribs and sternum. Because of its elasticity, chest compression may produce injury within the thorax without fractures in children. In elderly people, the costal cartilages become brittle, and they may undergo calcification. They become radiopaque in X-rays.

CASE 1
On examining, a routine posteroanterior chest radiograph of an 85-year-old woman, it was noticed that many of the costal cartilages showed scattered radiopaque areas. What is the likely explanation for these opacities?

CASE 2
A 60-year-old man and a 10-year-old boy were both involved in a severe automobile accident. In both cases the thorax has been badly crushed. On X-ray examination, the man was seen to have five fractured ribs, but the boy had no fractures. Comment on these findings.

CASE 3
A 32-year-old patient presents with pain associated with taking a deep breath. Palpation reveals tenderness over midaxillary region of ribs 5 and 6 on the right side. Radiologic findings confirm fractures of these ribs:
1. How did you determine the correct rib numbers?
2. Do the ribs move during breathing?
3. How do you explain the pain?
4. What other structures may be at risk?

Thoracic vertebrae: The thoracic vertebrae are 12 in number of which second to eighth thoracic vertebrae are typical, while first and 9th to 12th thoracic vertebrae are atypical.
The further details are discussed in Chapter 37.

JOINTS OF THE THORAX

Manubriosternal Joint

It is the joint between the body and the manubrium of the sternum. It is a secondary cartilaginous joint. It permits slight movements during respiration.

Costovertebral Joint

As we studied before the head of the typical rib presents two facets. Of which the lower facet articulates with the numerically corresponding vertebra (with upper facet on the body). The upper facet on the head of the rib articulates with the vertebra above (with lower facet on the body). It is a plane synovial joint with capsular ligament and triradiate ligament.

Costotransverse Joint

The tubercle of a typical rib articulates with the facet on the anterior aspect of the transverse process of the numerically corresponding vertebra. It is a synovial joint. In addition to the capsular ligament the joint has three costotransverse ligaments (Fig. 39.8A and B).

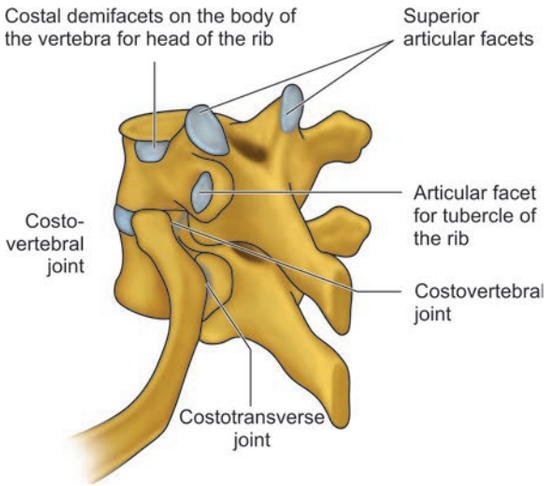

Fig. 39.8A: Joints of the ribs and vertebrae

a. Superior costotransverse ligament: It extends from the crest of the neck of the rib to the transverse process of the vertebra above.
b. Inferior costotransverse ligament: It extends from the posterior surface of the neck of the rib to the transverse process of its own vertebra.
c. Lateral costotransverse ligament: It extends from the lateral non-articular part of the tubercle of the rib to the tip of the transverse process of its own vertebra.
d. Radiate ligament: It connects the anterior part of the head of each rib with the side of the bodies of two vertebrae, and the intervertebral fibrocartilage between them.

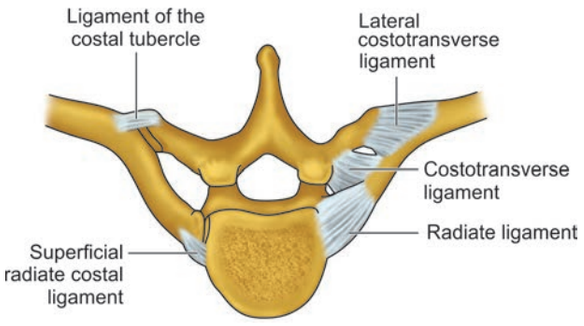

Fig. 39.8B: Joint between rib and vertebra (superior view)

It is interesting to note that the articular facets of the ribs vary and accordingly they bring different types of movement. For instance, the articular facets on the tubercles of the upper six ribs are convex and they permit the rotation of the neck of the rib for pump-handle movement. Their backward rotation helps in the forward and upward movement of the sternum which increases the anteroposterior diameter of the thorax.

Costochondral Joint

Each rib continues anteriorly with its cartilage. It is a primary cartilaginous joint. These joints do not allow any movement.

Chondrosternal Joint (between Costal Cartilages and Sternum)

The first chondrosternal joint is primary cartilaginous, and it does not permit any movement. The remaining second to seventh costal cartilages articulate with the sternum by synovial joints.

