Clinical app

Lung cancer
It is important to stage lung cancer because the treatment depends on its stage.

If a small malignant nodule is found within the lung, it can sometimes be excised and the prognosis is excellent. Unfortunately, many patients present with a tumor mass that has invaded structures in the mediastinum or the pleurae or has metastasized. The tumor may then be inoperable and is treated with radiotherapy and chemotherapy.

Spread of the tumor is by lymphatics to lymph nodes within the hila, mediastinum, and root of the neck.

Imaging methods to assess spread include plain radiography, computed tomography (Fig. 3.51), and magnetic resonance imaging (MRI). Increasingly, radionuclide studies using fluorodeoxyglucose positron emission tomography (FDG PET) are being used.

In FDG PET a gamma radiation emitter is attached to a glucose molecule. In areas of excessive metabolic activity (i.e., the tumor), excessive uptake occurs and is recorded by a gamma camera.

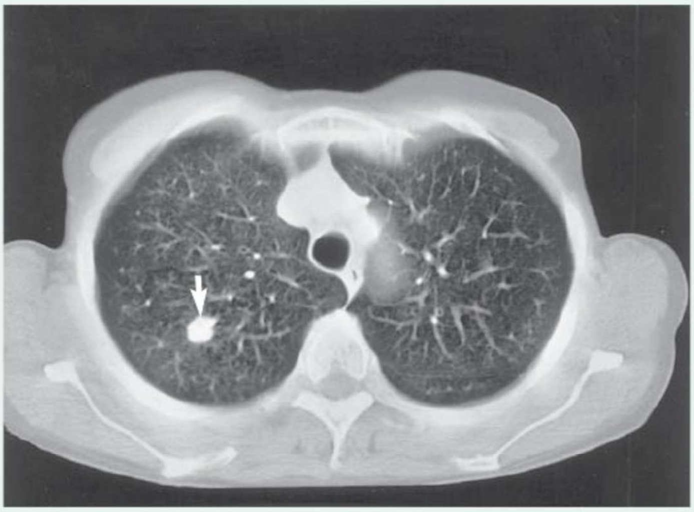


Fig. 3.51 Axial CT image of lungs showing tumor (arrow) in right lung.

Clinical app

Pneumonia
Chest infection is a common disease. In most patients the infection affects the large airways and bronchi. If the infection continues, exudates and transudates are produced, filling the alveoli and the secondary pulmonary lobules. The diffuse, patchy nature of this type of infection is termed bronchial pneumonia.

MEDIASTINUM

The **mediastinum** is a broad central partition that separates the two laterally placed pleural cavities (Fig. 3.52). It extends:

- from the sternum to the bodies of the vertebrae; and
- from the superior thoracic aperture to the diaphragm.

The mediastinum contains the thymus gland, the pericardial sac, the heart, the trachea, and the major arteries and veins. It also serves as a passageway for structures such as the esophagus, thoracic duct, and various components of the nervous system as they traverse the thorax on their way to the abdomen.

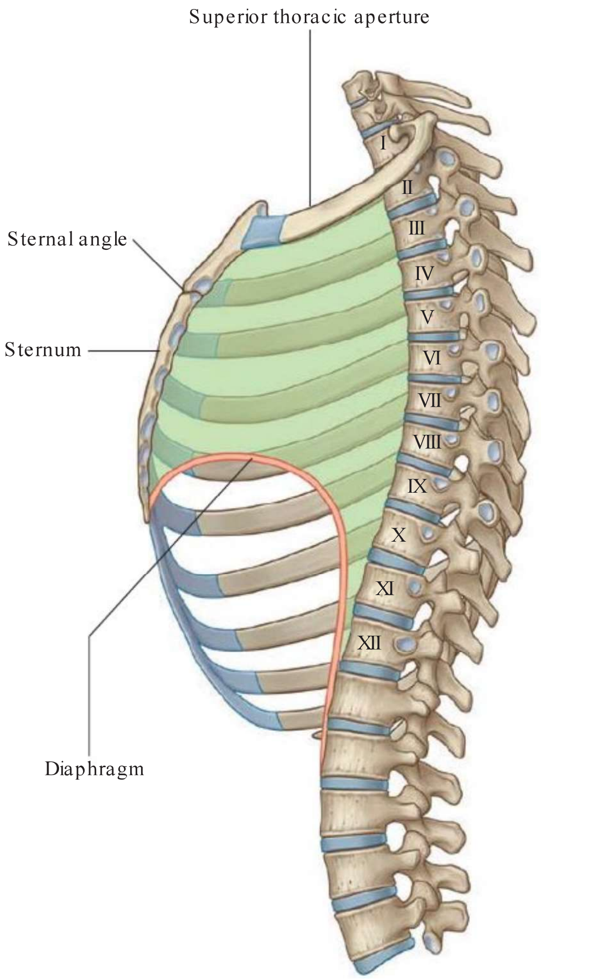


Fig. 3.52 Lateral view of the mediastinum.

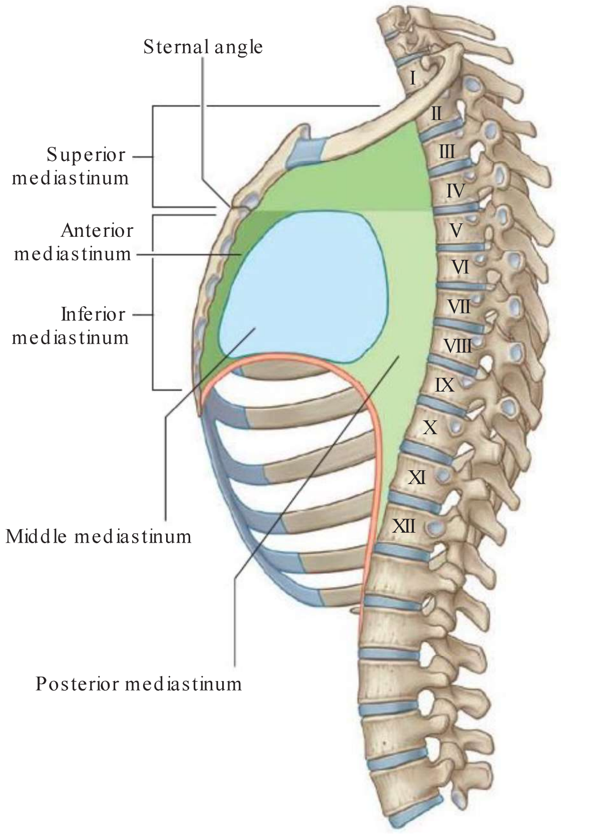


Fig. 3.53 Subdivisions of the mediastinum.

For organizational purposes, the mediastinum is subdivided into several smaller regions. A transverse plane extending from the sternal angle (the junction between the manubrium and the body of the sternum) to the intervertebral disc between vertebrae TIV and TV separates the mediastinum into the (Fig. 3.53):

- **superior mediastinum**; and
- **inferior mediastinum**, which is further partitioned into the **anterior**, **middle**, and **posterior mediastinum** by the pericardial sac.

The area anterior to the pericardial sac and posterior to the body of the sternum is the anterior mediastinum. The region posterior to the pericardial sac and the diaphragm and anterior to the bodies of the vertebrae is the posterior mediastinum. The area in the middle, which includes the pericardial sac and its contents, is the middle mediastinum (Fig. 3.53).

Middle mediastinum

The **middle mediastinum** is centrally located in the thoracic cavity. It contains the pericardium, heart, origins of the great vessels, various nerves, and smaller vessels.

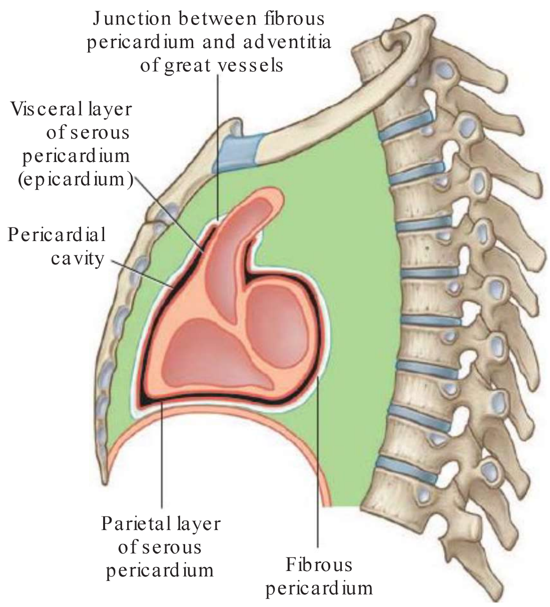


Fig. 3.54 Sagittal section of the pericardium.

Pericardium

The **pericardium** is a fibroserous sac surrounding the heart and the roots of the great vessels. It consists of two components, the fibrous pericardium and the serous pericardium (Fig. 3.54).

The **fibrous pericardium** is a tough connective tissue outer layer that defines the boundaries of the middle mediastinum. The **serous pericardium** is thin and consists of two parts:

- The **parietal layer** lines the inner surface of the fibrous.
- The **visceral layer** (**epicardium**) of serous pericardium adheres to the heart and forms its outer covering.

The parietal and visceral layers of serous pericardium are continuous at the roots of the great vessels. The narrow space created between the two layers of serous pericardium, containing a small amount of fluid, is the **pericardial cavity**. This potential space allows for the relatively uninhibited movement of the heart.

Fibrous pericardium

The **fibrous pericardium** is a cone-shaped bag with its base attached to the **central tendon of the diaphragm** and a small muscular area on the left side of the diaphragm and its apex continuous with the **adventitia** of the great vessels (Fig. 3.54). Anteriorly, it is attached to the posterior surface of the sternum by **sternopericardial ligaments**. These attachments help to retain the heart in its position in the thoracic cavity. The sac also limits cardiac distention.

The phrenic nerves, which innervate the diaphragm and originate from spinal cord levels C3 to C5, pass through the fibrous pericardium and innervate this structure as they travel from their point of origin to their final destination (Fig. 3.55). Their location, within the fibrous pericardium, is directly related to the embryological origin of the diaphragm and the formation of the pericardial cavity. Similarly, the **pericardiacophrenic vessels** are also located within and supply the fibrous pericardium as they pass through the thoracic cavity.

Serous pericardium

The parietal layer of serous pericardium is continuous with the visceral layers of serous pericardium around the roots of the great vessels. These reflections of serous pericardium (Fig. 3.56) occur in two locations:

- one superiorly, surrounding the arteries, the aorta, and pulmonary trunk;
- the second more posteriorly, surrounding the veins, the superior and inferior vena cava, and the pulmonary veins.

The zone of reflection surrounding the veins is J-shaped, and the cul-de-sac formed within the J, posterior to the left atrium, is the **oblique pericardial sinus**.

A passage between the two sites of reflected serous pericardium is the **transverse pericardial sinus**. This sinus lies posteriorly to the ascending aorta and the pulmonary trunk, anteriorly to the superior vena cava, and superiorly to the left atrium.

When the pericardium is opened anteriorly during surgery, a finger placed in the transverse sinus separates arteries from veins. A hand placed under the apex of the heart and moved superiorly slips into the oblique sinus.

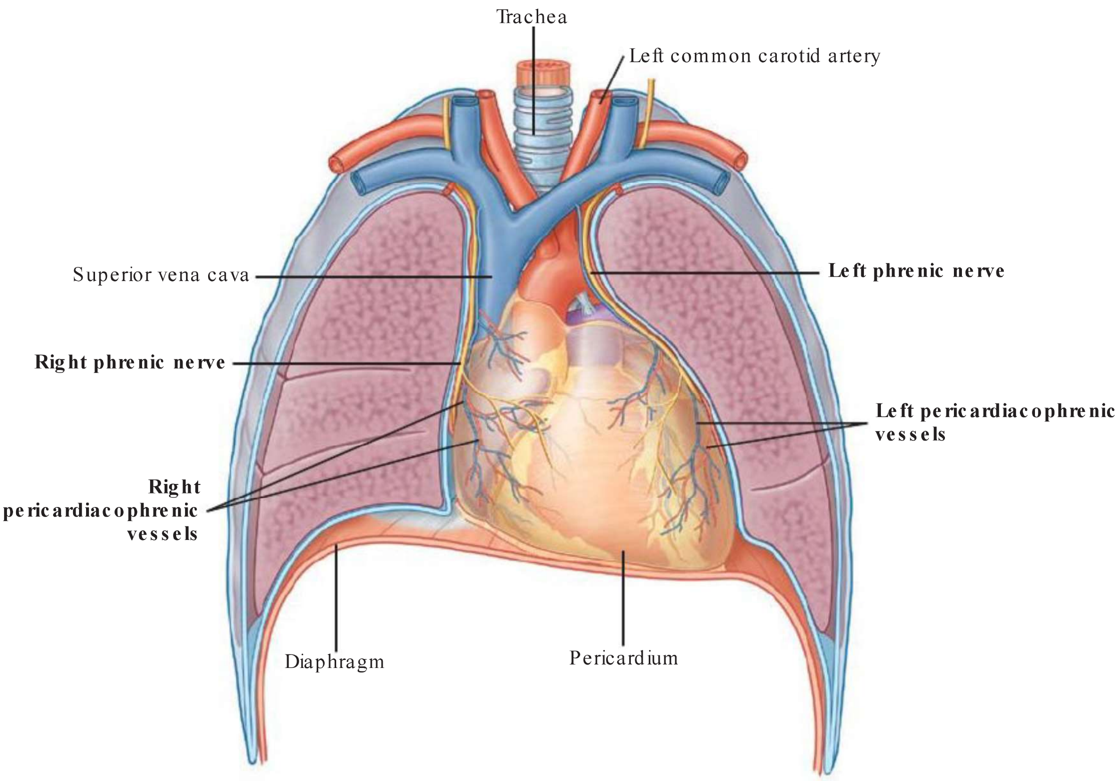


Fig. 3.55 Phrenic nerves and pericardiacophrenic vessels.

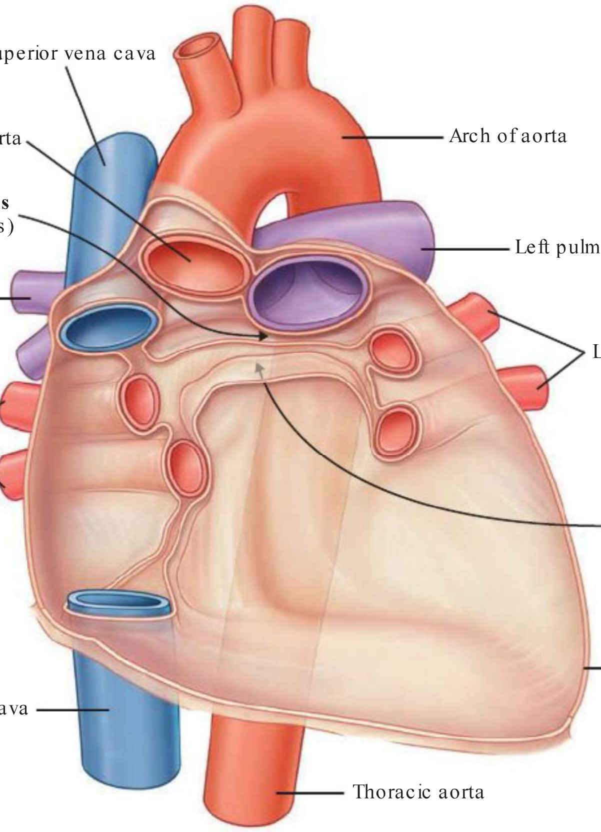


Fig. 3.56 Posterior portion of pericardial sac showing reflections of serous pericardium.

Vessels and nerves

Arteries supplying the pericardium are branches from the internal thoracic, pericardiacophrenic, musculophrenic, and inferior phrenic arteries, and the thoracic aorta.

Veins from the pericardium enter the azygos system of veins and the internal thoracic and superior phrenic veins.

Nerves supplying the pericardium arise from the vagus nerve [X], the sympathetic trunks, and the phrenic nerves.

Clinical app

Pericardial innervation

It is important to note that the source of somatic sensation (pain) from the parietal pericardium is carried by somatic afferent fibers in the phrenic nerves. For this reason, "pain" related to a pericardial problem may be referred to the supraclavicular region of the shoulder or lateral neck area, dermatomes for spinal cord segments C3, C4, and C5.

Clinical app

Pericarditis

Pericarditis is an inflammatory condition of the pericardium. Common causes are viral and bacterial infections, systemic illnesses (e.g., chronic renal failure), and postmyocardial infarction.

Clinical app

Pericardial effusion

Normally, only a tiny amount of fluid is present between the visceral and parietal layers of the serous pericardium. In certain situations, this space can be filled with excess fluid (pericardial effusion).

Because the fibrous pericardium is a "relatively fixed" structure that cannot expand easily, a rapid accumulation of excess fluid within the pericardial sac compresses the heart (cardiac tamponade), resulting in biventricular failure. Removing the fluid with a needle inserted into the pericardial sac can relieve the symptoms.

Clinical app

Constrictive pericarditis

Abnormal thickening of the pericardial sac (constrictive pericarditis) can compress the heart, impairing heart function resulting in heart failure.

Heart

Cardiac orientation

The shape and orientation of the heart is that of a pyramid that has fallen over and is resting on one of its sides. Placed in the thoracic cavity, the apex of this pyramid projects forward, downward, and to the left, whereas the base is opposite the apex and faces in a posterior direction (Fig. 3.57). The sides of the pyramid consist of:

- a diaphragmatic (inferior) surface on which the pyramid rests,
- an anterior (sternocostal) surface oriented anteriorly,
- a right pulmonary surface, and
- a left pulmonary surface.

Base (posterior surface) and apex

The **base of the heart** is quadrilateral and directed posteriorly (Fig. 3.58). It consists of:

- the left atrium,
- a small portion of the right atrium, and
- the proximal parts of the great veins (superior and inferior venae cavae and the pulmonary veins).

Because the great veins enter the base of the heart, with the pulmonary veins entering the right and left sides of the left atrium and the superior and inferior venae cavae at the upper and lower ends of the right atrium, the base of the heart is fixed posteriorly to the pericardial wall, opposite the bodies of vertebrae TV to TVIII (TVI to TIX when standing). The esophagus lies immediately posterior to the base.

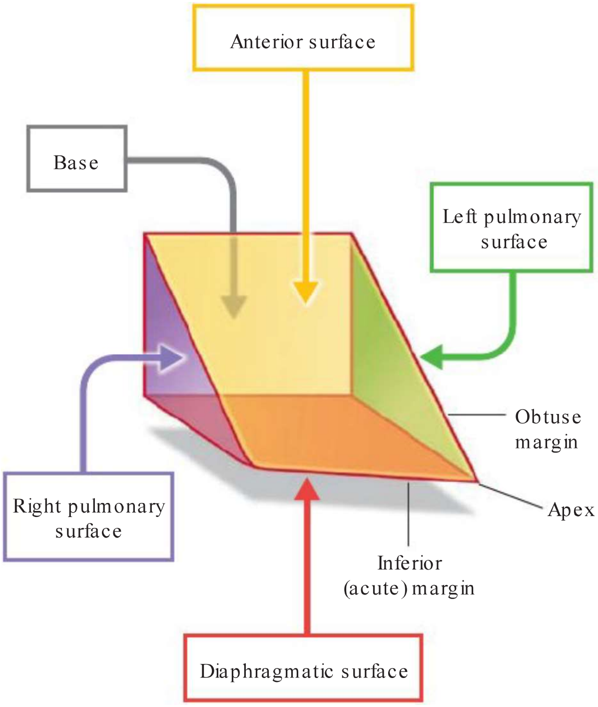


Fig. 3.57 Schematic illustration of the heart showing orientation, surfaces, and margins.

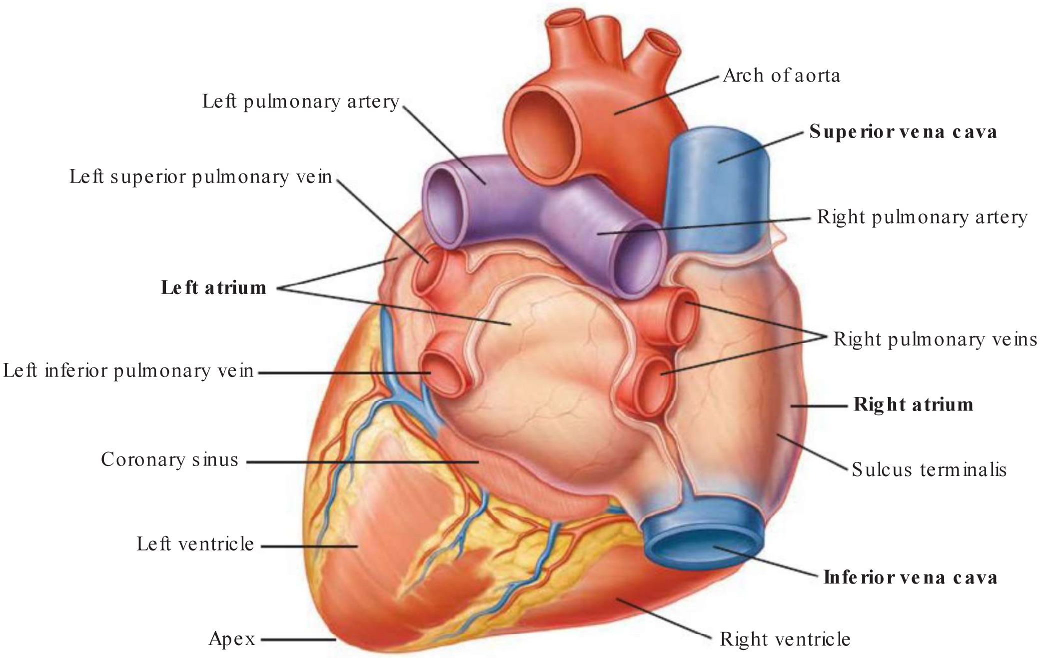


Fig. 3.58 Base of the heart.