MUSCLES OF THE THORACIC WALL

Thoracic wall muscles include intercostal, subcostal, sternocostalis, levator costae and serratus posterior. The thoracic cage forms the skeletal framework of the walls of the thorax. The gaps between the ribs are called **intercostal spaces**, which are filled up by intercostal muscles (Figs 39.9 and 39.10A to C). The intercostal muscles are a group of intrinsic thoracic cage muscles that occupy the 11 intercostal spaces. They are divided into three groups, from superficial to deep are:

1. External intercostal muscles
2. Internal intercostal muscles
3. Innermost intercostal muscles

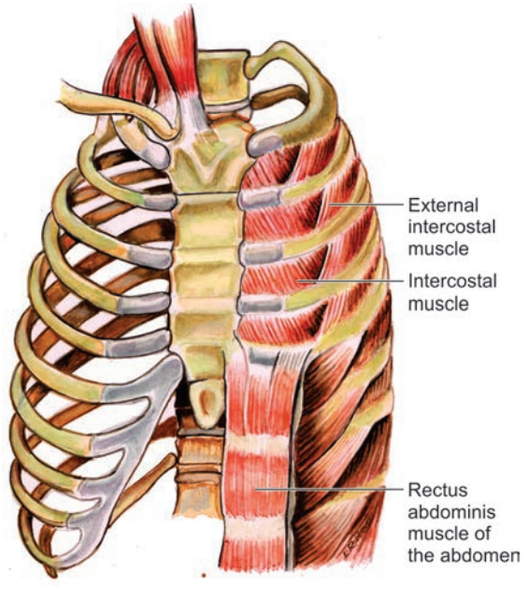

Fig. 39.9: Intercostal muscles

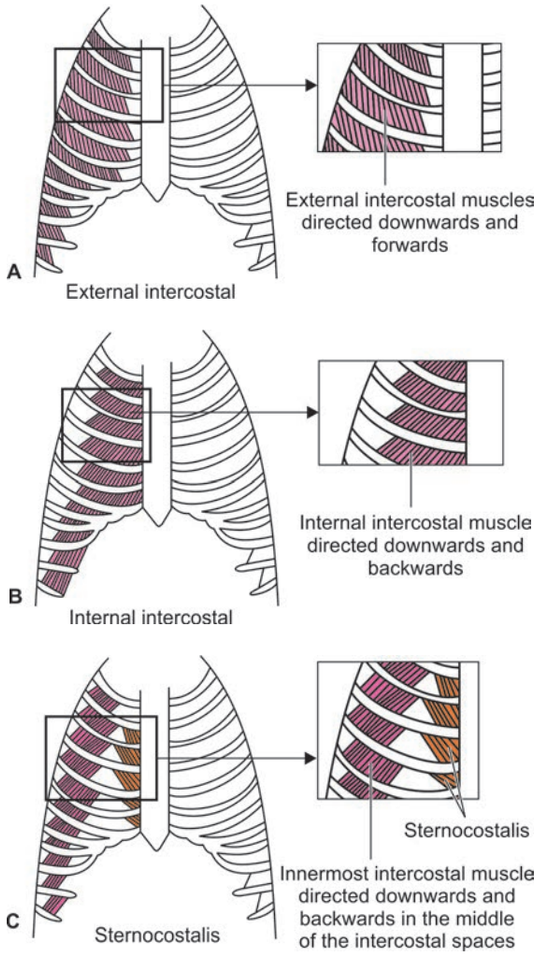

Fig. 39.10A to C: Intercostal muscles: Anterior view

All three groups of muscles support the rib cage. Moreover, they participate in the process of forced breathing.

1. External Intercostal Muscles

- In each intercostal space they extend from the angle of the ribs posteriorly to costochondral junction anteriorly.
- Between the lateral margin of the sternum and costochondral junction it is represented by an external intercostal (anterior intercostal) membrane.
- Each muscle arises from inferior border of upper ribs to the outer lip of the superior border of lower ribs.
- The directions of the muscles are downwards and medially in front and downwards and laterally in the posterior part (Fig. 39.10A).

2. Internal Intercostal Muscles

- They are present deep to the external intercostal muscle and its fibres are directed at right angle to the direction of external intercostal muscles (Fig. 39.10B).

- In each intercostal space the muscle extends from the angle of the ribs posteriorly to lateral border of the sternum anteriorly.
- In the posterior part of the intercostal space (beyond the angles of the ribs) it is represented by internal intercostal (posterior intercostal) membrane.
- Each muscle arises from the floor of the costal grooves to inner lip of the superior borders of the ribs inferior to them.

Subcostalis, sternocostalis and intercostalis intimi muscles are often grouped as transversus thoracis.

3. Innermost Intercostal Muscles (Intercostalis intimi)

- They are present deep to the internal intercostal muscle in the middle and lateral part of the intercostal spaces but separated from them by intercostal nerves and vessels (Fig. 39.11).
- The direction of the muscle fibres are same as internal intercostal muscles (downwards and backwards) (Fig. 39.10C).
- They extend from inner surface of the upper ribs to inner surface of the lower ribs.

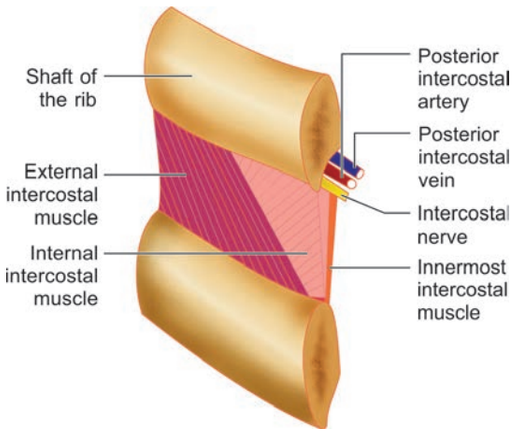

Fig. 39.11: Arrangements of intercostal muscles

Subcostalis

They arise from inner surface of lower ribs near their angles and extend to superior borders of 2 or 3 ribs below. They are better defined in lower intercostal spaces only.

Sternocostalis

It arises from the posterior surface of the lower part of the sternum. It extends **upwards** to inner surface of second to sixth costal cartilages (Fig. 39.10C).

It pulls ribs 2–6 towards the sternum during forced expiration, which results in depression of those ribs. This action consequently decreases the anteroposterior diameter of the thoracic cavity.

All these muscles are supplied by the intercostal nerves (thoracic spinal nerves).

Action of the Intercostal Muscles

a. The main action of the intercostal muscles is to prevent retraction of the intercostal spaces during inspiration and bulging during expiration. Such movements are an indication of the paralysis of the intercostal muscles.
b. The role of intercostal muscles in producing the movements of the ribs appear to be related mainly in forced respiration, the diaphragm being primary muscle of inspiration and expiration is passive (due to elastic tissues of the lungs).
c. It is believed that external intercostal and interchondral portions of the internal intercostal and levator costae may elevate the ribs during forceful inspiration.
d. The internal intercostal (except the interchondral part) and innermost intercostal may depress the ribs during forceful expiration.

Levator costarum: It extends from transverse processes of T7 to T11 vertebrae to subjacent ribs between tubercle and angle. It is supplied by posterior primary rami of C8–T11, nerves, and they elevate the ribs.

Serratus posterior superior: It arises from spinous process of C7 to T3 vertebrae and is inserted into upper borders of 2nd to 4th ribs. It is supplied by intercostal nerves (T2–T5) and known to elevate the ribs.

Serratus posterior inferior: It arises from spinous processes of T11 to L2 vertebrae and inserted into lower border of 8th to 12th ribs near their angles. They are supplied by lower intercostal and subcostal nerves (T9–T12) and are known to depress the ribs.

RESPIRATORY MOVEMENTS

In the medical world, breathing is defined as pulmonary ventilation. It is described as the movement of air between the atmosphere and the alveoli of the lung. It involves two events: inspiration, when the air moves into the lungs and expiration, when the air leaves the lungs.

Inspiratory Movement

Increase in thoracic volume (decrease in intrapulmonary pressure/pressure inside the lung) is achieved by movement of thoracic wall and diaphragm.

a. The increase in vertical diameter is due to contraction of the diaphragm. When diaphragm contracts, it descends, which leads to increase in vertical diameter of the thorax.
b. The increase in anteroposterior diameter of the thorax is due to contraction of intercostal

Table 39.1: Muscles of the thoracic wall—summarized

Name of the Muscle	Origin	Insertion	Nerve Supply	Actions
External intercostal Their fibres are directed downwards, forwards and medially when seen from the front	Lower border of the upper rib	Outer lip of the upper border of the rib below	Intercostal nerves	Elevate the ribs during forced inspiration
Internal intercostal Their fibres are directed obliquely, right angle to those of the external intercostals	From the floor of the costal groove	Inner lip of the upper border of the rib below	Intercostal nerves	Depress the ribs during forced expiration but interchondral part elevates the ribs during forced inspiration
Innermost intercostal The fibres are directed similar to that of the internal intercostals	Inner surface of the upper rib	Inner surface of the rib below	Intercostal nerves	Depress the ribs during forced expiration
Subcostales They are confined to the lower intercostal spaces only	Inner surface of one rib near the angle	Inner surface of the second or third rib below	Intercostal nerve	Depresses the ribs
Sternocostalis	Lower part of the posterior surface of the sternum and xiphoid process and costal cartilages	The fibres ascend laterally and inserted into lower border and inner surfaces of second to sixth ribs	Intercostal nerves	It pulls ribs 2–6 towards the sternum during forced expiration, which results in depression of those ribs.

muscles. Movement of the ribs (2nd to 6th) at the costovertebral joints around an axis passing through necks of the ribs causes anterior ends of the ribs to rise. Since anterior ends of the ribs are directed downwards, their elevation results in anteroposterior movement of the sternum. This is called **pump handle movement** (Fig. 39.12A).

c. The increase in transverse diameter of the thorax is also due to contraction of intercostal muscles. Movements of lower ribs rise the middle part of the ribs, thus increasing transverse diameter. This is called **bucket handle movement** (Fig. 39.12B).

With increase in the thoracic volume, the pressure inside the lung is reduced. So, air is drawn into the lungs through, nose, mouth, larynx and trachea.

Expiratory Movement

The air is expelled out from the lung, due to elastic recoiling tendency of the lungs. It is a passive act. The diaphragm and intercostal muscle relax, thus decreasing the thoracic volume and increasing the pressure inside the lungs.