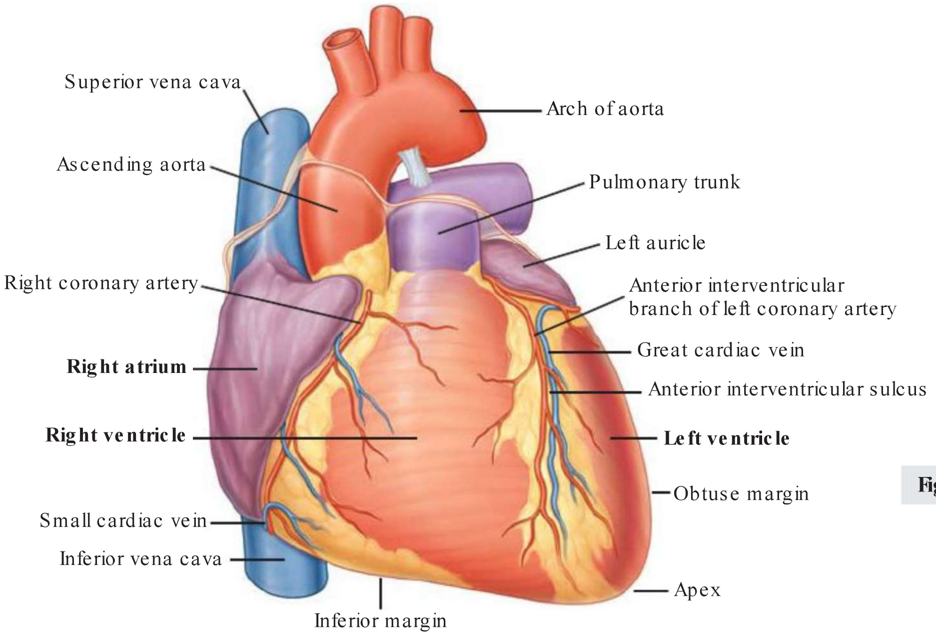


Fig. 3.59 Anterior surface of the heart.

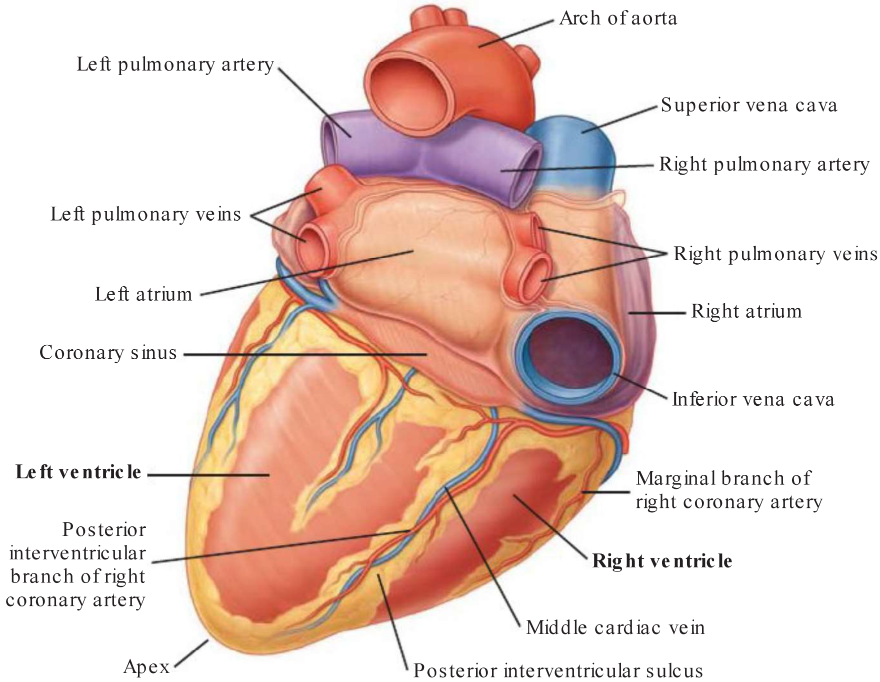


Fig. 3.60 Diaphragmatic surface of the heart.

From the base the heart projects forward, downward, and to the left, ending in the apex. The **apex of the heart** is formed by the inferolateral part of the left ventricle (Fig. 3.59) and is posterior to the left fifth intercostal space, 8 to 9 cm from the midsternal line.

Surfaces of the heart

The **anterior surface** faces anteriorly and consists mostly of the right ventricle, with some of the right atrium on the right and some of the left ventricle on the left (Fig. 3.59).

The heart in the anatomical position rests on the **diaphragmatic surface**, which consists of the left ventricle and a small portion of the right ventricle separated by the posterior interventricular groove (Fig. 3.60). This surface faces inferiorly, rests on the diaphragm, is separated from the base of the heart by the coronary sinus, and extends from the base to the apex of the heart.

The **left pulmonary surface** faces the left lung, is broad and convex, and consists of the left ventricle and a portion of the left atrium.

The **right pulmonary surface** faces the right lung, is broad and convex, and consists of the right atrium.

Margins and borders

Some general descriptions of cardiac orientation refer to right, left, inferior (acute), and obtuse margins:

- The **right** and **left margins** are the same as the right and left pulmonary surfaces of the heart.
- The **inferior margin** is defined as the sharp edge between the anterior and diaphragmatic surfaces of the heart (Figs. 3.57, 3.59)—it is formed mostly by the right ventricle and a small portion of the left ventricle near the apex.
- The **obtuse margin** separates the anterior and left pulmonary surfaces (Fig. 3.57)—it is round and extends from the left auricle to the cardiac apex (Fig. 3.59), and is formed mostly by the left ventricle and superiorly by a small portion of the left auricle.

Imaging app

Visualizing the heart

For radiological evaluations, a thorough understanding of the structures defining the cardiac borders is critical. The right border in a standard posterior–anterior view consists of the superior vena cava, the right atrium, and the inferior vena cava (Fig. 3.61A). The left border in a similar view consists of the arch of the aorta, the pulmonary trunk, and the left ventricle. The inferior border in this radiological study consists of the right ventricle and the left ventricle at the apex. In lateral views, the right ventricle is seen anteriorly, and the left atrium is visualized posteriorly (Fig. 3.61B).

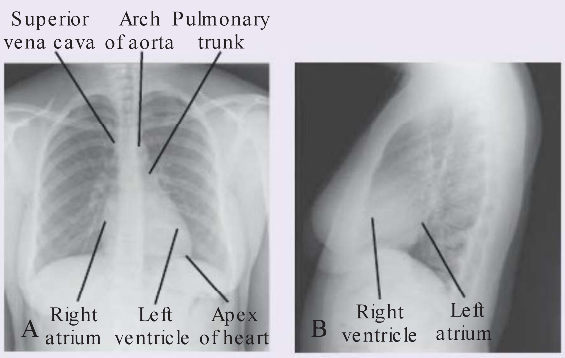


Fig. 3.61 Chest radiographs. **A.** Standard posterior-anterior view of the chest. **B.** Standard lateral view of the heart.

External sulci

Internal partitions divide the heart into four chambers (i.e., two atria and two ventricles) and produce surface or external grooves referred to as sulci.

- The **coronary sulcus** circles the heart, separating the atria from the ventricles (Fig. 3.62). It contains the right coronary artery, the small cardiac vein, the coronary sinus, and the circumflex branch of the left coronary artery.
- The **anterior** and **posterior interventricular sulci** separate the two ventricles—the anterior interventricular sulcus on the anterior surface of the heart containing the anterior interventricular artery and the great cardiac vein, and the posterior interventricular sulcus on the diaphragmatic surface of the heart containing the posterior interventricular artery and the middle cardiac vein.

These sulci are continuous inferiorly, just to the right of the apex of the heart.

Cardiac chambers

Functionally, the heart consists of two pumps separated by a partition (Fig. 3.63).

- The right pump receives deoxygenated blood from the body and sends it to the lungs.
- The left pump receives oxygenated blood from the lungs and sends it to the body.

Each pump consists of an atrium and a ventricle separated by a valve.

The thin-walled atria receive blood coming into the heart, whereas the relatively thick-walled ventricles pump blood out of the heart. More force is required to pump blood through the body than through the lungs, so the muscular wall of the left ventricle is thicker than the right.

Interatrial, interventricular, and atrioventricular septa separate the four chambers of the heart (Fig. 3.64). The internal anatomy of each chamber is critical to its function.

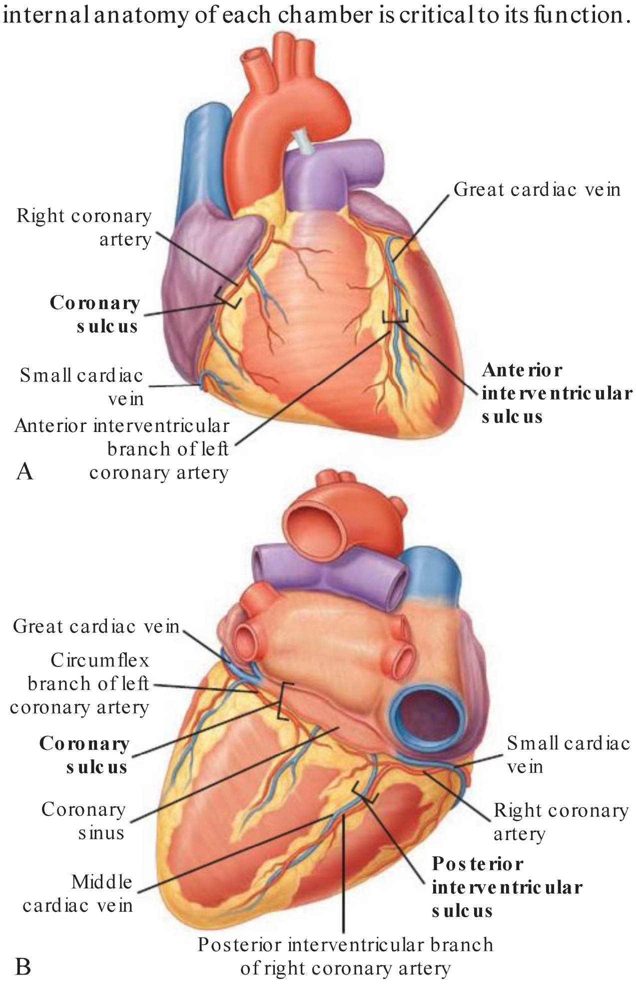


Fig. 3.62 Sulci of the heart. **A.** Anterior surface of the heart. **B.** Diaphragmatic surface and base of the heart.

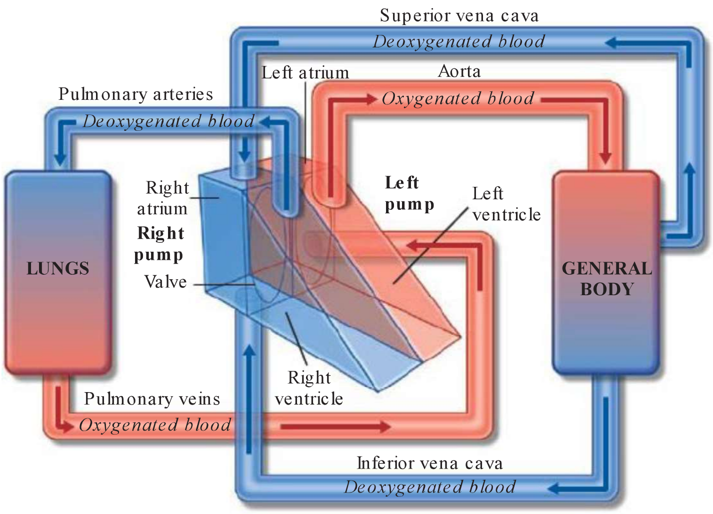


Fig. 3.63 The heart has two pumps.

Imaging app

Visualizing the chambers of the heart

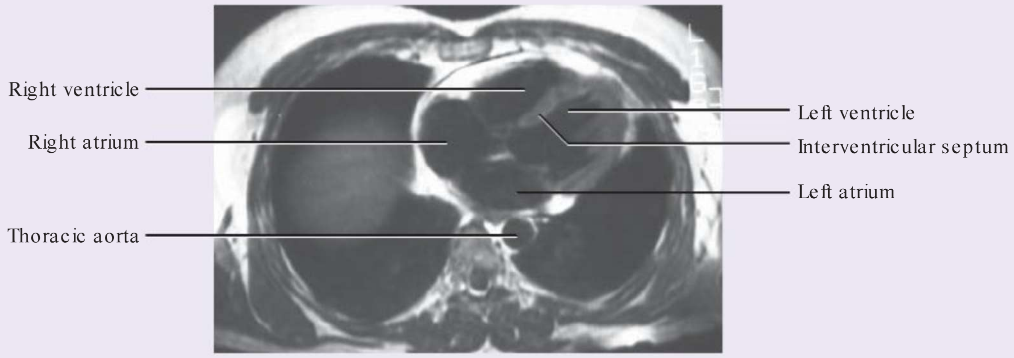


Fig. 3.64 Magnetic resonance image of midthorax showing all four chambers and septa.

Surface anatomy

Visualizing the margins of the heart

Surface landmarks can be palpated to visualize the outline of the heart (Fig. 3.65).

- The upper limit of the heart reaches as high as the third costal cartilage on the right side of the sternum and the second intercostal space on the left side of the sternum.
- The right margin of the heart extends from the right third costal cartilage to near the right sixth costal cartilage.
- The left margin of the heart descends laterally from the second intercostal space to the apex located near the midclavicular line in the fifth intercostal space.
- The lower margin of the heart extends from the sternal end of the right sixth costal cartilage to the apex in the fifth intercostal space near the midclavicular line.

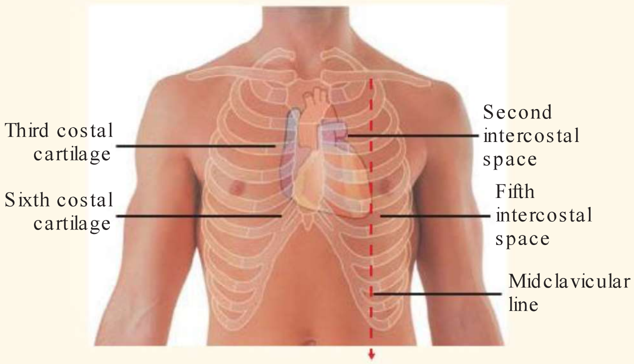


Fig. 3.65 Anterior view of the chest wall of a man showing skeletal structures and the surface projection of the heart.

Right atrium

In the anatomical position, the **right atrium** forms the right border of the heart and contributes to the right portion of the heart's anterior surface (Fig. 3.66).

Blood returning to the right atrium enters through one of three vessels. These are:

- the superior and inferior venae cavae, which together deliver blood to the heart from the body; and
- the coronary sinus, which returns blood from the walls of the heart itself.

The superior vena cava enters the upper posterior portion of the right atrium, and the inferior vena cava and coronary sinus enter the lower posterior portion of the right atrium (Fig. 3.66).

From the right atrium, blood passes into the right ventricle through the **right atrioventricular orifice**. This opening faces forward and medially and is closed during ventricular contraction by the tricuspid valve.

The interior of the right atrium is divided into two continuous spaces. Externally, this separation is indicated by a shallow, vertical groove (the **sulcus terminalis cordis**), which extends from the right side of the opening of the superior vena cava to the right side of the opening of the inferior vena cava. Internally, this division is indicated by the **crista terminalis** (Fig. 3.66), which is a smooth, muscular ridge that begins on the roof of the atrium just in front of the opening of the superior vena cava and extends down the lateral wall to the anterior lip of the inferior vena cava.

The space posterior to the crista is the **sinus of venae cavae** and is derived embryologically from the right horn of the sinus venosus. This component of the right atrium has smooth, thin walls, and both venae cavae empty into this space.

The space anterior to the crista, including the **right auricle**, is sometimes referred to as the **atrium proper**. This terminology is based on its origin from the embryonic primitive atrium. Its walls are covered by ridges called the **musculi pectinati** (**pectinate muscles**), which fan out from the crista like the "teeth of a comb." These ridges are also found in the right auricle, which is an ear-like, conical, muscular pouch that externally overlaps the ascending aorta.

An additional structure in the right atrium is the **opening of coronary sinus**, which receives blood from most of the cardiac veins and opens medially to the **opening of inferior vena cava**. Associated with these openings are small folds of tissue derived from the valve of the embryonic sinus venosus (the **valve of coronary sinus** and the **valve of inferior vena cava**, respectively). During development, the valve of inferior vena cava helps direct incoming oxygenated blood through the foramen ovale and into the left atrium.

Separating the right atrium from the left atrium is the **interatrial septum**, which faces forward and to the right because the left atrium lies posteriorly and to the

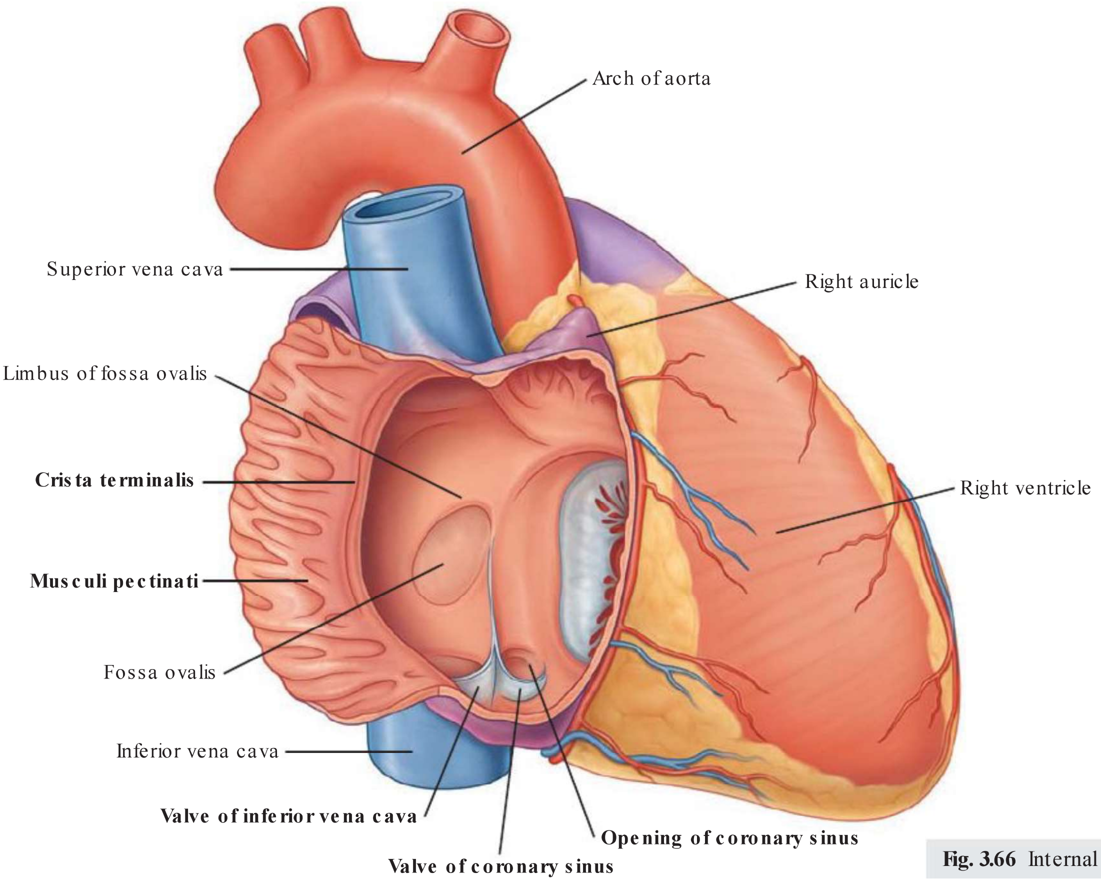


Fig. 3.66 Internal view of right atrium.

left of the right atrium. A depression is clearly visible in the septum just above the orifice of the inferior vena cava. This is the **fossa ovalis** (**oval fossa**), with its prominent margin, the **limbus fossa ovalis** (**border of oval fossa**) (Fig. 3.66).