Muscles involved: Muscles that are helpful in expanding the thoracic cavity are called

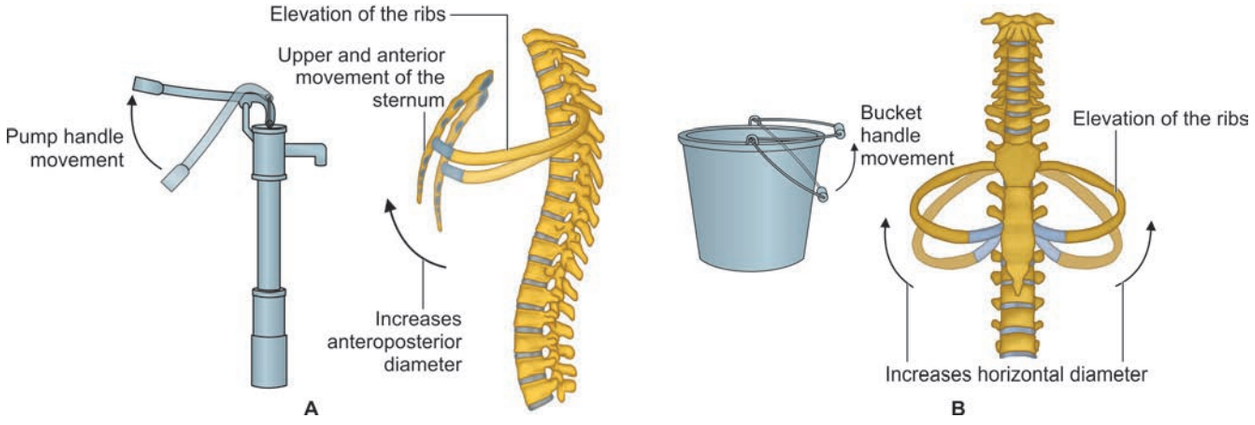

Fig. 39.12: Respiratory movements. **A:** Pump handle movement; **B:** Bucket handle movement

the inspiratory muscles because they help in inhalation, while those that compress the thoracic cavity are called expiratory muscles and they induce exhalation. The specialty of these muscles are that they are composed of fatigue resistant muscle fibres, they are controlled by both voluntary and involuntary mechanisms (if we want to take a breath we can, even if we do not think about breathing the body automatically does it). The muscles of inspiration elevate the ribs and sternum, and the muscles of expiration depress them.

Chief muscles of inspiration: Diaphragm

Deep inspiration: External intercostal and interchondral portion of the internal intercostal.

Accessory muscles of inspiration: The accessory inspiratory muscles are the sternocleidomastoid, the scalenus anterior, medius, and posterior, the pectoralis major and minor, the inferior fibres of serratus anterior and latissimus dorsi, the serratus posterior superior.

Chief muscles of forceful expiration: Interosseous part of the internal intercostal muscle and anterior abdominal wall muscles.

CASE 4

A mother, on looking at her newborn baby lying on its back in a cradle, was astonished and horrified to see its anterior abdominal wall bulging in and out with each respiration. Can you explain this in anatomical terms?

Endothoracic fascia: The thoracic cage is internally lined by a thin fibroareolar membrane called endothoracic fascia. It connects the costal part of the parietal pleura to the inner aspect of the thoracic wall. It is better defined over the apices of the lungs as the suprapleural membrane.

Suprapleural membrane (Sibson's fascia): It is the thicker part of the endothoracic fascia (or from scalenus minimus/pleuralis muscle) covering the cervical pleura and the apex of the lung which lies deep to it. It is attached to the inner border of the 1st rib and its costal cartilage and tip of the transverse process of 7th cervical vertebra. It prevents puffing off of lung apex during expiratory phase of respiration.

CASE 5

A carpenter who had received a knife wound in the neck two years before now noticed that when he blew his nose or sneezed, the skin above the clavicle bulged upward. Explain this upward bulging of the skin in anatomical terms.

TYPICAL INTERCOSTAL SPACE

The spaces between the typical ribs and traversed by intercostal nerves supplying only thorax are known as **typical intercostal spaces**. The 3rd, 4th, 5th and 6th intercostal spaces are typical.

Each space is directed downwards and forwards. It is narrow at the posterior part (towards vertebra) and wider at the anterior part (towards sternum).

Contents: Intercostal muscles, nerves and vessels.

Intercostal Nerves

The 12 pairs of thoracic spinal nerves supply the thoracic wall after dividing into anterior and posterior primary rami. The posterior rami of thoracic spinal nerves pass posteriorly to supply the muscles of the back and skin of the back. The anterior primary rami of 1st to 11th thoracic spinal nerves are called **intercostal nerves** since they course through intercostal space. The anterior primary ramus of 12th thoracic spinal nerve is called subcostal nerve.

First thoracic ventral ramus: The anterior/ventral primary ramus of first thoracic spinal nerve divides into two branches. The larger branch joins with anterior primary ramus (ventral ramus) of 8th cervical spinal nerve to form lower trunk of the brachial plexus. It means T1 fibres are distributed through upper limb. The smaller branch of anterior primary ramus of 1st thoracic spinal nerve form 1st intercostal nerve, **which courses along the under surface of the 1st rib. It does not give any cutaneous branch**.

The 2nd intercostal nerve gives lateral cutaneous branch and is called 'intercostobrachial nerve', which supplies skin of the floor of the axilla. The 7th to 11th intercostal nerves in addition to intercostal spaces, also supply anterior abdominal wall.

Typical Intercostal Nerves

The 3rd to 6th intercostal nerves, which are confined only to thoracic wall, are called typical intercostal nerves (Fig. 39.13).

Course

a. At the posterior ends of the intercostal space (vertebral end), each intercostal nerve travels between parietal pleura and posterior intercostal membrane, crossing behind the sympathetic chain.
b. Each nerve, medial to the angle of the rib enters the costal groove to occupy with intercostal vessels. The arrangement of the structures from above downwards is '**VAN**'—**v**ein, **a**rtery and **n**erve.
c. The nerve proceeds between internal intercostal and innermost intercostal muscles.

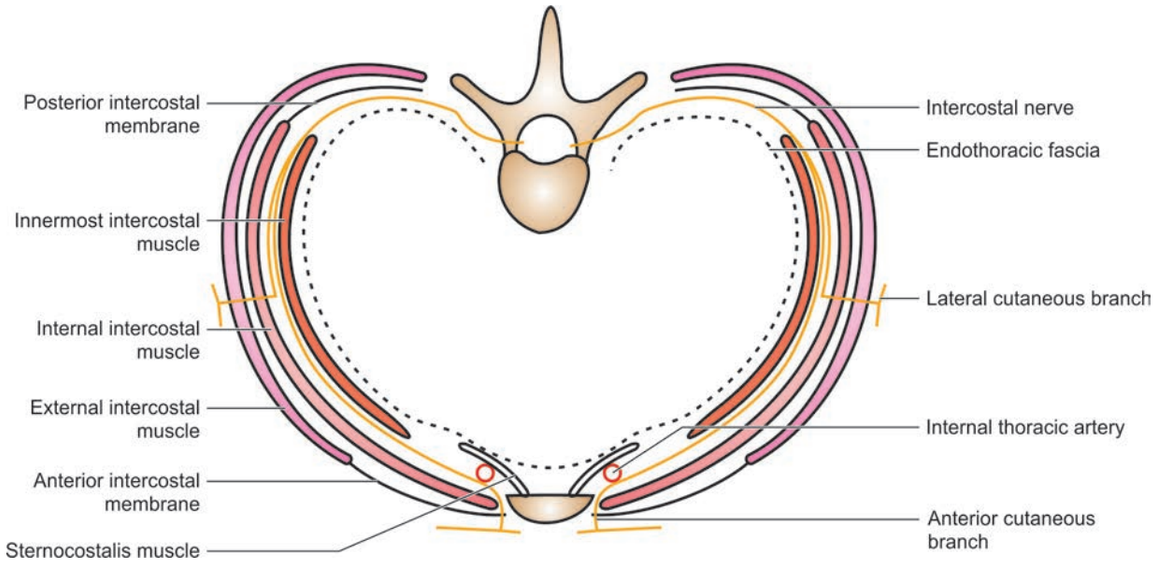

Fig. 39.13: Typical intercostal nerve (a schematic cross sectional view)

d. Near the anterior ends of the intercostal space (sternal end), each nerve crosses in front of the internal thoracic artery, pierces internal intercostal muscle, anterior intercostal membrane, pectoralis major muscle. It terminates as anterior cutaneous nerve.

Branches and Distribution

1. **Collateral branch:** It arises near the angle of the rib and proceeds in the lower part of the same intercostal space (upper margin of the lower ribs). It may join the main trunk in the anterior part of the intercostal space. It supplies intercostal muscles and parietal pleura.
2. **Lateral cutaneous branch:** It arises near the angle of the rib, runs with main trunk. At the midaxillary line it pierces the intercostal muscles and becomes superficial. It divides into anterior and posterior branches, which supply skin of the lateral thoracic wall.
3. **Muscular branches:** It supplies intercostal muscles, subcostal, sternocostalis, and the 4th and 5th typical intercostal nerve also supplies serratus posterior superior.
4. **Sensory branches:** The intercostal nerves apart from supplying skin and muscles, it also carries sensory (pain) fibres from parietal pleura. (The atypical, thoracoabdominal intercostal nerves, apart from supplying skin and muscles of the anterior abdominal wall. It also supplies parietal peritoneum.)
5. **Anterior cutaneous branches:** They are the continuation of intercostal nerves, pierces typical intercostal nerve (a schematic cross sectional view) on either side of the sternum to become superficial. After dividing into medial and lateral branches, supply the skin of the anterior aspect of the sternum.

Components of Intercostal Nerve

- Afferent: Cutaneous sensation from thoracic and abdominal wall
- Afferent: Sensation from costal and peripheral part of the diaphragmatic pleura
- Efferent: Motor fibres to intercostal muscles
- Efferent: Sympathetic fibres present in it, supplies sweat glands (sudomotor), Arrector pili muscles of the dermis (pilomotor) and the smooth muscles present at the wall of the blood vessels (vasomotor).