The fossa ovalis marks the location of the embryonic **foramen ovale**, which is an important part of fetal circulation. The foramen ovale allows oxygenated blood entering the right atrium through the inferior vena cava to pass directly to the left atrium and so bypass the lungs, which are nonfunctional before birth.

Finally, numerous small openings—the **openings of the smallest cardiac veins** (the **foramina of the venae cordis minimae**)—are scattered along the walls of the right atrium. These are small veins that drain the myocardium directly into the right atrium.

Right ventricle

In the anatomical position, the right ventricle forms most of the anterior surface of the heart and a portion of the diaphragmatic surface (Fig. 3.67). It is to the right of the right atrium and located in front of and to the left of the right atrioventricular orifice. Blood entering the right ventricle from the right atrium therefore moves in a horizontal and forward direction.

The outflow tract of the right ventricle, which leads to the pulmonary trunk, is the **conus arteriosus** (**infundibulum**) (Fig. 3.67). This area has smooth walls and derives from the embryonic bulbus cordis.

The walls of the inflow portion of the right ventricle have numerous muscular, irregular structures called **trabeculae carneae** (Fig. 3.67). Most of these are either attached to the ventricular walls throughout their length, forming ridges, or attached at both ends, forming bridges.

A few trabeculae carneae (**papillary muscles**) have only one end attached to the ventricular surface, whereas the other end serves as the point of attachment for tendon-like fibrous cords (the **chordae tendineae**), which connect to the free edges of the cusps of the tricuspid valve.

There are three papillary muscles in the right ventricle. Named relative to their point of origin on the ventricular surface, they are the anterior, posterior, and septal papillary muscles (Fig. 3.67).

- The **anterior papillary muscle** is the largest and most constant papillary muscle, and arises from the anterior wall of the ventricle.
- The **posterior papillary muscle** may consist of one, two, or three structures, with some chordae tendineae arising directly from the ventricular wall.

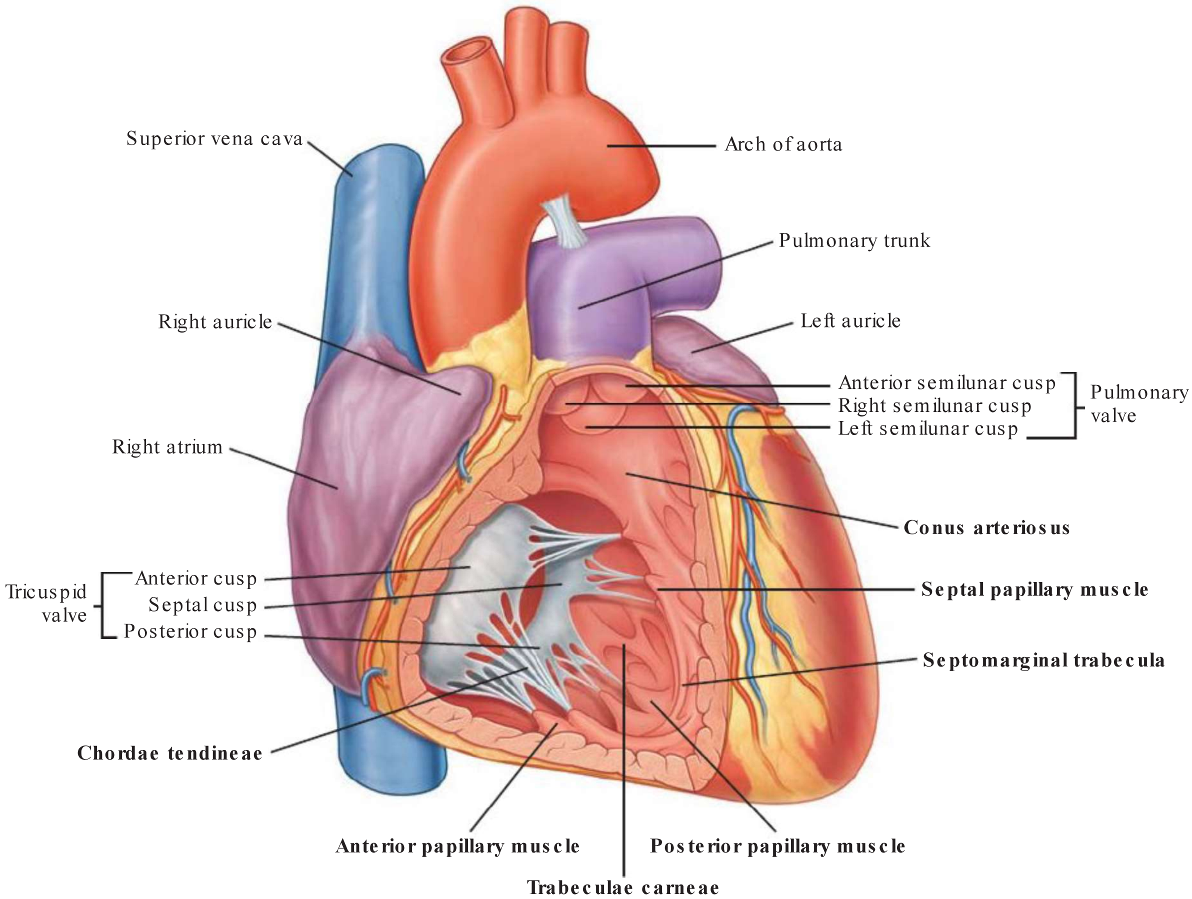


Fig. 3.67 Internal view of the right ventricle.

- The **septal papillary muscle** is the most inconsistent papillary muscle, being either small or absent, with chordae tendineae emerging directly from the septal wall.

A single specialized trabeculum, the **septomarginal trabecula** (**moderator band**), forms a bridge between the lower portion of the **interventricular septum** and the base of the anterior papillary muscle. The septomarginal trabecula carries a portion of the cardiac conduction system, the right bundle of the atrioventricular bundle, to the anterior wall of the right ventricle.

Tricuspid valve

The right atrioventricular orifice is closed during ventricular contraction by the **tricuspid valve** (**right atrioventricular valve**), so named because it usually consists of three cusps or leaflets (Fig. 3.67). The base of each cusp is secured to a fibrous ring surrounding the atrioventricular orifice. This fibrous ring helps maintain the shape of the opening. The cusps are continuous with each other near their bases at sites termed **commissures**.

The naming of the three cusps, the **anterior**, **septal**, and **posterior cusps**, is based on their relative position in the right ventricle (Fig. 3.67). The free margins of the cusps are attached to the chordae tendineae, which arise from the tips of the papillary muscles.

During filling of the right ventricle, the tricuspid valve is open, and the three cusps project into the right ventricle.

Without the presence of a compensating mechanism, when the ventricular musculature contracts, the valve cusps would be forced upward with the flow of blood and blood would move back into the right atrium. However, contraction of the papillary muscles attached to the cusps by chordae tendineae prevent the cusps from being everted into the right atrium.

Simply put, the papillary muscles and associated chordae tendineae keep the valves closed during the dramatic changes in ventricular size that occur during contraction.

In addition, chordae tendineae from two papillary muscles attach to each cusp. This helps prevent separation of the cusps during ventricular contraction. Proper closing of the tricuspid valve causes blood to exit the right ventricle and move into the pulmonary trunk.

Necrosis of a papillary muscle following a myocardial infarction (heart attack) may result in prolapse of the related valve.

Pulmonary valve

At the apex of the infundibulum, the outflow tract of the right ventricle, the opening into the pulmonary trunk is closed by the **pulmonary valve** (Fig. 3.68), which consists of three **semilunar cusps** with free edges projecting upward into the lumen of the pulmonary trunk. The free superior edge of each cusp has a middle, thickened portion, the **nodule of the semilunar cusp**; and a thin lateral portion, the **lunula of the semilunar cusp** (Fig. 3.68).

The cusps are named the **left**, **right**, and **anterior semilunar cusps** (see Fig. 3.75). Each cusp forms a pocket-like sinus (Fig. 3.68)—a dilation in the wall of the initial portion of the pulmonary trunk. After ventricular contraction, the recoil of blood fills these **pulmonary sinuses** and forces the cusps closed. This prevents blood in the pulmonary trunk from refilling the right ventricle.

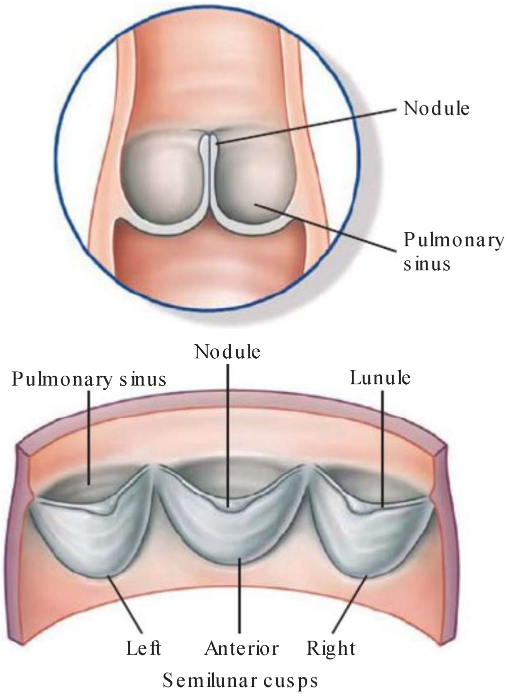


Fig. 3.68 Posterior view of the pulmonary valve.

Imaging app

Visualizing the right atrium and pulmonary veins

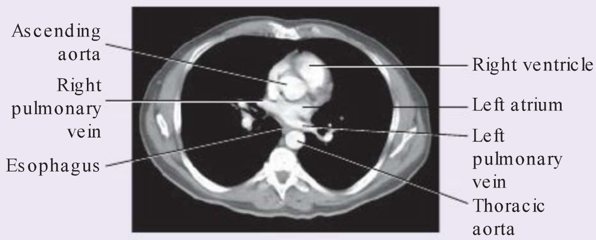


Fig. 3.69 Axial computed tomography image showing the pulmonary veins entering the left atrium.

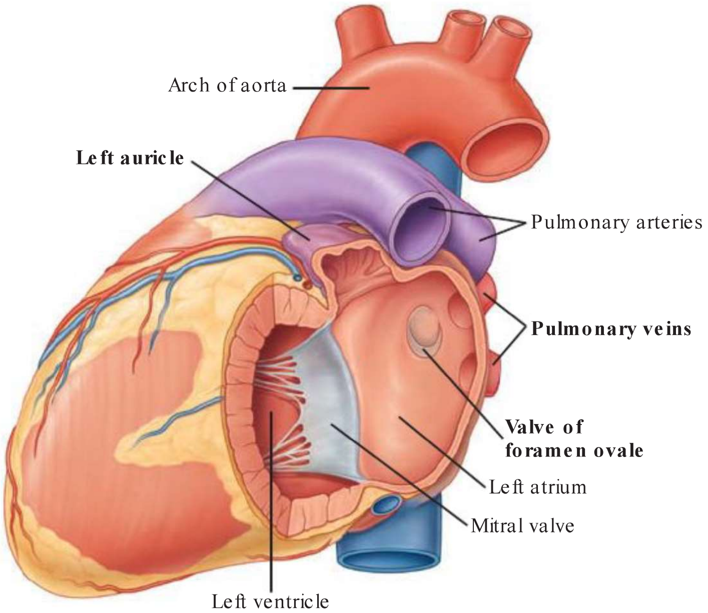


Fig. 3.70 Internal view of left atrium

Left atrium

The **left atrium** forms most of the base or posterior surface of the heart.

As with the right atrium, the left atrium is derived embryologically from two structures.

- The posterior half, or inflow portion, receives the four pulmonary veins (Fig. 3.70). It has smooth walls and derives from the proximal parts of the pulmonary veins that are incorporated into the left atrium during development.
- The anterior half is continuous with the left auricle. It contains musculi pectinati and derives from the embryonic primitive atrium. Unlike the crista terminalis in the right atrium, no distinct structure separates the two components of the left atrium.

The interatrial septum is part of the anterior wall of the left atrium. The thin area or depression in the septum is the valve of the foramen ovale and is opposite the floor of the fossa ovalis in the right atrium.

During development, the **valve of foramen ovale** prevents blood from passing from the left atrium to the right atrium. This valve may not be completely fused in some adults, leaving a "probe patent" passage between the right atrium and the left atrium.

Left ventricle

The left ventricle lies anterior to the left atrium. It contributes to the anterior, diaphragmatic, and left pulmonary surfaces of the heart, and forms the apex.

Blood enters the ventricle through the **left atrioventricular orifice** and flows in a forward direction to the apex (Fig. 3.71). The chamber itself is conical, is longer than the right ventricle, and has the thickest layer of **myocardium**. The outflow tract (the **aortic vestibule**) is posterior to the infundibulum of the right ventricle, has smooth walls, and is derived from the embryonic bulbus cordis.

The **trabeculae carneae** in the left ventricle are fine and delicate in contrast to those in the right ventricle. The general appearance of the trabeculae with muscular ridges and bridges is similar to that of the right ventricle (Fig. 3.71).

Papillary muscles, together with chordae tendineae, are also observed and their structure is as described above for the right ventricle. Two papillary muscles, the **anterior** and **posterior papillary muscles**, are usually found in the left ventricle and are larger than those of the right ventricle (Fig. 3.71).

In the anatomical position, the left ventricle is somewhat posterior to the right ventricle. The interventricular septum therefore forms the anterior wall and some of the wall on the right side of the left ventricle. The septum is described as having two parts:

- a **muscular part**, and
- a **membranous part**.

The muscular part is thick and forms the major part of the septum, whereas the membranous part is the thin, upper part of the septum. A third part of the septum may be considered an atrioventricular part because of its

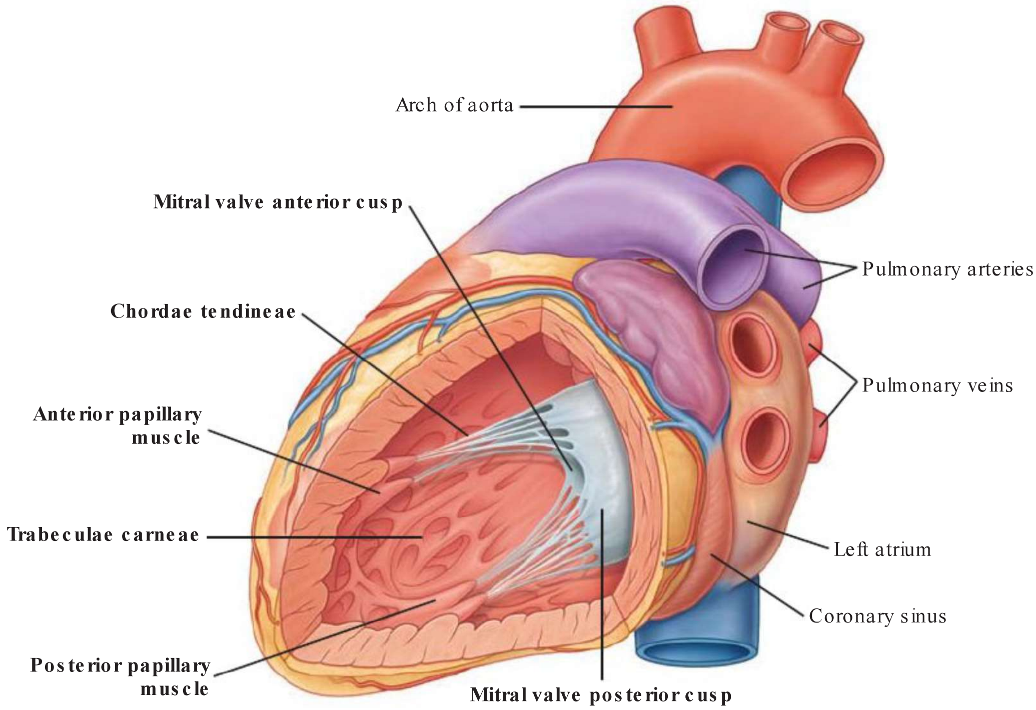


Fig. 3.71 Internal view of the left ventricle.

position above the septal cusp of the tricuspid valve. This superior location places this part of the septum between the left ventricle and right atrium.

Mitral valve

The left atrioventricular orifice opens into the posterior right side of the superior part of the left ventricle. It is closed during ventricular contraction by the **mitral valve** (**left atrioventricular valve**), which is also referred to as the bicuspid valve because it has two cusps, the **anterior** and **posterior cusps** (Fig. 3.71). At their base, the cusps are secured to a fibrous ring surrounding the opening, and are continuous with each other at the commissures. The coordinated action of the papillary muscles and chordae tendineae is as described for the right ventricle.

Aortic valve

The aortic vestibule, or outflow tract of the left ventricle, is continuous superiorly with the ascending aorta. The opening from the left ventricle into the aorta is closed by the **aortic valve**. This valve is similar in structure to the pulmonary valve. It consists of three **semilunar cusps** with the free edge of each projecting upward into the lumen of the ascending aorta (Fig. 3.72).

Between the semilunar cusps and the wall of the ascending aorta are pocket-like sinuses—the **right**, **left**, and **posterior aortic sinuses**. The right and left coronary arteries originate from the right and left aortic sinuses. Because of this, the posterior aortic sinus and cusp are sometimes referred to as the **noncoronary sinus and cusp**.

The functioning of the aortic valve is similar to that of the pulmonary valve with one important additional process: as blood recoils after ventricular contraction and fills the aortic sinuses, it is automatically forced into the coronary arteries because these vessels originate from the right and left aortic sinuses.

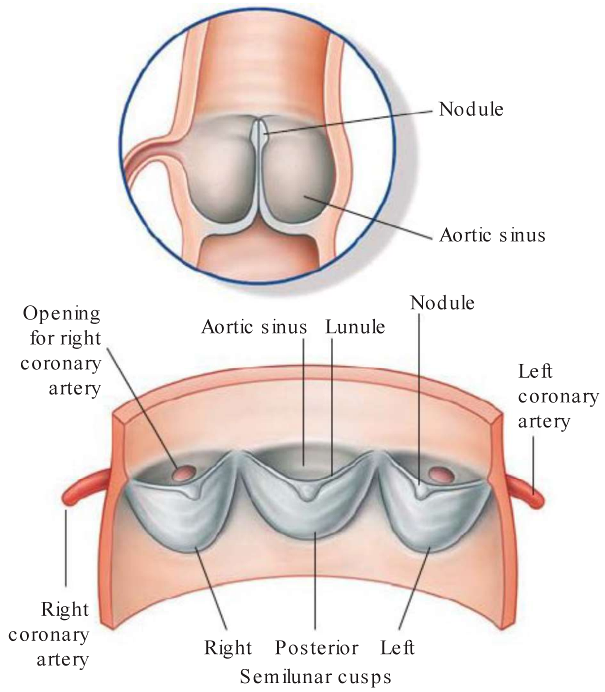


Fig. 3.72 Anterior view of the aortic valve.

Surface anatomy

Where to listen for heart sounds

To listen for valve sounds, position the stethoscope downstream from the flow of blood through the valves (Fig. 3.73).

- The tricuspid valve is heard just to the left of the lower part of the sternum near the fifth intercostal space.
- The mitral valve is heard over the apex of the heart in the left fifth intercostal space at the midclavicular line.
- The pulmonary valve is heard over the medial end of the left second intercostal space.
- The aortic valve is heard over the medial end of the right second intercostal space.

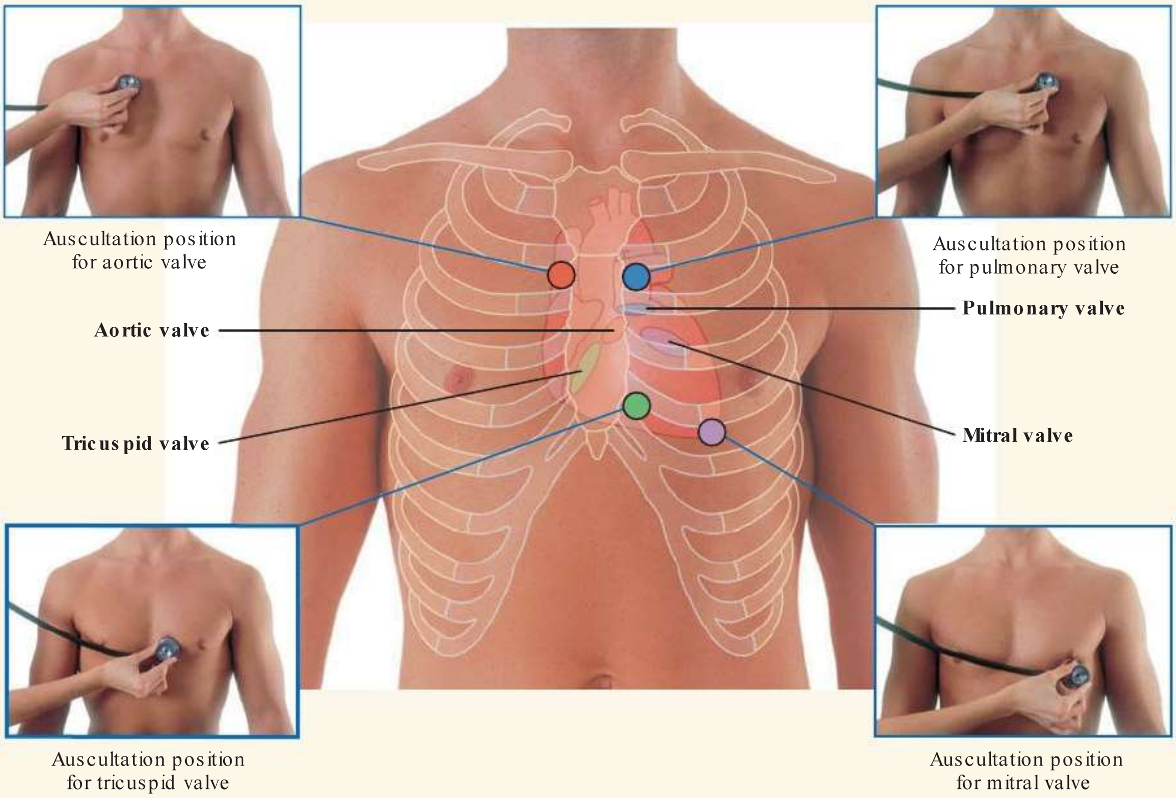


Fig. 3.73 Anterior view of the chest wall of a man showing skeletal structures, heart, location of the heart valves, and auscultation points.

Clinical app

Valve disease

Valve problems consist of two basic types:

- incompetence (insufficiency), which results from poorly functioning valves, and
- stenosis, a narrowing of the orifice, caused by the valve's inability to open fully.

Mitral valve disease is usually a mixed pattern of stenosis and incompetence, one of which usually predominates. Both stenosis and incompetence lead to a poorly functioning valve and subsequent heart changes, which include:

- left ventricular hypertrophy (this is appreciably less marked in patients with mitral stenosis),
- increased pulmonary venous pressure,
- pulmonary edema, and
- enlargement (dilation) and hypertrophy of the left atrium.

Aortic valve disease—both aortic stenosis and aortic regurgitation (backflow) can produce heart failure.

Valve disease in the right side of the heart (affecting the tricuspid or pulmonary valve) is most likely caused by infection. The resulting valve dysfunction produces abnormal pressure changes in the right atrium and right ventricle, and these can induce cardiac failure.

Clinical app

Common congenital heart defects

The most common abnormalities that occur during development are those produced by a defect in the interatrial and interventricular septa.

A **defect in the interatrial septum** allows blood to pass from one side of the heart to the other from the chamber with the higher pressure; this is clinically referred to as a shunt. An **atrial septal defect (ASD)** allows oxygenated blood to flow from the left atrium (higher pressure) across the ASD into the right atrium (lower pressure). Many patients with ASD are asymptomatic, but in some cases the ASD may need to be closed surgically or by endovascular devices. The most common of all congenital heart defects are those that occur in the interventricular septum—**ventricular septal defect** (**VSD**). These lesions are most frequent in the membranous portion of the septum and they allow blood to move from the left ventricle (higher pressure) to the right ventricle (lower pressure); this leads to right ventricular hypertrophy and pulmonary arterial hypertension. If large enough and left untreated, VSDs can produce marked clinical problems that might require surgery.

Occasionally, the **ductus arteriosus**, which connects the left branch of the pulmonary artery to the inferior aspect of the aortic arch, fails to close at birth. When this occurs, the oxygenated blood in the aortic arch (higher pressure) passes into the left branch of the pulmonary artery (lower pressure) and produces pulmonary hypertension. This is termed a **patent** or **persistent ductus arteriosus** (**PDA**).

Cardiac skeleton

The cardiac skeleton consists of dense, fibrous connective tissue in the form of four rings with interconnecting areas between the atria and the ventricles (Fig. 3.75). The four rings surround the two atrioventricular orifices, the aortic orifice and opening of the pulmonary trunk. They are the **anulus fibrosus**. The interconnecting areas include:

- the **right fibrous trigone**—a thickened area of connective tissue between the aortic ring and right atrioventricular ring (Fig. 3.75); and
- the **left fibrous trigone**—a thickened area of connective tissue between the aortic ring and the left atrioventricular ring (Fig. 3.75).

The cardiac skeleton helps maintain the integrity of the openings it surrounds and provides points of attachment for the cusps. It also separates the atrial musculature from the ventricular musculature. The atrial myocardium originates from the upper border of the rings, whereas the ventricular myocardium originates from the lower border of the rings.

The cardiac skeleton also serves as a dense connective tissue partition that electrically isolates the atria from the ventricles. The atrioventricular bundle, which passes through the anulus, is the single connection between these two groups of myocardium.

Clinical app

Cardiac auscultation

Auscultation of the heart reveals the normal audible cardiac cycle, which allows the clinician to assess heart rate, rhythm, and regularity. Furthermore, cardiac murmurs that have characteristic sounds within the phases of the cardiac cycle can be demonstrated (Fig. 3.74).

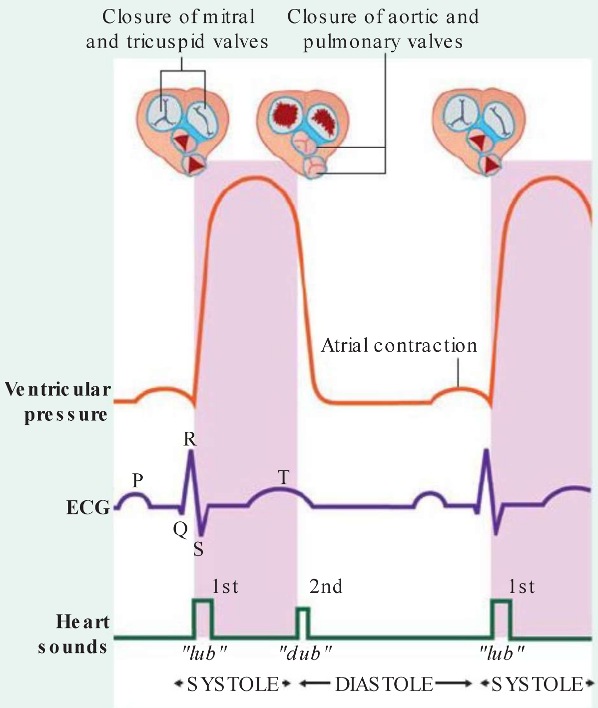


Fig. 3.74 Heart sounds and how they relate to valve closure, the electrocardiogram, and ventricular pressure.

Coronary vasculature

Two coronary arteries arise from the aortic sinuses in the initial portion of the ascending aorta and supply the muscle and other tissues of the heart. They circle the heart in the coronary sulcus, with marginal and interventricular branches, in the interventricular sulci, converging toward the apex of the heart.

The returning venous blood passes through cardiac veins, most of which empty into the coronary sinus. This large venous structure is located in the coronary sulcus on the posterior surface of the heart between the left atrium and left ventricle. The coronary sinus empties into the right atrium between the opening of the inferior vena cava and the right atrioventricular orifice.

Coronary arteries

The right coronary artery branches from the right aortic sinus of the ascending aorta, passing anterior and to the right between the right auricle and the pulmonary trunk. It then descends vertically between the right atrium and right ventricle in the coronary sulcus (Fig. 3.76).

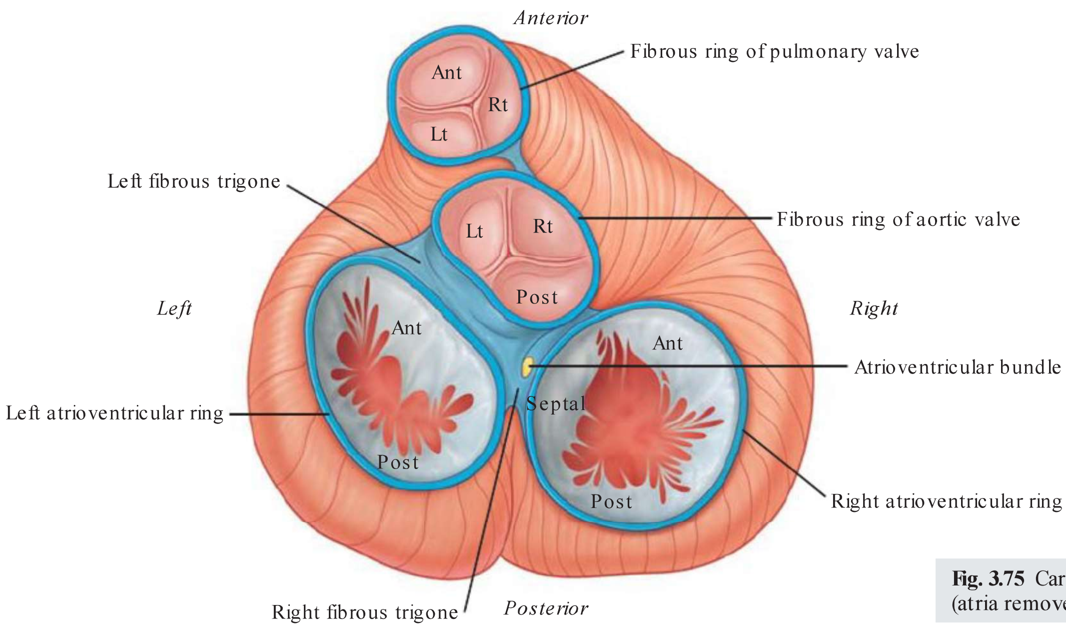


Fig. 3.75 Cardiac skeleton (atria removed).

Reaching the inferior margin of the heart, it turns posteriorly and continues in the sulcus onto the diaphragmatic surface and base of the heart. During this course, the following branches arise:

- an early **atrial branch,** passing between the right auricle and ascending aorta, gives off the **sinu-atrial nodal branch**, which passes posteriorly around the superior vena cava to supply the sinu-atrial node;
- a **right marginal branch** arising as the right coronary artery approaches the inferior (acute) margin of the heart. This branch continues along this border toward the apex of the heart;
- a small branch to the atrioventricular node as the right coronary artery continues on the base/ diaphragmatic surface of the heart; and
- the **posterior interventricular branch,** its final branch, which lies in the posterior interventricular sulcus.

The right coronary artery supplies the right atrium and right ventricle, the sinu-atrial and atrioventricular nodes, the interatrial septum, a portion of the left atrium, the posteroinferior one-third of the interventricular septum, and a portion of the posterior part of the left ventricle.

The **left coronary artery** branches from the left aortic sinus of the ascending aorta passing between the pulmonary trunk and the left auricle before entering the coronary sulcus. Posterior to the pulmonary trunk, the artery divides into its two terminal branches, the anterior interventricular and the circumflex (Fig. 3.76).

- The **anterior interventricular branch** (**left anterior descending artery—LAD**) continues around the left side of the pulmonary trunk and descends obliquely toward the apex of the heart in the anterior interventricular sulcus. During its course, one or two large **diagonal branches** may arise and descend diagonally across the anterior surface of the left ventricle.
- The **circumflex branch** continues to the left in the coronary sulcus and onto the base/diaphragmatic surface of the heart. It usually ends before reaching the posterior interventricular sulcus. A large branch, the **left marginal artery**, usually arises from it and continues across the rounded obtuse margin of the heart.

The left coronary artery supplies most of the left atrium and left ventricle, and most of the interventricular septum, including the atrioventricular bundle and its branches.

Variations in the distribution patterns of coronary arteries. Several major variations in the basic distribution patterns of the coronary arteries occur.

- The distribution pattern described above for both right and left coronary arteries is the most common and consists of a right dominant coronary artery. This means that the posterior interventricular branch arises from the right coronary artery. The right coronary artery therefore supplies a large portion of the posterior wall of the left ventricle, and the circumflex branch of the left coronary artery is relatively small.
- In contrast, in hearts with a left dominant coronary artery, the posterior interventricular branch arises from an enlarged circumflex branch and supplies most of the posterior wall of the left ventricle (Fig. 3.77).
- Another point of variation relates to the arterial supply to the sinu-atrial and atrioventricular nodes. In most cases, these two structures are supplied by the right coronary artery. However, vessels from the circumflex branch of the left coronary artery occasionally supply these structures.

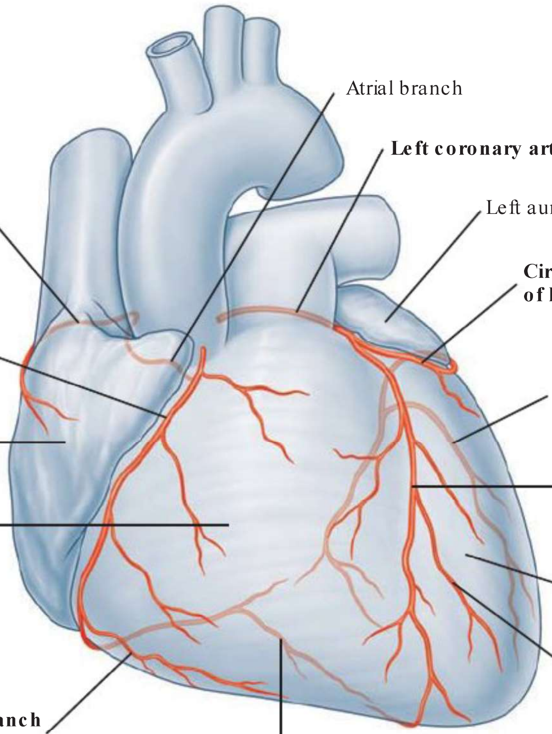


Fig. 3.76 Anterior view of coronary arterial system. Right dominant coronary artery.

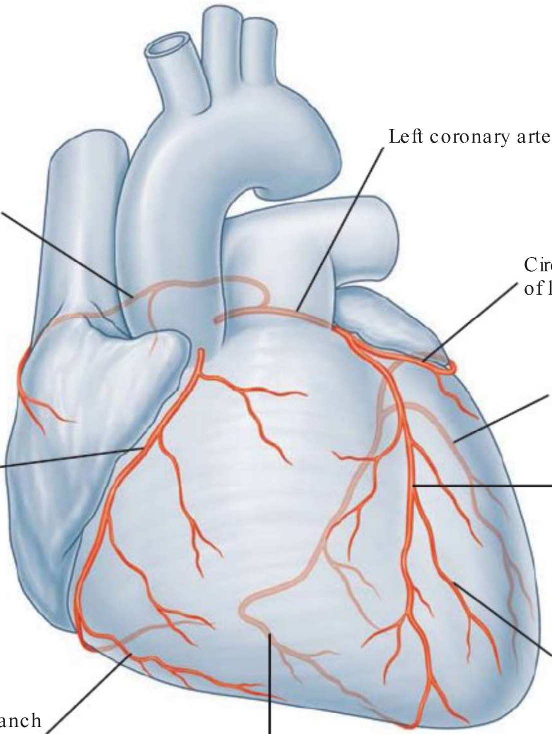


Fig. 3.77 Left dominant coronary artery.

Clinical app

Clinical terminology for coronary arteries
In practice, physicians use alternative names for the coronary vessels. The short left coronary artery is referred to as the **left main stem vessel**. One of its primary branches, the anterior interventricular artery, is termed the **left anterior descending artery** (**LAD**). Similarly, the terminal branch of the right coronary artery, the posterior interventricular artery, is termed the **posterior descending artery** (**PDA**).

Cardiac veins

The **coronary sinus** receives four major tributaries: the great, middle, small, and posterior cardiac veins.

The **great cardiac vein** begins at the apex of the heart (Fig. 3.78A) and ascends in the anterior interventricular sulcus, where it travels with the anterior interventricular artery. In this location it may be referred to as the **anterior interventricular vein**. At the coronary sulcus, it turns to the left and continues onto the base/diaphragmatic surface of the heart and is associated with the circumflex branch of the left coronary artery. Continuing along its path in the coronary sulcus, the great cardiac vein gradually enlarges becoming the coronary sinus, which enters the right atrium (Fig. 3.78B).

The **middle cardiac vein** (**posterior interventricular vein**) begins near the apex of the heart and ascends in the posterior interventricular sulcus toward the coronary sinus (Fig. 3.78B). It is associated with the posterior interventricular branch of the right or left coronary artery throughout its course.

The **small cardiac vein** begins in the lower anterior section of the coronary sulcus, between the right atrium and right ventricle (Fig. 3.78A). It continues in this groove onto the base/diaphragmatic surface of the heart and enters the coronary sinus at its atrial end. It is a companion of the right coronary artery throughout its course and may receive the **right marginal vein** (Fig. 3.78A). This small vein accompanies the marginal branch of the right coronary artery along the acute margin of the heart. If the right marginal vein does not join the small cardiac vein, it enters the right atrium directly.

The **posterior cardiac vein** lies on the posterior surface of the left ventricle just to the left of the middle cardiac vein (Fig. 3.78B). It either enters the coronary sinus directly or joins the great cardiac vein.

Other cardiac veins. Two additional groups of cardiac veins are also involved in the venous drainage of the heart.

- The **anterior veins of right ventricle** (**anterior cardiac veins**) are small veins that arise on the anterior surface of the right ventricle (Fig. 3.78A). They cross the coronary sulcus and enter the anterior wall of the right atrium. They drain the anterior portion of the right ventricle. The right marginal vein may be part of this group if it does not enter the small cardiac vein.
- A group of the smallest cardiac veins (**venae cordis minimae** or **veins of Thebesius**) have also been described. Draining directly into the cardiac chambers, they are numerous in the right atrium and right ventricle, are occasionally associated with the left atrium, and are rarely associated with the left ventricle.

Coronary lymphatics

The lymphatic vessels of the heart follow the coronary arteries and drain mainly into:

- brachiocephalic nodes, anterior to the brachiocephalic veins; and
- tracheobronchial nodes, at the inferior end of the trachea.

Cardiac conduction system

The cardiac conduction system initiates and coordinates contraction of the musculature of the atria and ventricles (Fig. 3.79). It consists of nodes and networks of specialized cardiac muscle cells organized into four basic components:

- the sinu-atrial node,
- the atrioventricular node,
- the atrioventricular bundle with its right and left bundle branches, and
- the subendocardial plexus of conduction cells (the Purkinje fibers).

The unique distribution pattern of the cardiac conduction system is an important unidirectional pathway of excitation/contraction. Throughout its course, large branches of the conduction system are insulated from the surrounding myocardium by connective tissue. This tends to decrease inappropriate stimulation and contraction of cardiac muscle fibers.

Thus, a unidirectional wave of excitation and contraction is established, which moves from the papillary muscles and apex of the ventricles to the arterial outflow tracts.

Clinical app

Cardiac conduction system
The cardiac conduction system can be affected by coronary artery disease. The normal rhythm may be disturbed if the blood supply to the coronary conduction system is disrupted. If a dysrhythmia affects the heart rate or the order in which the chambers contract, heart failure and death may ensue.

Sinu-atrial node

Impulses begin at the **sinu-atrial node**, the cardiac pacemaker. This collection of cells is located at the superior end of the crista terminalis at the junction of the superior vena cava and the right atrium (Fig. 3.79A). This is also the junction between the parts of the right atrium derived from the embryonic sinus venosus and the atrium proper.

The excitation signals generated by the sinu-atrial node spread across the atria, causing the muscle to contract.

Atrioventricular node

Concurrently, the wave of excitation in the atria stimulates the **atrioventricular node**, which is located near the opening of the coronary sinus, close to the attachment of the septal cusp of the tricuspid valve, and within the atrioventricular septum (Fig. 3.79A).