Clinical Notes

Intercostal nerve block: To produce anesthesia in one or two intercostal spaces, anesthetic solution is injected around the intercostal nerve. The intercostal nerve can be blocked anywhere proximal to the midaxillary line, where the lateral cutaneous branch originates. In children, the block is commonly carried out at the posterior axillary line. In adults, the most popular site for intercostal nerve block is at the angle of the rib (6–8 cm from the spinous processes). Just **lateral to the angle** of the rib, the rib is relatively superficial and easy to palpate, and the costal groove is the widest, theoretically reducing the probability of pleural puncture. Blockade medial to the angle of the rib is not recommended because the nerve lies deep to the posterior intercostal membrane with very little tissue between it and the parietal pleura, while the overlying sacrospinalis muscle makes rib palpation difficult. Blockade distal to the anterior axillary line is more difficult because the nerve has left the costal groove and re-entered the intercostal space and lies in the substance of the internal intercostal muscle.

Intercostal nerve block is used in a great variety of acute and chronic pain conditions affecting the thorax and upper abdomen. Complete loss of sensation usually does not occur unless two or more intercostal nerves are anesthetized.

Herpes zoster infection: Herpes zoster (or simply zoster), commonly known as shingles is a viral disease characterized by a painful skin rash with blisters in a limited area on one side of the body, often in a stripe. Years or decades after a chickenpox infection, the virus may break out of nerve cell bodies (example; dorsal root ganglia) and travel down through axons to cause viral infection of the skin in the region, supplied by that particular spinal nerve (dermatome). It can also be associate with muscular weakness.

The diseases of the thoracic vertebrae may irritate the intercostal nerves and pus from the tuberculous thoracic vertebrae may track along the neurovascular plane.

Blood Vessels of Thoracic Wall

Internal thoracic artery (internal mammary artery)

Origin: It arises from the under surface of the first part of the subclavian artery.

Course: The artery is crossed by phrenic nerve near its origin. It descends lateral to the sternum, deep to the costal cartilages, anterior to sternocostalis muscle. At the sixth intercostal space, it ends by dividing into two terminal branches; superior epigastric artery and musculophrenic artery (Fig. 39.14). Internal thoracic artery is accompanied by venae commitantes (pair of veins).

Branches

1. **Anterior intercostal arteries:** In the upper six intercostal space, there are two anterior intercostal arteries. The upper branch, anastomose with main trunk of the posterior intercostal artery, whereas the lower branch anastomoses with collateral branch of the posterior intercostal artery.
2. **Pericardiophrenic artery:** It accompanies the phrenic and descends in front of the root of the lungs. The artery is located between the fibrous pericardium and the parietal pleura in the middle mediastinum and extends inferiorly into the diaphragm. It supplies diaphragm and also phrenic nerve.
3. Pericardial, thymic, sternal and mediastinal branches.
4. Perforating branches in 2nd and 3rd intercostal space in females supply mammary gland.
5. The superior epigastric artery enters rectus sheath through xiphoid and sternal origins of diaphragm. It anastomoses with inferior epigastric artery (a branch from the external iliac artery).
6. The musculophrenic artery descends obliquely parallel to costal margin. Apart from supplying diaphragm, it also gives anterior intercostal arteries of 7th to 9th intercostal space. It anastomoses with inferior phrenic, lower two posterior intercostal arteries and ascending branch of the deep circumflex iliac arteries.

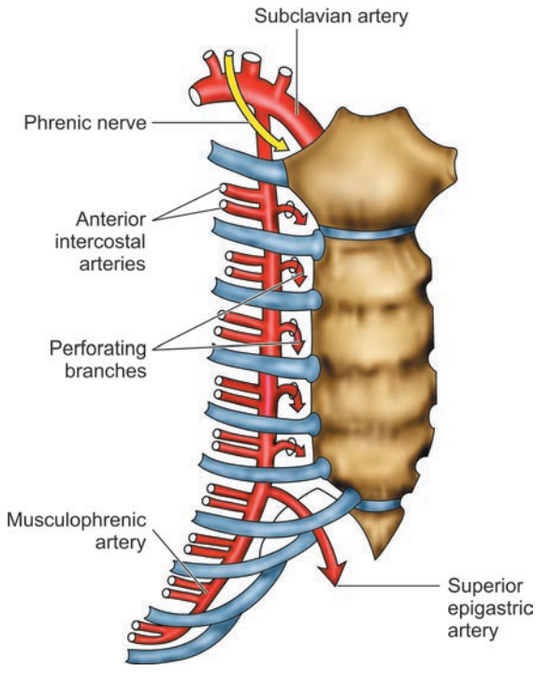

Fig. 39.14: Internal thoracic artery

Clinical Notes

The internal thoracic artery is the cardiac surgeon's artery of choice for coronary artery bypass grafting. It has superior long-term patency compared to saphenous vein grafts. Several histological (more elastic tissue), physiological (release more nitric oxide, which inhibits proliferation of smooth muscles in tunica intima) and anatomical (nearer to the coronary artery) advantages of internal thoracic artery is claimed.

Intercostal Arteries

In each intercostal space there are two anterior intercostal arteries and one posterior intercostal artery (with exception of 10th and 11th intercostal spaces).

In the upper six intercostal space, anterior intercostal arteries are branches of internal thoracic artery, while in 7th to 9th intercostal spaces-, they are branches of musculophrenic artery.