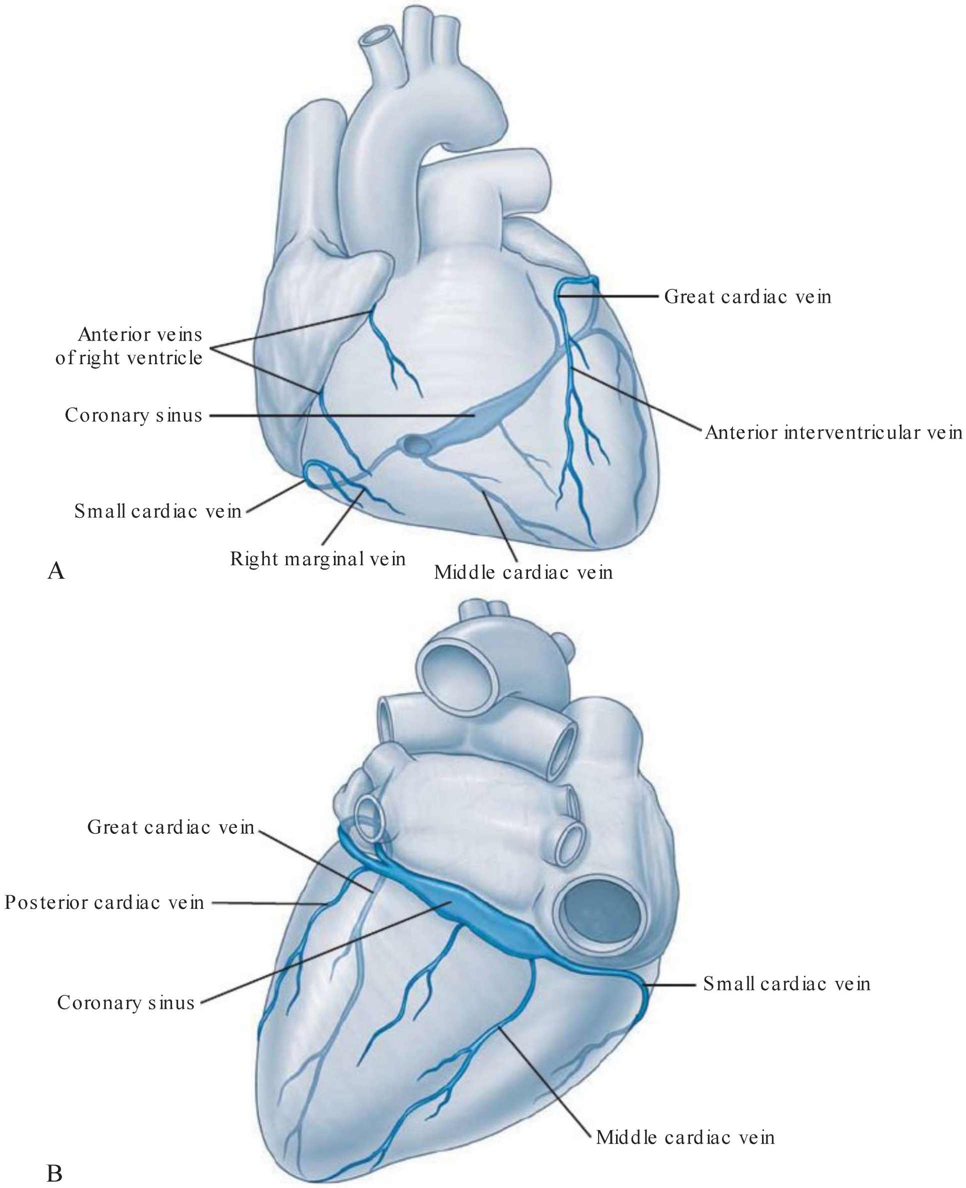


Fig. 3.78 Major cardiac veins. **A.** Anterior view of major cardiac veins. **B.** Posteroinferior view of major cardiac veins.

The atrioventricular node is a collection of specialized cells that form the beginning of an elaborate system of conducting tissue, the atrioventricular bundle, which extends the excitatory impulse to all ventricular musculature.

Atrioventricular bundle

The **atrioventricular bundle** is a direct continuation of the atrioventricular node (Fig. 3.79A). It follows the lower border of the membranous part of the interventricular septum before splitting into right and left bundles.

The **right bundle branch** continues on the right side of the interventricular septum toward the apex of the right ventricle. From the septum it enters the septomarginal trabecula to reach the base of the anterior papillary muscle. At this point, it divides and is continuous with the final component of the cardiac conduction system, the subendocardial plexus of ventricular conduction cells or Purkinje fibers. This network of specialized cells spreads throughout the ventricle to supply ventricular musculature including the papillary muscles.

The **left bundle branch** passes to the left side of the muscular interventricular septum and descends to the apex of the left ventricle (Fig. 3.79B). Along its course it gives off branches that eventually become continuous with the **subendocardial plexus of conduction cells** (**Purkinje fibers**). As with the right side, this network of specialized cells spreads the excitation impulses throughout the left ventricle.

Cardiac innervation

The autonomic division of the peripheral nervous system is directly responsible for regulating:

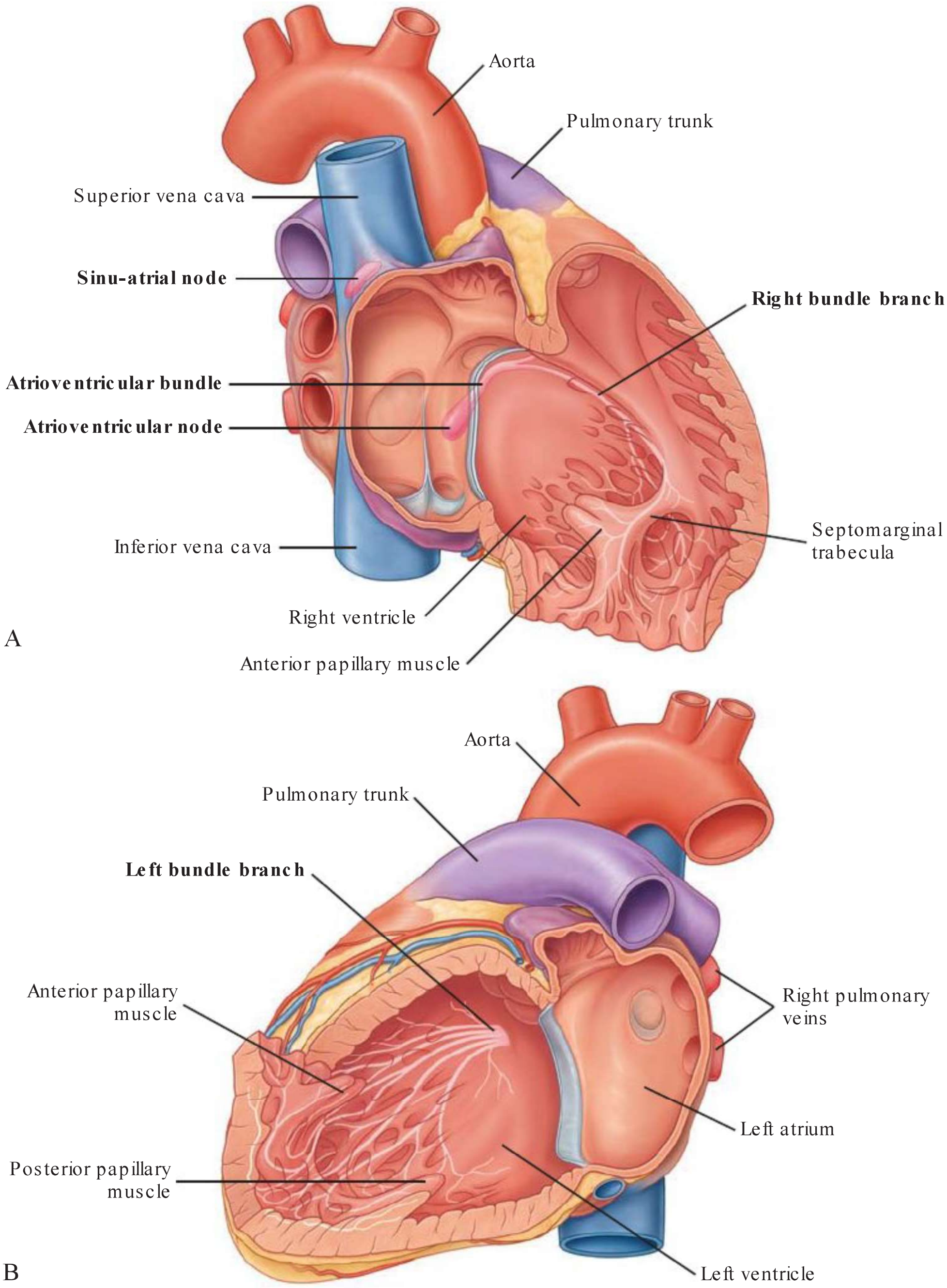


Fig. 3.79 Conduction system of the heart. **A.** Right chambers. **B.** Left chambers.

- heart rate,
- force of each contraction, and
- cardiac output.

Branches from both the parasympathetic and sympathetic systems contribute to the formation of the **cardiac plexus**. This plexus consists of a **superficial part**, inferior to the aortic arch and between it and the pulmonary trunk (Fig. 3.80A), and a **deep part**, between the aortic arch and the tracheal bifurcation (Fig. 3.80B).

From the cardiac plexus, small branches that are mixed nerves containing both sympathetic and parasympathetic fibers supply the heart. These branches affect nodal tissue and other components of the conduction system, coronary blood vessels, and atrial and ventricular musculature.

Parasympathetic innervation

Stimulation of the parasympathetic system:

- decreases heart rate,
- reduces force of contraction, and
- constricts the coronary arteries.

The preganglionic parasympathetic fibers reach the heart as cardiac branches from the right and left vagus nerves (Fig. 3.80). They enter the cardiac plexus and synapse in ganglia located either within the plexus or in the walls of the atria.

Sympathetic innervation

Stimulation of the sympathetic system:

- increases heart rate, and
- increases the force of contraction.

Sympathetic fibers reach the cardiac plexus through the cardiac nerves from the sympathetic trunk (Fig. 3.80). Preganglionic sympathetic fibers from the upper four or five segments of the thoracic spinal cord enter and move through the sympathetic trunk. They synapse in cervical and upper thoracic sympathetic ganglia, and postganglionic fibers proceed as bilateral branches from the sympathetic trunk to the cardiac plexus.

Visceral afferents

Visceral afferents from the heart are also a component of the cardiac plexus. These fibers pass through the cardiac plexus and return to the central nervous system in the cardiac nerves from the sympathetic trunk and in the vagal cardiac branches.

The afferents associated with the vagal cardiac nerves return to the vagus nerve [X]. They sense alterations in blood pressure and blood chemistry and are therefore primarily concerned with cardiac reflexes.

The afferents associated with the cardiac nerves from the sympathetic trunks return to either the cervical or the thoracic portions of the sympathetic trunk. If they are in the cervical portion of the trunk, they normally descend to the thoracic region where they reenter the upper four or five thoracic spinal cord segments along with the afferents from the thoracic region of the sympathetic trunk.

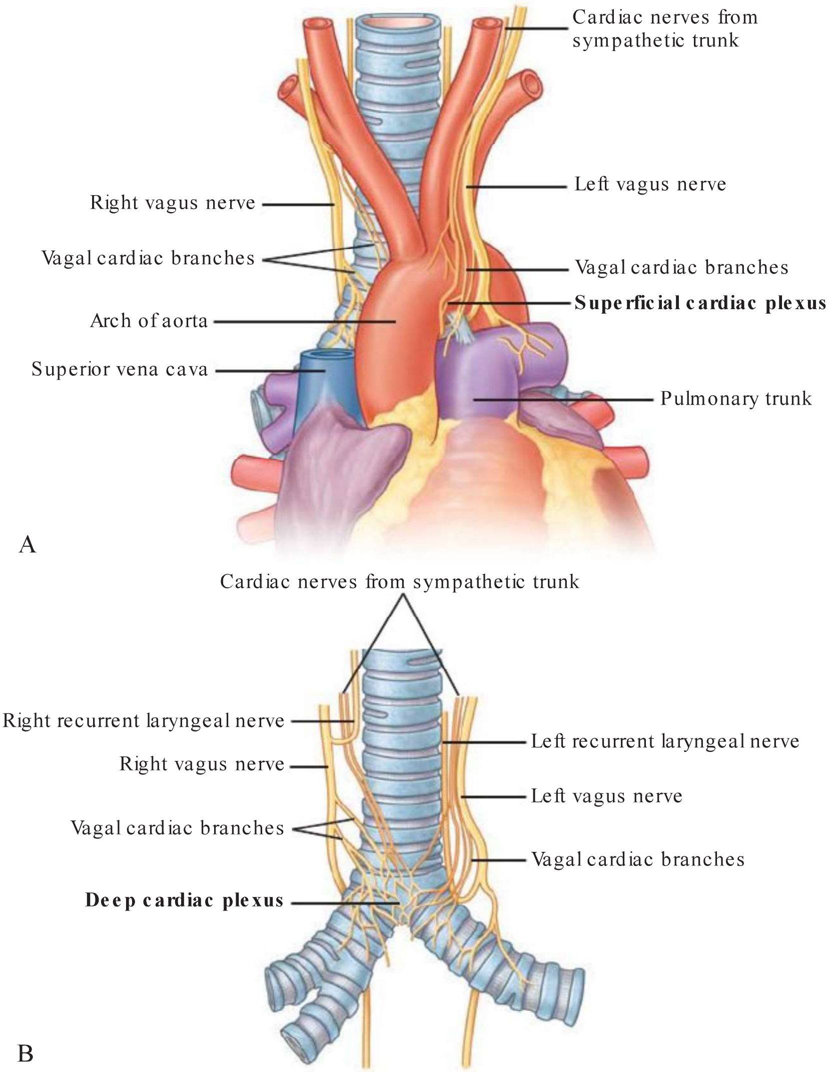


Fig. 3.80 Cardiac plexus. **A.** Superficial. **B.** Deep.

Clinical app

Heart attack
A heart attack occurs when the perfusion to the myocardium is insufficient to meet the metabolic needs of the tissue, leading to irreversible tissue damage. The most common cause is a total occlusion of a major coronary artery.

Coronary artery disease
Occlusion of a major coronary artery, usually due to atherosclerosis, leads to inadequate oxygenation of an area of myocardium and cell death. The severity of the problem will be related to the size and location of the artery involved, whether or not the blockage is complete, and whether there are collateral vessels to provide perfusion to the territory from other vessels. Depending on the severity, patients can develop pain (angina) or a myocardial infarction (MI).

Percutaneous coronary intervention
This is a technique in which a long fine tube (a catheter) is inserted into the femoral artery in the thigh, passed through the external and common iliac arteries and into the abdominal aorta. It continues to be moved upward through the thoracic aorta to the origins of the coronary arteries. The coronaries may also be approached via the radial or brachial arteries. A fine wire is then passed into the coronary artery and is used to cross the stenosis. A fine balloon is then passed over the wire and may be inflated at the level of the obstruction, thus widening it; this is termed angioplasty. More commonly, this is augmented by placement of a fine wire mesh (a stent) inside the obstruction to hold it open. Other percutaneous interventions are suction extraction of a coronary thrombus and rotary ablation of a plaque.

Coronary artery bypass grafts
If coronary artery disease is too extensive to be treated by percutaneous intervention, surgical coronary artery bypass grafting may be necessary. The great saphenous vein, in the lower limb, is harvested and used as a graft. It is divided into several pieces, each of which is used to bypass blocked sections of the coronary arteries. The internal thoracic and radial arteries can also be used.

Clinical app

Classic symptoms of heart attack
The typical symptoms are chest heaviness or pressure, which can be severe, lasting more than 20 minutes, and often associated with sweating. The pain in the chest (which may be described as an "elephant sitting on my chest" or by using a clenched fist to describe the pain [Levine sign]) often radiates to the arms (left more common than the right), and can be associated with nausea. The severity of ischemia and infarction depends on the rate at which the occlusion or stenosis has occurred and whether or not collateral channels have had a chance to develop.

Clinical app

Referred pain
When cardiac cells die during an MI, pain fibers (visceral afferents) are stimulated. They detect events at the cellular level as tissue-damaging events (i.e., cardiac ischemia). These visceral sensory fibers follow the course of sympathetic fibers that innervate the heart and enter the spinal cord between T1 and T4 spinal levels. At this level, somatic sensory fibers from spinal nerves T1 to T4 also enter the spinal cord via the posterior roots. Both types of fibers (visceral and somatic) synapse with interneurons, which then synapse with second neurons whose fibers pass across the cord and then ascend to the somatosensory areas of the brain that represent the T1 to T4 levels. The brain is unable to distinguish clearly

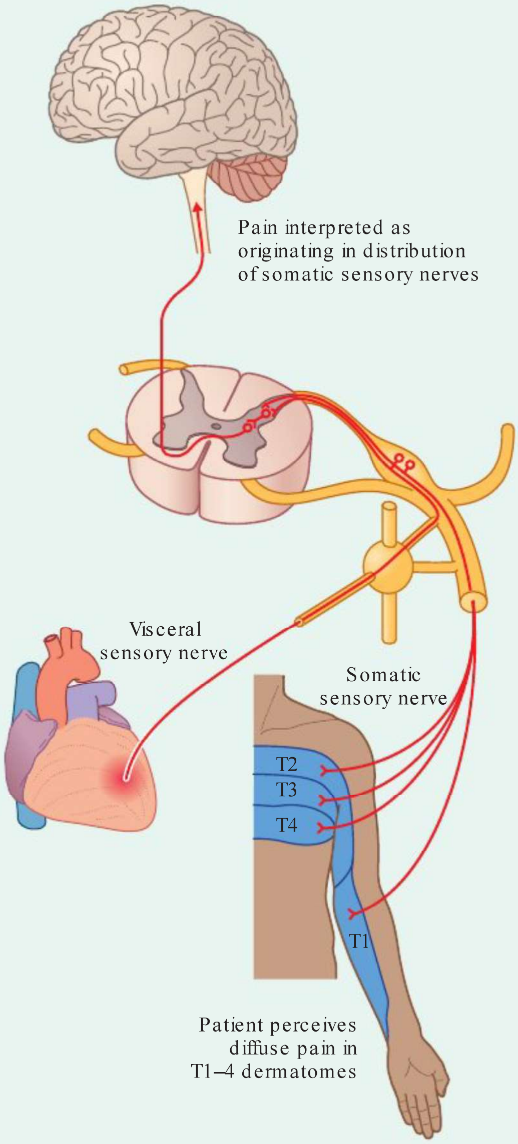


Fig. 3.81 Mechanism for perceiving heart pain in T1–T4 dermatomes.

between the visceral sensory distribution and the somatic sensory distribution, and therefore the pain is interpreted as arising from the somatic regions rather than the visceral organ (i.e., the heart; Fig. 3.81).

Clinical app

Are heart attack symptoms the same in men and women?

Although men and women can experience the typical symptoms of severe chest pain, cold sweats, and pain in the left arm, women are more likely than men to have subtler, less recognizable symptoms. These may include abdominal pain, achiness in the jaw or back, nausea, shortness of breath and/or simply fatigue. The mechanism of this difference is not understood, but it is important to consider cardiac ischemia for a wide range of symptoms.

Pulmonary trunk

The **pulmonary trunk** is within the pericardial sac (Fig. 3.82A), covered by the visceral layer of serous pericardium and enclosed in a common sheath with the ascending aorta. Arising from the conus arteriosus of the right ventricle it is slightly anterior to the aortic orifice and ascends, moving posteriorly and to the left, lying initially anterior and then to the left of the ascending aorta. At approximately the level of the intervertebral disc between vertebrae TV and TVI, opposite the left border of the sternum and posterior to the third left costal cartilage, the pulmonary trunk divides into:

- the right pulmonary artery, which passes to the right, posterior to the ascending aorta and the superior vena cava, to enter the right lung (Fig. 3.82B); and
- the left pulmonary artery, which passes inferiorly to the arch of the aorta and anteriorly to the descending aorta to enter the left lung (Fig. 3.82A,B).

Ascending aorta

The **ascending aorta** is within the pericardial sac and covered by a visceral layer of serous pericardium, which also surrounds the pulmonary trunk in a common sheath (Fig. 3.82A).

The origin of the ascending aorta is the aortic orifice at the base of the left ventricle, which is level with the lower edge of the third left costal cartilage and posterior to the left half of the sternum. Moving superiorly, slightly forward and to the right, the ascending aorta continues to the level of the second right costal cartilage. At this point, it enters the superior mediastinum and is then referred to as the **arch of the aorta**.

Immediately superior to the point where the ascending aorta arises from the left ventricle are three small outward bulges opposite the semilunar cusps of the aortic valve. These are the posterior, right, and left aortic sinuses. The right and left coronary arteries originate from the right and left aortic sinuses, respectively.

Other vasculature

Passing through the fibrous pericardium at approximately the level of the second costal cartilage, the inferior half of the **superior vena cava** is within the pericardial sac (Fig. 3.82B). It enters the right atrium at the lower level of the third costal cartilage. The portion within the pericardial sac is covered with serous pericardium except for a small area on its posterior surface.

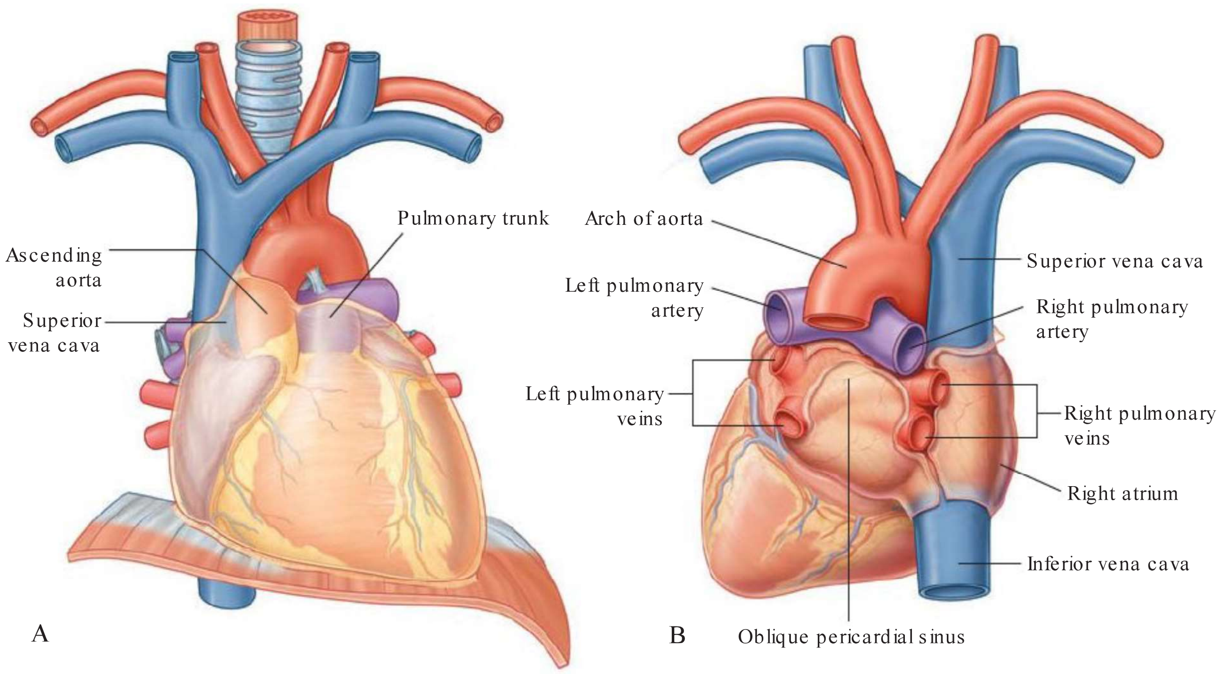


Fig. 3.82 Major vessels within the middle mediastinum. **A.** Anterior view. **B.** Posterior view.

After passing through the diaphragm, at approximately the level of vertebra TVIII, the **inferior vena cava** enters the fibrous pericardium. A short portion of this vessel is within the pericardial sac before entering the right atrium. While within the pericardial sac, it is covered by serous pericardium except for a small portion of its posterior surface (Fig. 3.82B).

A very short segment of each of the pulmonary veins is also within the pericardial sac. These veins, usually two from each lung, pass through the fibrous pericardium and enter the superior region of the left atrium on its posterior surface. In the pericardial sac, all but a portion of the posterior surface of these veins is covered by serous pericardium. In addition, the **oblique pericardial sinus** is between the right and left pulmonary veins, within the pericardial sac (Fig. 3.82B).

Superior mediastinum

Posterior to the manubrium of the sternum and anterior to the bodies of the first four thoracic vertebrae is the **superior mediastinum** (see Fig. 3.53).

- Superior border—an oblique plane passing from the jugular notch upward and posteriorly to the superior border of vertebra TI.
- Inferior border—a transverse plane passing from the sternal angle to the intervertebral disc between vertebra TIV/V separates it from the inferior mediastinum.
- Lateral borders—the mediastinal part of the parietal pleura on either side.

The superior mediastinum is continuous with the neck superiorly and with the inferior mediastinum inferiorly.

Major structures found in the superior mediastinum (Figs. 3.83, 3.84) include the:

- thymus,
- right and left brachiocephalic veins,
- left superior intercostal vein,
- superior vena cava,
- arch of the aorta with its three large branches,
- trachea,
- esophagus,
- phrenic nerves,
- vagus nerves,
- left recurrent laryngeal branch of the left vagus nerve,
- thoracic duct, and
- other small nerves, blood vessels, and lymphatics.

Thymus

Lying immediately posterior to the manubrium of the sternum, the thymus, asymmetrical and bilobed, is the most anterior component of the superior mediastinum (Fig. 3.85).

The upper extent of the thymus can reach into the neck as high as the thyroid gland and a lower portion typically extends into the anterior mediastinum over the pericardial sac.

Involved in the early development of the immune system, the thymus is a large structure in the child, begins to atrophy after puberty, and shows considerable size variation in the adult. In the elderly adult, it is barely identifiable as an organ, consisting mostly of fatty tissue that is sometimes arranged as two lobulated fatty structures.

Arteries to the thymus are small branches from the internal thoracic arteries. Venous drainage is usually into the left brachiocephalic vein and possibly into the internal thoracic veins.

Lymphatic drainage returns to multiple groups of nodes at one or more of the following locations:

- along the internal thoracic arteries (parasternal),
- at the tracheal bifurcation (tracheobronchial), and
- in the root of the neck.

Clinical app

Ectopic parathyroid glands in the thymus
The parathyroid glands develop from the third pharyngeal pouch, which also forms the thymus. The thymus is therefore a common site for ectopic parathyroid glands and, potentially, ectopic parathyroid hormone production.

Right and left brachiocephalic veins

The **left and right brachiocephalic veins** are located immediately posterior to the thymus and form on each side at the junction between the internal jugular and subclavian veins (see Fig. 3.83). The left brachiocephalic vein crosses the midline and joins with the right brachiocephalic vein to form the superior vena cava (Fig. 3.86).

- The **right brachiocephalic vein** begins posterior to the medial end of the right clavicle and passes vertically downward, forming the superior vena cava when it is joined by the left brachiocephalic vein (Fig. 3.83). Venous tributaries include the vertebral, first posterior intercostal, and internal thoracic veins. The inferior thyroid and thymic veins may also drain into it.

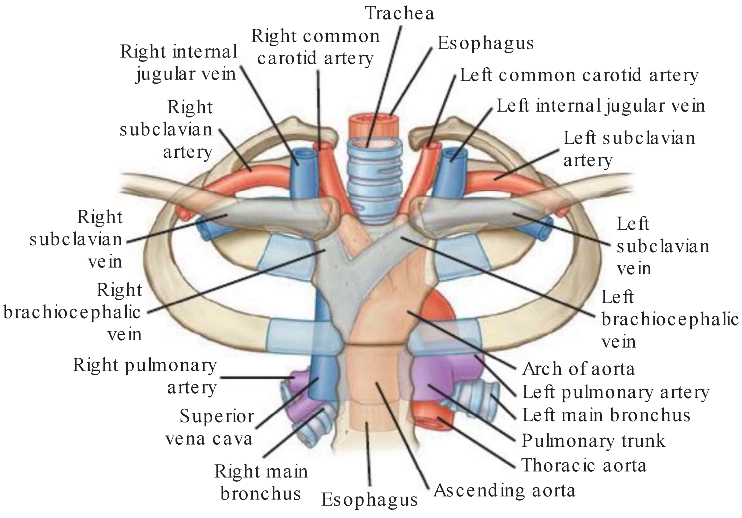


Fig. 3.83 Structures in the superior mediastinum.

- The **left brachiocephalic vein** begins posterior to the medial end of the left clavicle (Fig. 3.83). It crosses to the right, moving in a slightly inferior direction, and joins with the right brachiocephalic vein to form the superior vena cava posterior to the lower edge of the right first costal cartilage close to the right sternal border. Venous tributaries include the vertebral, first posterior intercostal, left superior intercostal, inferior thyroid, and internal thoracic veins. It may also receive thymic and pericardial veins.

Imaging app

Visualizing structures in the superior mediastinum

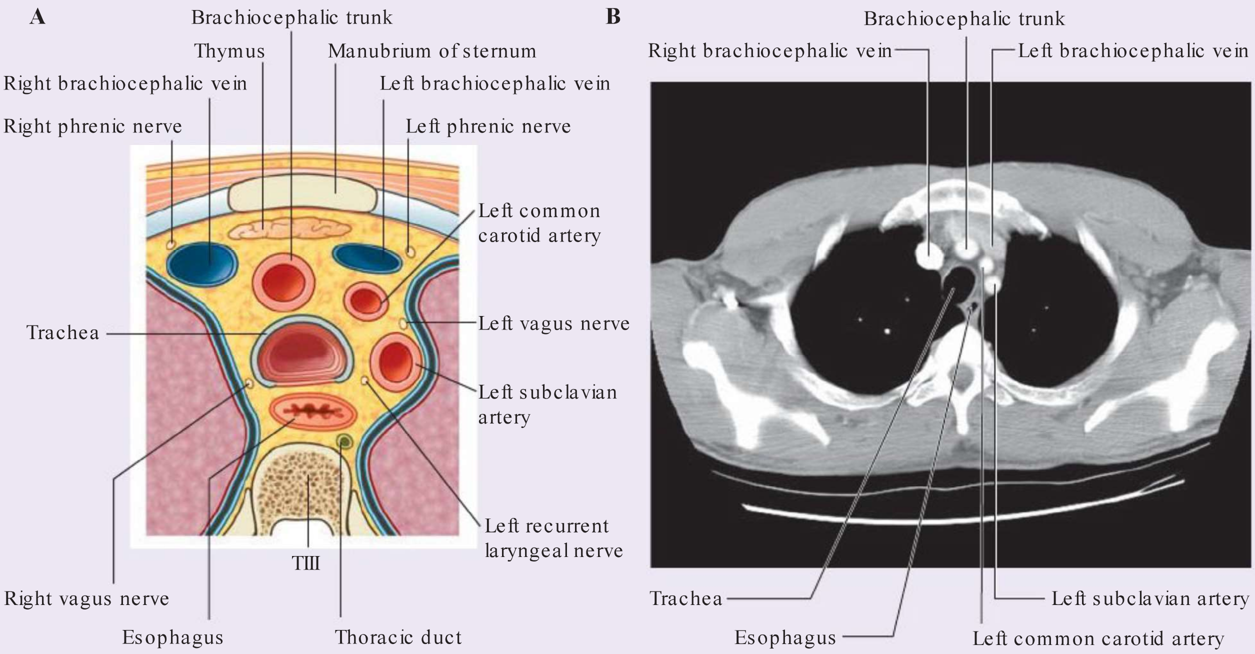


Fig. 3.84 Cross-section through the superior mediastinum at the level of vertebra TIII. **A.** Diagram. **B.** Axial computed tomography image.

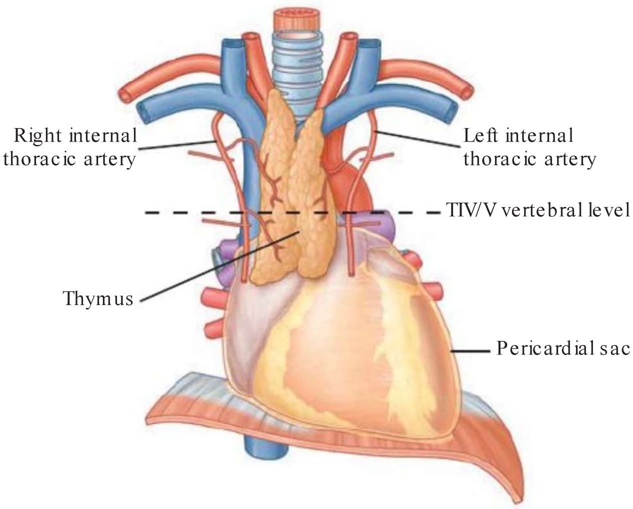


Fig. 3.85 Thymus.

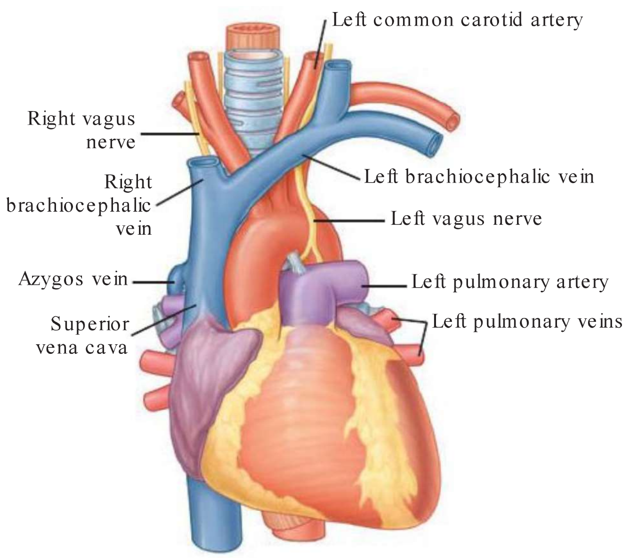


Fig. 3.86 Superior mediastinum with thymus removed.

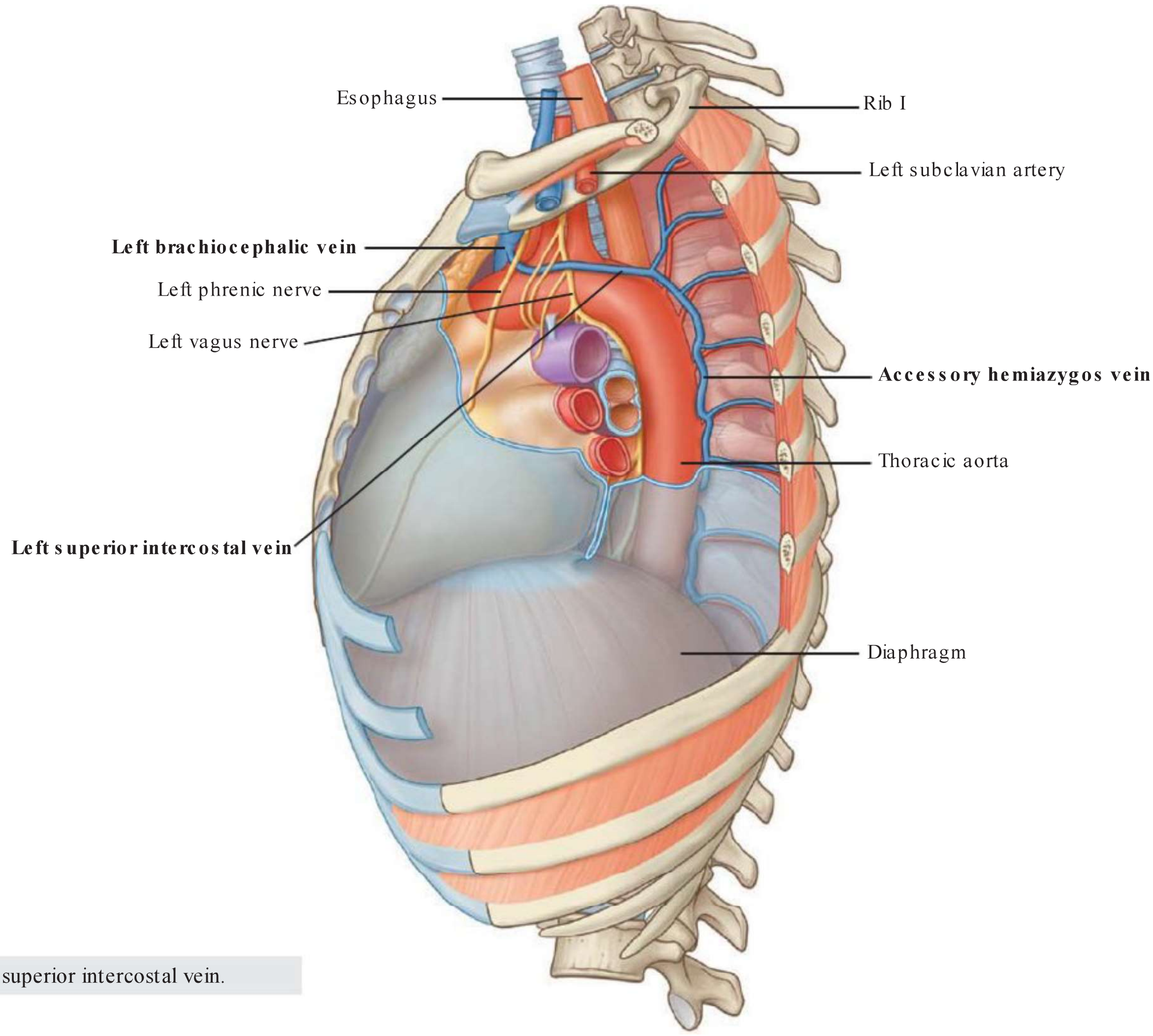


Fig. 3.87 Left superior intercostal vein.

Clinical app

Left brachiocephalic vein
The left brachiocephalic vein crosses the midline posterior to the manubrium in the adult. In infants and children, the left brachiocephalic vein rises above the superior border of the manubrium and therefore is less protected.

Left superior intercostal vein

The **left superior intercostal vein** receives the second, third, and sometimes the fourth left posterior intercostal veins, usually the left bronchial veins, and sometimes the left pericardiacophrenic vein. It passes over the left side of the aortic arch, lateral to the left vagus nerve and medial to the left phrenic nerve, before entering the left brachiocephalic vein (Fig. 3.87). Inferiorly, it may connect with the **accessory hemiazygos vein** (**superior hemiazygos vein**).

Superior vena cava

The vertically oriented **superior vena** cava begins posterior to the lower edge of the right first costal cartilage, where the right and left brachiocephalic veins join, and terminates at the lower edge of the right third costal cartilage, where it joins the right atrium (see Fig. 3.83).

The lower half of the superior vena cava is within the pericardial sac and contained in the middle mediastinum.

The superior vena cava receives the azygos vein immediately before entering the pericardial sac and may also receive pericardial and mediastinal veins.

Clinical app

Venous access for central and dialysis lines
Large systemic veins are used to establish central venous access for administering large amounts of fluid, drugs, and blood. Most of these lines (small bore tubes) are introduced through venous puncture into the axillary, subclavian, or internal jugular veins. The lines are then passed through the main veins of the superior mediastinum, with the tips of the lines usually residing in the distal portion of the superior vena cava or in the right atrium.

Similar devices, such as dialysis lines, are inserted into patients who have renal failure, so that a large volume of blood can be aspirated through one channel and reinfused through a second channel.

Clinical app

Using the superior vena cava to access the inferior vena cava

Because the superior and inferior vena cava are oriented along the same vertical axis, a guidewire, catheter, or line can be passed from the superior vena cava through the right atrium and into the inferior vena cava. This is a common route of access for such procedures as:

- transjugular liver biopsy,
- transjugular intrahepatic portosystemic shunts (TIPS), and
- insertion of an inferior vena cava filter to catch emboli dislodged from veins in the lower limb and pelvis (i.e., patients with deep vein thrombosis [DVT]).

Arch of aorta and its branches

The thoracic portion of the aorta can be divided into **ascending aorta**, **arch of aorta**, and **thoracic (descending) aorta**. Only the arch of the aorta is in the superior mediastinum. It begins when the ascending aorta emerges from the pericardial sac and courses upward, backward, and to the left as it passes through the superior mediastinum, ending on the left side at vertebral level TIV/V. Extending as high as the midlevel of the manubrium of sternum, the arch is initially anterior and finally lateral to the trachea (Figs. 3.88, 3.89).

Three branches arise from the superior border of the arch of the aorta and, at their origins, all three are crossed anteriorly by the left brachiocephalic vein.

The first branch

Beginning on the right, the first branch of the arch of aorta is the **brachiocephalic trunk** (Fig. 3.88). It is the largest of the three branches and, at its point of origin behind the manubrium of sternum, is slightly anterior to the other two branches. It ascends slightly posteriorly and to the right. At the level of the upper edge of the right sternoclavicular joint, the brachiocephalic trunk divides into:

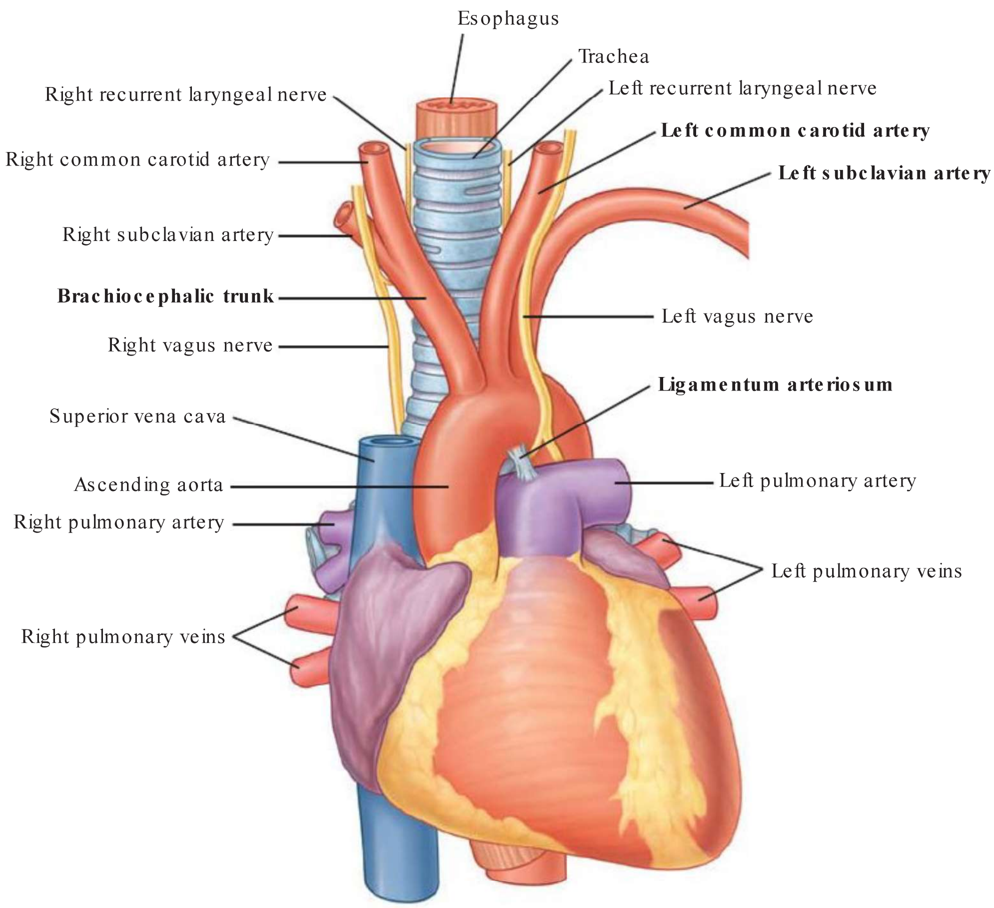


Fig. 3.88 Superior mediastinum with thymus and venous channels removed.