Posterior Intercostal Arteries

In the upper two intercostal spaces, it arises from superior intercostal artery (a branch of the costocervical trunk of the subclavian artery). In the remaining spaces it arises from descending thoracic aorta (Fig. 39.15).

The right posterior intercostal arteries are longer since thoracic aorta is slightly to the left of the vertebral column and have to cross in front of the vertebral bodies. Each posterior intercostal artery is accompanied by posterior intercostal vein and intercostal nerve in the costal groove. Anteriorly they end by anastomosing with upper anterior intercostal arteries. The third right posterior intercostal artery can give origin to right bronchial artery.

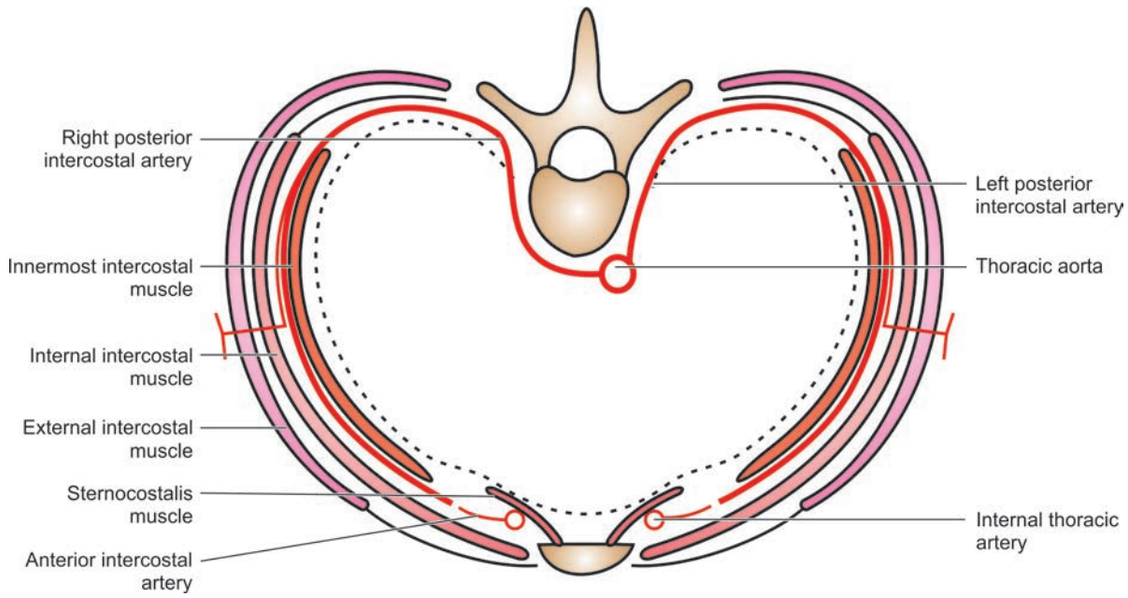

Fig. 39.15: Posterior intercostal artery (a schematic cross-section view)

The anastomoses between anterior and posterior intercostal arteries provide a connection between subclavian artery and thoracic aorta. These anastomoses become important in case of coarctation of aorta providing collateral circulation, which is discussed in detail in Chapter 46.

Superior Intercostal Artery

It is a branch arising from the costocervical trunk of the subclavian artery. It descends between the pleura and neck of the first and second ribs and anastomose with the third posterior intercostal artery. While crossing the neck of the first rib. It is closely related to ventral ramus of first thoracic nerve and stellate ganglion. It gives posterior intercostal artery to the first intercostal space and then continues as second posterior intercostal artery.

The venous drainage of the thoracic wall is discussed in Chapter 45.

Lymphatic Drainage of the Thoracic Wall

Parasternal nodes: These are placed along the internal thoracic vessels. They drain deeper tissue of the anterior thoracic wall and anterior abdominal wall (up to the level of umbilicus) and also mammary gland. The efferent lymphatic vessels arising from them join bronchomediastinal trunk (refer to lymphatic drainage of lungs).

Posterior intercostals nodes: These are located at the posterior ends of the intercostals spaces. They drain part of the mammary gland and posterolateral wall of the thoracic wall. Their efferent vessels drain into thoracic duct.

Clinical Notes

Clinical Examination of Thoracic Wall

Inspection and palpation: Usually inspection and palpation are discussed together because there is an intimate relationship between these two processes in the chest examination. Palpation not only confirms the results in inspection but also discovers diagnostic signs. Through careful palpation, the examiner should aim to determine the location and size of the cardiac apex impulse, characterize its contour, and identify any abnormal precordial pulsations.

Percussion: The chest is percussed to confirm the cardiac borders, size contour and position in the thorax.

Auscultation: The purpose of auscultation of the heart is to find the normal and abnormal sounds of the heart. It plays a very important role in the diagnosis of heart disease.

Solutions to the clinical case studies

Case 1: In old age the costal cartilages may undergo ossification. They then become radiopaque and may give rise to some confusion when examining a chest radiograph of an elderly patient.

Case 2: The thoracic wall of the child is very elastic, and fractures of ribs in children are rare. But in aged people the ribs become brittle and more prone to be fractured.