- the **right common carotid artery,** and
- the **right subclavian artery**.

The arteries mainly supply the right side of the head and neck and the right upper limb, respectively.

Occasionally, the brachiocephalic trunk has a small branch, the **thyroid ima artery**, which contributes to the vascular supply of the thyroid gland.

The second branch

The second branch of the arch of aorta is the **left common carotid artery** (Fig. 3.88). It arises from the arch immediately to the left and slightly posterior to the brachiocephalic trunk and ascends through the superior mediastinum along the left side of the trachea.

The left common carotid artery supplies the left side of the head and neck.

The third branch

The third branch of the arch of the aorta is the **left subclavian artery** (Fig. 3.88). It arises from the arch of aorta immediately to the left of, and slightly posterior to, the left common carotid artery and ascends through the superior mediastinum along the left side of the trachea.

The left subclavian artery is the major blood supply to the left upper limb.

Ligamentum arteriosum

The **ligamentum arteriosum** is also in the superior mediastinum and is important in embryonic circulation, when it is a patent vessel (the **ductus arteriosus**). It connects the pulmonary trunk with the arch of aorta and allows blood to bypass the lungs during development (Fig. 3.88). The vessel closes soon after birth and forms the ligamentous connection observed in the adult.

Clinical app

Coarctation of the aorta

Coarctation of the aorta is a congenital abnormality in which the aortic lumen is constricted just distal to the origin of the left subclavian artery. At this point, the aorta becomes significantly narrowed and the blood supply to the lower limbs and abdomen is diminished. Over time, collateral vessels develop around the chest wall and abdomen to supply the lower body. The coarctation also affects the heart, which has to pump the blood at higher pressure to maintain peripheral perfusion. This in turn may produce cardiac failure.

Clinical app

Traumatic injury to the aorta

The aorta has three fixed points of attachment:

- the aortic valve,
- the ligamentum arteriosum, and
- the point of entry behind the crura of the diaphragm.

A serious deceleration injury (e.g., in a traffic accident) is most likely to cause aortic trauma at these fixed points. The rest of the aorta is relatively free from attachment to other structures of the mediastinum and is less likely to be injured.

Imaging app

Visualizing structures at the TIV vertebral level

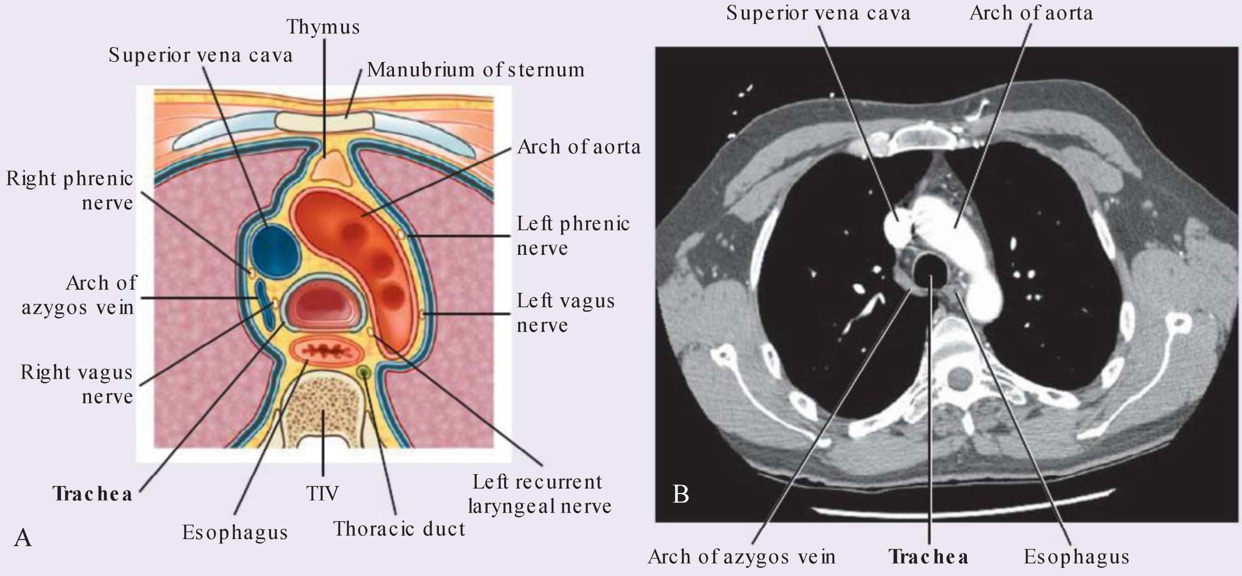


Fig. 3.89 Cross-section through the superior mediastinum at the level of vertebra TIV. **A.** Diagram. **B.** Axial computed tomography image.

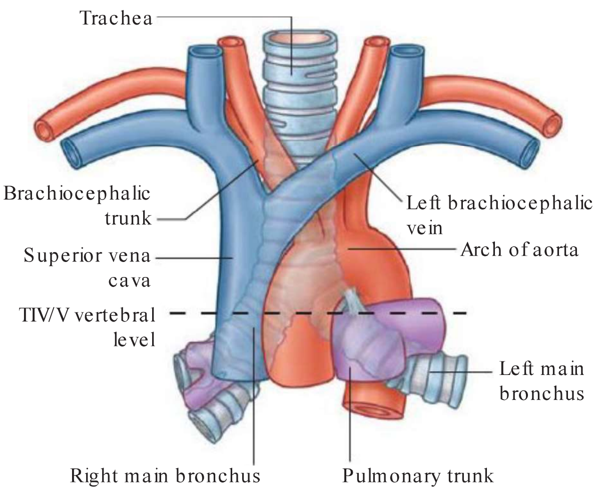


Fig. 3.90 Trachea in the superior mediastinum.

Clinical app

Aortic dissection

In certain conditions, such as in severe arteriovascular disease, the wall of the aorta can split longitudinally, creating a false channel, which may or may not rejoin into the true lumen distally. This aortic dissection occurs between the intima and media anywhere along its length. If it occurs in the ascending aorta or arch of the aorta, blood flow in the coronary and cerebral arteries may be disrupted, resulting in MI or stroke. In the abdomen the visceral vessels may be disrupted, producing ischemia to the gut or kidneys.

Clinical app

Aortic arch and its anomalies

A right-sided arch of aorta occasionally occurs and may be asymptomatic. It can be associated with **dextrocardia** (right-sided heart) and, in some instances, with complete **situs inversus** (left-to-right inversion of the body's organs). It can also be associated with abnormal branching of the great vessels.

Clinical app

Abnormal origin of great vessels

Great vessels occasionally have an abnormal origin, including:

- a common origin of the brachiocephalic trunk and the left common carotid artery,
- the left vertebral artery originating from the aortic arch, and
- the right subclavian artery originating from the distal portion of the aortic arch and passing behind the esophagus to supply the right arm—as a result, the great vessels form a vascular ring around the trachea and the esophagus, which can potentially produce difficulty swallowing.

Trachea and esophagus

The **trachea** is a midline structure that is palpable in the jugular notch as it enters the superior mediastinum. Posterior to it is the **esophagus**, which is immediately anterior to the vertebral column (Fig. 3.89; also see Fig 3.83). Significant mobility exists in the vertical positioning of these structures as they pass through the superior mediastinum.

As the trachea and esophagus pass through the superior mediastinum, they are crossed laterally by the azygos vein on the right side and the arch of aorta on the left side.

The trachea divides into the right and left main bronchi at, or just inferior to, the transverse plane between the sternal angle and vertebral level TIV/V (Fig. 3.90), whereas the esophagus continues into the posterior mediastinum.

Nerves of the superior mediastinum

Vagus nerves

The **vagus nerves** [X] pass through the superior and posterior divisions of the mediastinum on their way to the abdominal cavity. As they pass through the thorax, they provide parasympathetic innervation to the thoracic viscera and carry visceral afferents from the thoracic viscera.

Visceral afferents in the vagus nerves relay information to the central nervous system about normal physiological processes and reflex activities. They do not transmit pain sensation.

Right vagus nerve

The **right vagus nerve** enters the superior mediastinum between the right brachiocephalic vein and the brachiocephalic trunk. It descends in a posterior direction toward the trachea (Fig. 3.91), crosses the lateral surface of the

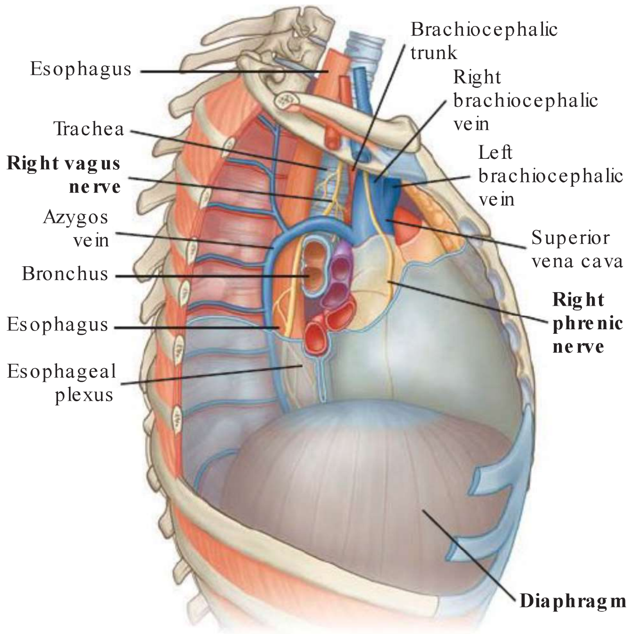


Fig. 3.91 Right vagus nerve passing through the superior mediastinum.

trachea. and passes posteriorly to the root of the right lung to reach the esophagus. Just before the esophagus, it is crossed by the arch of the azygos vein.

As it passes through the superior mediastinum, branches are given off to the esophagus, cardiac plexus, and pulmonary plexus.

Left vagus nerve

The **left vagus nerve** enters the superior mediastinum posterior to the left brachiocephalic vein between the left common carotid and left subclavian arteries (Fig. 3.92). It passes into the superior mediastinum just deep to the mediastinal part of the parietal pleura and crosses the left side of the arch of aorta. It descends in a posterior direction and passes posterior to the root of the left lung to reach the esophagus in the posterior mediastinum.

As the left vagus nerve passes through the superior mediastinum, branches go to the esophagus, cardiac plexus, and pulmonary plexus.

The left vagus nerve also gives rise to the **left recurrent laryngeal nerve**, which arises at the inferior margin of the arch of aorta just lateral to the ligamentum arteriosum (Fig. 3.92). The left recurrent laryngeal nerve passes inferior to the arch of aorta before ascending on its medial surface. Entering a groove between the trachea and esophagus, the left recurrent laryngeal nerve continues superiorly to enter the neck and terminate in the larynx (Fig. 3.93).

Phrenic nerves

The phrenic nerves arise in the cervical region from the third, fourth, and fifth cervical spinal cord segments. They descend through the thorax to supply motor and sensory innervation to the diaphragm and its associated membranes. As they pass through the thorax, they provide innervation through somatic afferent fibers to the mediastinal pleura, fibrous pericardium, and parietal layer of the serous pericardium.

Right phrenic nerve

The **right phrenic nerve** enters the superior mediastinum lateral to the right vagus nerve, and lateral and slightly posterior to the beginning of the right brachiocephalic vein (see Fig. 3.91). It continues inferiorly along the right side of this vein and the superior vena cava.

On entering the middle mediastinum, the right phrenic nerve descends along the right side of the pericardial sac, within the fibrous pericardium, anterior to the root of the right lung. The pericardiacophrenic vessels accompany it through most of its course in the thorax (see Fig. 3.55). It leaves the thorax by passing through the diaphragm with the inferior vena cava.

Left phrenic nerve

The **left phrenic nerve** enters the superior mediastinum in a position similar to the path taken by the right phrenic nerve. It lies lateral to the left vagus nerve and lateral and slightly posterior to the beginning of the left brachiocephalic vein (Fig. 3.92), and continues to descend across the left lateral surface of the arch of aorta, passing superficially to the left vagus nerve and the left superior intercostal vein.

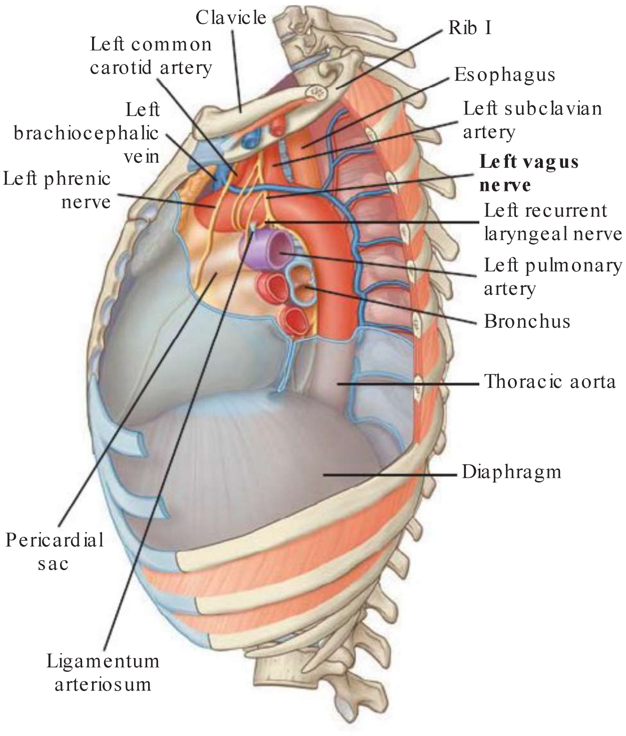


Fig. 3.92 Left vagus nerve passing through the superior mediastinum.

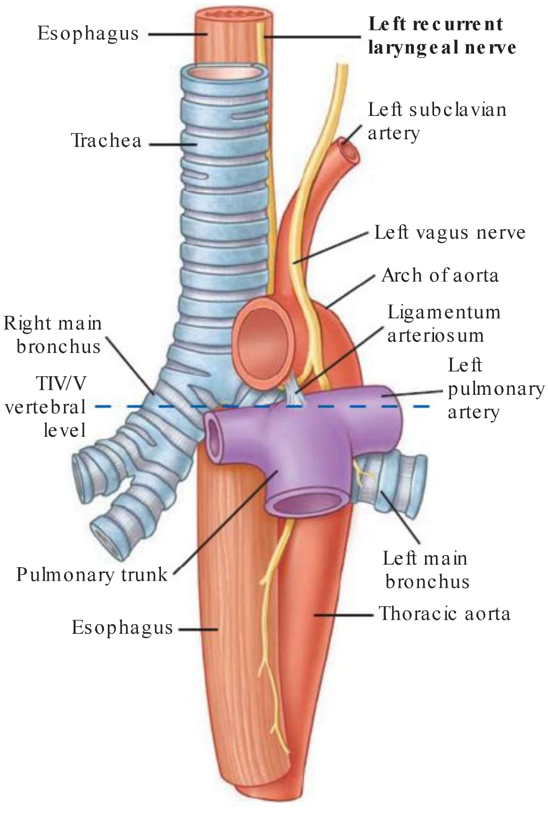


Fig. 3.93 Left recurrent laryngeal nerve passing through the superior mediastinum.

On entering the middle mediastinum, the left phrenic nerve follows the left side of the pericardial sac, within the fibrous pericardium, anterior to the root of the left lung, and is accompanied by the pericardiacophrenic vessels (see Fig. 3.55). It leaves the thorax by piercing the diaphragm near the apex of the heart.

Surface anatomy

Visualizing structures in the superior mediastinum

A number of structures in the superior mediastinum in adults can be visualized based on their positions relative to skeletal landmarks that can be palpated through the skin (Fig. 3.94).

- On each side, the internal jugular and subclavian veins join to form the brachiocephalic veins behind the sternal ends of the clavicles near the sternoclavicular joints.
- The left brachiocephalic vein crosses from left to right behind the manubrium of sternum.
- The brachiocephalic veins unite to form the superior vena cava behind the lower border of the costal cartilage of the right first rib.
- The arch of aorta begins and ends at the transverse plane between the sternal angle anteriorly and vertebral level TIV/V posteriorly. The arch may reach as high as the midlevel of the manubrium of sternum.

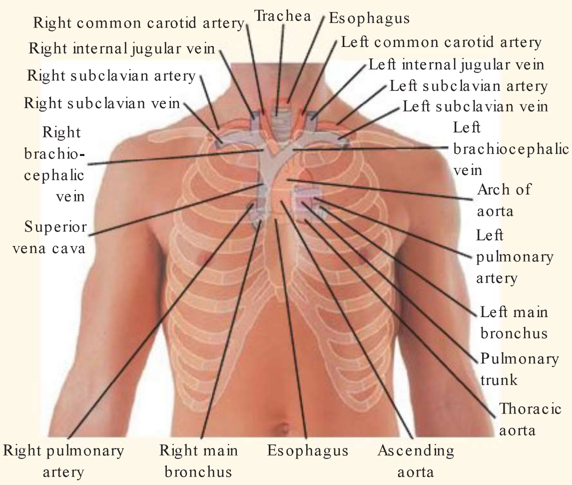


Fig. 3.94 Anterior view of the chest wall of a man showing the locations of different structures in the superior mediastinum as they relate to the skeleton.

Clinical app

The vagus nerves, recurrent laryngeal nerves, and hoarseness

The left recurrent laryngeal nerve is a branch of the left vagus nerve. It passes between the pulmonary artery and the aorta, a region known clinically as the **aortopulmonary window** and may be compressed in any patient with a pathological mass in this region. This compression results in vocal cord paralysis and hoarseness of the voice. Lymph node enlargement, often associated with the spread of lung cancer, is a common condition that may produce compression. Chest radiography is therefore usually carried out for all patients whose symptoms include a hoarse voice.

More superiorly, the right vagus nerve gives off the right recurrent laryngeal nerve, which "hooks" around the right subclavian artery at the superior sulcus of the right lung. If a patient has a hoarse voice and a right vocal cord palsy is demonstrated with a laryngoscopy, a chest CT should be obtained to assess for cancer in the right lung apex (**Pancoast's tumor**).

Thoracic duct in the superior mediastinum

The **thoracic duct**, the major lymphatic vessel in the body, passes through the posterior portion of the superior mediastinum (see Figs. 3.84A, 3.89A). It:

- enters the superior mediastinum inferiorly, slightly to the left of the midline, having moved to this position just before leaving the posterior mediastinum opposite vertebral level TIV/V; and
- continues through the superior mediastinum, posterior to the arch of aorta, and the initial portion of the left subclavian artery, between the esophagus and the left mediastinal part of the parietal pleura.

Posterior mediastinum

The **posterior mediastinum** is posterior to the pericardial sac and diaphragm and anterior to the bodies of the mid and lower thoracic vertebrae (see Fig. 3.53).

- Its superior boundary is a transverse plane from the sternal angle to the TIV and TV intervertebral disc.
- Its inferior boundary is the diaphragm.
- Laterally, it is bordered by the mediastinal part of parietal pleura on either side.
- Superiorly, it is continuous with the superior mediastinum.

Major structures in the posterior mediastinum include the:

- esophagus and its associated nerve plexus,
- thoracic aorta and its branches,
- azygos system of veins,
- thoracic duct and associated lymph nodes,
- sympathetic trunks, and
- thoracic splanchnic nerves.

Esophagus

The **esophagus** is a muscular tube passing between the pharynx in the neck and the stomach in the abdomen. It begins at the inferior border of the cricoid cartilage, opposite vertebra CVI, and ends at the cardiac opening of the stomach, opposite vertebra TXI.

The esophagus descends on the anterior aspect of the bodies of the vertebrae, generally in a midline position as it moves through the thorax (Fig. 3.95). As it approaches the diaphragm, it moves anteriorly and to the left, crossing from the right side of the thoracic aorta to a position anterior to it. It passes through the esophageal hiatus, an opening in the muscular part of the diaphragm, at vertebral level TX.

The esophagus has a slight anterior-to-posterior curvature that parallels the thoracic portion of the vertebral column, and is secured superiorly in the neck by its attachment to the pharynx and inferiorly in the thorax by its attachment to the diaphragm.

Relationships to important structures in the posterior mediastinum

In the posterior mediastinum, the right side of the esophagus is covered by the mediastinal part of the parietal pleura.

Posterior to the esophagus, the thoracic duct is on the right side inferiorly, but crosses to the left more superiorly. Also on the left side of the esophagus is the thoracic aorta.

Anterior to the esophagus, below the level of the tracheal bifurcation, are the right pulmonary artery and the left main bronchus. The esophagus then passes immediately posteriorly to the left atrium, separated from it only by pericardium. Inferior to the left atrium, the esophagus is related to the diaphragm.