Case 3:

1. The ribs are usually counted from the level of sternal angle which corresponds to second costal cartilage. There are other bony landmarks which also help to determine the correct rib number like, xyphisternal joint corresponds to seventh costal cartilage.
2. Ribs move during respiratory movements (*refer* to bucket handle and pump handle movement in respiratory movements)
3. Pain is due to fracture of the ribs
4. Lungs

Case 4: A newborn does not breathe evenly like adults do, in and out. Instead, they breathe in clusters of many breaths followed by long pauses that can be terrifying for new parents.

Case 5: The suprapleural membrane was damaged by knife and was not repaired during surgery. Subsequently, herniation of the cervical pleura and apex of the lung took place, which resulted in the skin above the clavicle bulging upward during forced expiration.

MCQs

1. The second costal cartilage can be located by palpating which of this structure?
A. Costal margin
B. Sternal angle
C. Sternal notch
D. Sternoclavicular joint

2. The tubercle of the 7th rib articulates with which structure?
A. Body of vertebra T6
B. Transverse process of vertebra T7
C. Body of vertebra T7
D. Transverse process of vertebra T6

3. Which of this bony structure can be palpated below the inferior margin of the medial portion of the clavicle?
A. Acromion
B. Atlas
C. First rib
D. Second rib

4. A wrestler's chest is compressed during a match, causing a posterior displacement of the clavicle at the sternoclavicular joint. Which of the following structures would be most at risk?
A. Aorta
B. Oesophagus
C. Trachea
D. Superior vena cava

5. A medical student inserting an intercostal drain for the first time forgets her anatomy and passes it at the lower border of the rib. Which of this structure is most likely to be damaged?
A. Intercostal artery
B. Intercostal nerve
C. Intercostal vein
D. Internal intercostal muscle

6. A 21-year-old female college student is involved in a road accident. She sustains a blunt force injury to the chest, resulting in fracture of the left seventh rib. The patient is experiencing severe pain from this fracture. To relive this pain, a resident administers a local anesthetic. Which of the following sites would be the most appropriate site for this injection?
A. 7th intercostal space immediately below the 7th rib in the midclavicular line
B. 7th intercostal space immediately below the 7th rib just lateral to the angle of the rib
C. 7th intercostal space immediately below the 7th rib just medial to the angle of the rib
D. 6th intercostal space immediately above the 7th rib in the midclavicular line

7. Which of the following layers provides a natural cleavage plane for surgical separation of the costal pleura from the thoracic wall?
A. Deep fascia
B. Endothoracic fascia
C. Parietal pleura
D. Visceral pleura

8. A patient rush into the hospital complaining of dyspnea (shortness of breath). He complains that breathing in air is difficult. Which of the following is a muscle of inspiration?
A. Rectus abdominis
B. Internal intercostais
C. Innermost intercostals
D. Interchondral part of internal intercostals

9. A doctor informs his colleagues to insert a catheter in patient at the 7th intercostal space. Which of the following is the correct insertion point of catheter?
A. Just above 7th rib
B. Just below 7th rib
C. Just above the 8th rib
D. Just below the 8th rib

ANSWERS TO THE MCQs

1. B	2. B	3. D	4. C	5. B
6. B	7. B	8. D	9. C	

JUST BEFORE THE EXAM

Thoracic cage → Boundaries: anteriorly by the sternum, posteriorly by the 12 thoracic vertebrae with intervertebral discs between them and on either side by 12 pairs of ribs and their costal cartilages.

Ribs → There are 12 pairs of ribs, of which the 3–9 ribs are typical ribs. Each rib articulates posteriorly with the body and transverse process of the thoracic vertebrae through synovial joints.

Intercostal space → The spaces between the ribs are called intercostal space. The third to sixth intercostal spaces are considered as typical intercostal space.

Contents of the intercostal space → Mainly three muscles—external intercostals, internal intercostals and innermost intercostals, intercostal nerves and vessels.

External intercostals → These are directed downwards forwards and medially and they elevate the ribs during forced inspiration.

Internal intercostals → These are directed right angle to the direction of external intercostal (downwards and laterally). The interchondral part of the muscle elevates the ribs in forced inspiration while interosseous part of the muscle depresses the ribs during forced expiration.

Innermost intercostals → These are confined to the middle part of the intercostal space. The muscles are directed similar to that of the internal intercostals. They depress the ribs during forced expiration.

Neurovascular structure of the intercostal space includes → Posterior intercostal vein, posterior intercostal artery and intercostal nerves (their arrangements in the costal groove of the ribs from above downwards is VAN —Vein, Artery and Nerve).

Intercostal nerves → The ventral ramus of T1 to T11 spinal nerves are called intercostal nerves, of which third to sixth intercostal nerves are typical intercostal nerves. Each intercostal nerve supplies intercostal muscles, skin of the anterolateral chest walls, parietal pleura and also sensory fibres to the diaphragm.

Internal thoracic (internal mammary) artery → A branch from the first part of the subclavian artery. It terminates by dividing into superior epigastric and musculophrenic arteries. In each of the upper six intercostal spaces they give two anterior intercostal arteries which anastomose with posterior intercostal arteries.