Structures other than the thoracic duct posterior to the esophagus include portions of the hemiazygos veins, the right posterior intercostal vessels, and, near the diaphragm, the thoracic aorta.

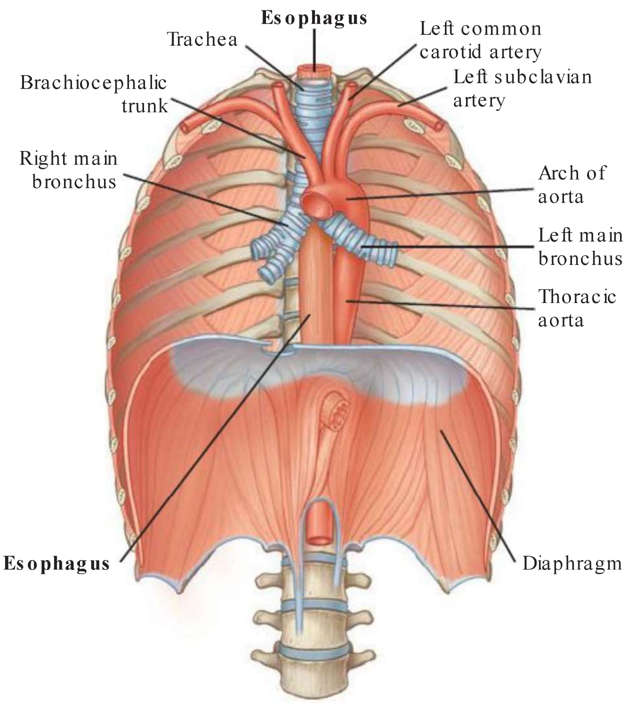


Fig. 3.95 Esophagus.

Clinical app

Esophagus constrictions

The esophagus is a flexible, muscular tube that can be compressed or narrowed by surrounding structures at four locations (Fig. 3.96):

- the junction of the esophagus with the pharynx in the neck,
- in the superior mediastinum where the esophagus is crossed by the arch of aorta,
- in the posterior mediastinum where the esophagus is compressed by the left main bronchus,
- in the posterior mediastinum at the esophageal hiatus in the diaphragm.

These constrictions have important clinical consequences. For example, a swallowed object is most likely to lodge at a constricted area. An ingested corrosive substance would move more slowly through a narrowed region, causing more damage at this site than elsewhere along the esophagus. Also, constrictions present problems during the passage of instruments.

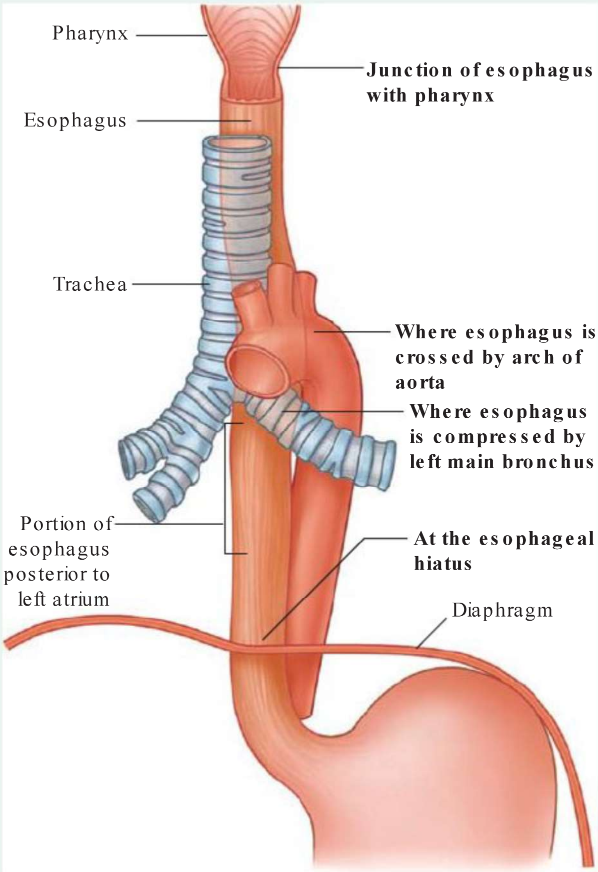


Fig. 3.96 Sites of normal esophageal constrictions.

Arterial supply and venous and lymphatic drainage

The arterial supply and venous drainage of the esophagus in the posterior mediastinum involve many vessels. Esophageal arteries arise from the thoracic aorta, bronchial arteries, and ascending branches of the left gastric artery in the abdomen.

Venous drainage involves small vessels returning to the azygos vein, hemiazygos vein, and esophageal branches to the left gastric vein in the abdomen.

Lymphatic drainage of the esophagus in the posterior mediastinum returns to posterior mediastinal and left gastric nodes.

Innervation

Innervation of the esophagus, in general, is complex. Esophageal branches arise from the vagus nerves and sympathetic trunks.

Striated muscle fibers in the superior portion of the esophagus originate from the branchial arches and are innervated by branchial efferents from the vagus nerves.

Smooth muscle fibers are innervated by components of the parasympathetic part of the autonomic division of the peripheral nervous system, visceral efferents from the vagus nerves. These are preganglionic fibers that synapse in the myenteric and submucosal plexuses of the enteric nervous system in the esophageal wall.

Sensory innervation of the esophagus involves visceral afferent fibers originating in the vagus nerves, sympathetic trunks, and splanchnic nerves.

The visceral afferents from the vagus nerves are involved in relaying information back to the central nervous system about normal physiological processes and reflex activities. They are not involved in the relay of pain recognition.

The visceral afferents that pass through the sympathetic trunks and the splanchnic nerves are the primary participants in detection of esophageal pain and transmission of this information to various levels of the central nervous system.

Esophageal plexus

After passing posteriorly to the root of the lungs, the right and left vagus nerves approach the esophagus. As they reach the esophagus, each nerve divides into several branches that spread over this structure, forming the **esophageal plexus** (Fig. 3.97). There is some mixing of fibers from the two vagus nerves as the plexus continues inferiorly on the esophagus toward the diaphragm. Just above the diaphragm, fibers of the plexus converge to form two trunks:

- the **anterior vagal trunk** on the anterior surface of the esophagus, mainly from fibers originally in the left vagus nerve;
- the **posterior vagal trunk** on the posterior surface of the esophagus, mainly from fibers originally in the right vagus nerve.

The vagal trunks continue on the surface of the esophagus as it passes through the diaphragm into the abdomen.

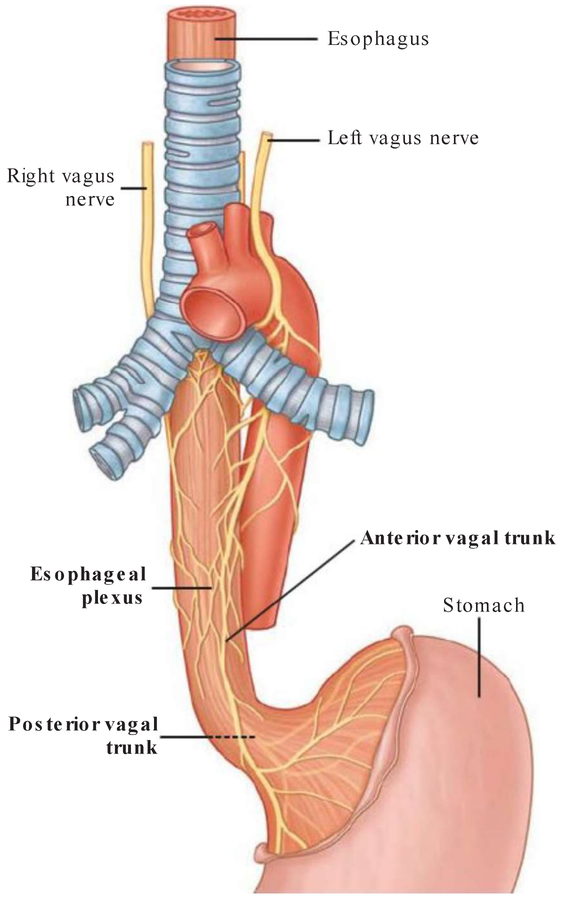


Fig. 3.97 Esophageal plexus.

Clinical app

Esophageal cancer

When patients present with esophageal cancer, it is important to note which portion of the esophagus contains the tumor, because tumor location determines the sites to which the disease will spread.

Esophageal cancer spreads quickly to lymphatics, draining to lymph nodes in the neck and around the celiac artery in the abdomen. Endoscopy or barium swallow is used to assess the site. CT and MRI may be necessary to stage the disease.

Once the extent of the disease has been assessed, treatment can be planned.

Clinical app

Esophageal rupture

The first case of esophageal rupture was described by Herman Boerhaave in 1724. This case was fatal, but early diagnosis has increased the survival rate up to 65%. If the disease is left untreated, mortality is 100%.

Typically, the rupture occurs in the lower third of the esophagus with a sudden rise in intraluminal esophageal pressure produced by vomiting together with failure of the cricopharyngeus muscle in the lower neck to relax. Because the tears typically occur on the left, they are often associated with a large left pleural effusion that contains the gastric contents.

Thoracic aorta

The thoracic portion of the descending aorta (**thoracic aorta**) begins at the lower edge of vertebra TIV, where it is continuous with the arch of aorta. It ends anterior to the lower edge of vertebrae TXII, where it passes through the aortic hiatus posterior to the diaphragm. Situated to the left of the vertebral column superiorly, it approaches the midline inferiorly, lying directly anterior to the lower thoracic vertebral bodies (Fig. 3.98). Throughout its course, it gives off a number of branches, which are summarized in Table 3.3.

Azygos system of veins

The azygos system of veins consists of a series of longitudinal vessels on each side of the body that drain blood from the body wall and move it superiorly to the superior vena cava. Blood from some of the thoracic viscera may also enter the system, and there are anastomotic connections with abdominal veins.

The longitudinal vessels may or may not be continuous and are connected to each other from side to side at various points throughout their course (Fig. 3.99).

The azygos system of veins serves as an important anastomotic pathway capable of returning venous blood from the lower part of the body to the heart if the inferior vena cava is blocked.

The major veins in the system are:

- the azygos vein, on the right, and
- the hemiazygos vein and the accessory hemiazygos vein, on the left.

There is significant variation in the origin, course, tributaries, anastomoses, and termination of these vessels.

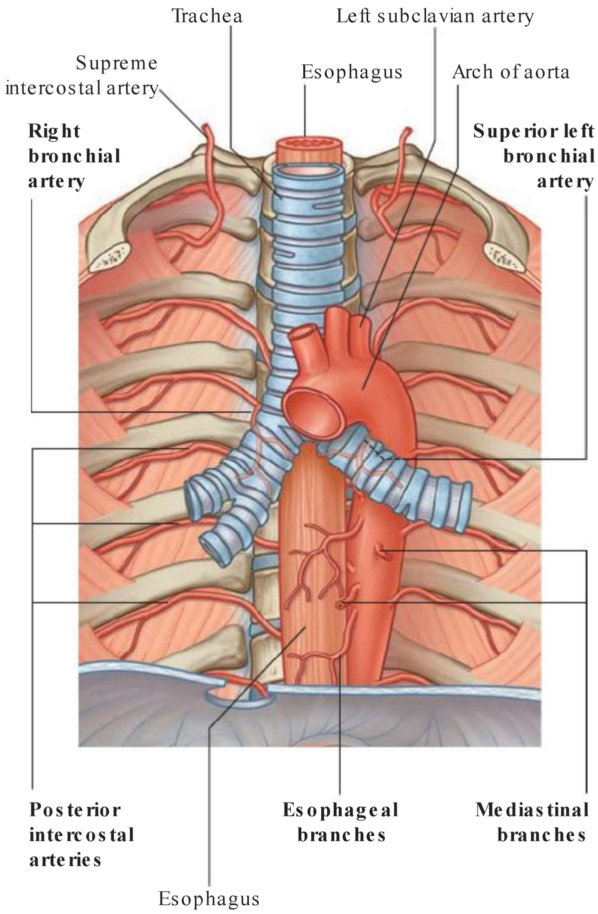


Fig. 3.98 Thoracic aorta and branches.

Table 3.3 Branches of the thoracic aorta

Branches	Origin and course
Pericardial branches	A few small vessels to the posterior surface of the pericardial sac
Bronchial branches	Vary in number, size, and origin—usually two left bronchial arteries from the thoracic aorta and one right bronchial artery from the third posterior intercostal artery or the superior left bronchial artery
Esophageal branches	Four or five vessels from the anterior aspect of the thoracic aorta, which form a continuous anastomotic chain—anastomotic connections include esophageal branches of the inferior thyroid artery superiorly, and esophageal branches of the left inferior phrenic and the left gastric arteries inferiorly
Mediastinal branches	Several small branches supplying lymph nodes, vessels, nerves, and areolar tissue in the posterior mediastinum
Posterior intercostal arteries	Usually nine pairs of vessels branching from the posterior surface of the thoracic aorta—usually supply the lower nine intercostal spaces (first two spaces are supplied by the supreme intercostal artery—a branch of the costocervical trunk)
Superior phrenic arteries	Small vessels from the lower part of the thoracic aorta supplying the posterior part of the superior surface of the diaphragm—they anastomose with the musculophrenic and pericardiacophrenic arteries
Subcostal artery	The lowest pair of branches from the thoracic aorta located inferior to rib XII

Azygos vein

The **azygos vein** arises opposite vertebra LI or LII at the junction of the **right ascending lumbar vein** and the **right subcostal vein** (Fig. 3.99). It may also arise as a direct branch of the inferior vena cava, which is joined by a common trunk from the junction of the right ascending lumbar vein and the right subcostal vein.

The azygos vein enters the thorax through the aortic hiatus of the diaphragm, or through or posterior to the right crus of the diaphragm. It ascends through the posterior mediastinum, usually to the right of the thoracic duct. At approximately vertebral level TIV, it arches anteriorly, over the root of the right lung, to join the superior vena cava before the superior vena cava enters the pericardial sac.

Tributaries of the azygos vein include:

- the **right superior intercostal vein** (a single vessel formed by the second, third, and fourth intercostal veins),
- fifth to eleventh right posterior intercostal veins,
- the hemiazygos vein,
- the accessory hemiazygos vein,
- esophageal veins,
- mediastinal veins,
- pericardial veins, and
- right bronchial veins.

Hemiazygos vein

The **hemiazygos vein** (**inferior hemiazygos vein**) usually arises at the junction between the **left ascending lumbar vein** and the **left subcostal vein** (Fig. 3.99). It may also arise from either of these veins alone and often has a connection to the left renal vein.

The hemiazygos vein usually enters the thorax through the left crus of the diaphragm, but may enter through the aortic hiatus. It ascends through the posterior mediastinum, on the left side, to approximately vertebral level TIX. At this point, it crosses the vertebral column, posterior to the thoracic aorta, esophagus, and thoracic duct, to enter the azygos vein.

Tributaries joining the hemiazygos vein include:

- the lowest four or five left posterior intercostal veins,
- esophageal veins, and
- mediastinal veins.

Accessory hemiazygos vein

The **accessory hemiazygos vein** (**superior hemiazygos vein**) descends on the left side from the superior portion of the posterior mediastinum to approximately vertebral level TVIII (Fig. 3.99). At this point, it crosses the vertebral column to join the azygos vein, or ends in the hemiazygos vein, or has a connection to both veins. Usually, it also has a connection superiorly to the **left superior intercostal vein**.

Vessels that drain into the accessory hemiazygos vein include:

- the fourth to eighth left posterior intercostal veins, and
- sometimes, the left bronchial veins.

Thoracic duct in the posterior mediastinum

The thoracic duct is the principal channel through which lymph from most of the body is returned to the venous system. It begins as a confluence of lymph trunks in the abdomen, sometimes forming a saccular dilation referred to as the **cisterna chyli** (**chyle cistern**), which drains the abdominal viscera and walls, pelvis, perineum, and lower limbs.

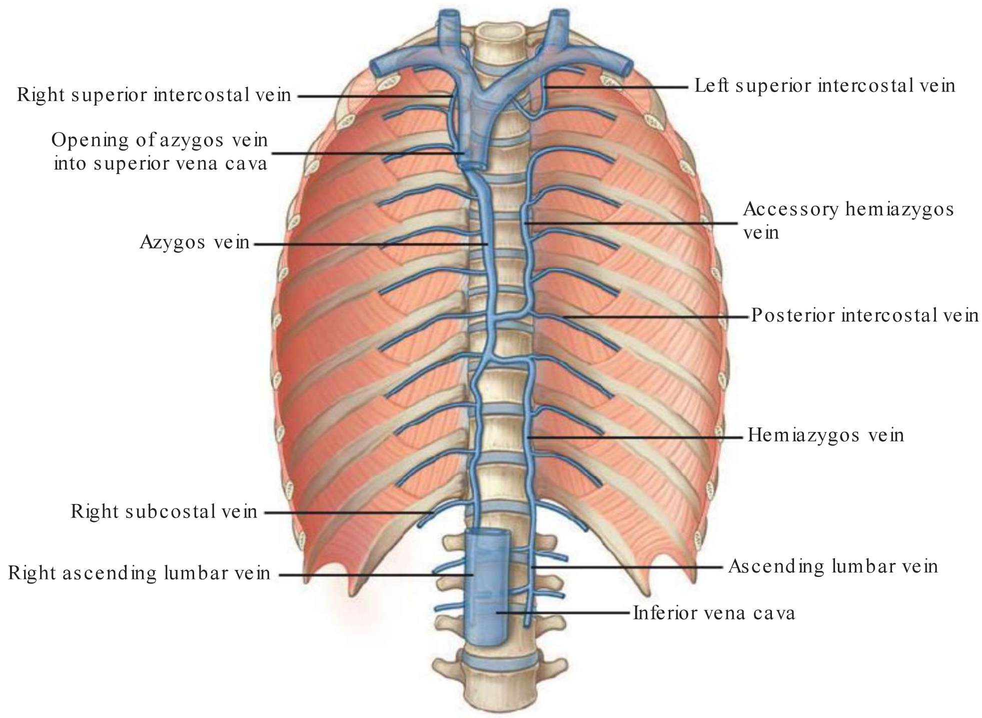


Fig. 3.99 Azygos system of veins.

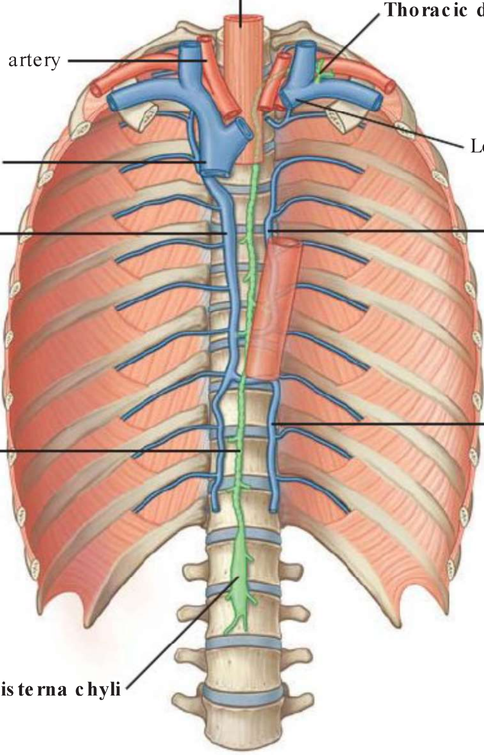


Fig. 3.100 Thoracic duct.

The thoracic duct extends from vertebra LII to the root of the neck.

Entering the thorax, posterior to the aorta, through the aortic hiatus of the diaphragm, the thoracic duct ascends through the posterior mediastinum to the right of midline between the thoracic aorta on the left and the azygos vein on the right (Fig. 3.100). It lies posterior to the diaphragm and the esophagus and anterior to the bodies of the vertebrae.

At vertebral level TV, the thoracic duct moves to the left of midline and enters the superior mediastinum. It continues through the superior mediastinum and into the neck.

After being joined, in most cases, by the **left jugular trunk**, which drains the left side of the head and neck, and the **left subclavian trunk**, which drains the left upper limb, the thoracic duct empties into the junction of the left subclavian and left internal jugular veins.

The thoracic duct usually receives the contents from:

- the confluence of lymph trunks in the abdomen,
- descending thoracic lymph trunks draining the lower six or seven intercostal spaces on both sides,
- upper intercostal lymph trunks draining the upper left five or six intercostal spaces,
- ducts from posterior mediastinal nodes, and
- ducts from posterior diaphragmatic nodes.

Sympathetic trunks

The **sympathetic trunks** are an important component of the sympathetic part of the autonomic division of the peripheral nervous system and are usually considered a component of the posterior mediastinum as they pass through the thorax (also see Chapter 1, pp. 23–26).

This portion of the sympathetic trunks consists of two parallel cords punctuated by 11 or 12 **ganglia** (Fig. 3.101). The ganglia are connected to adjacent thoracic spinal nerves by **white** and **gray rami communicantes** and are numbered according to the thoracic spinal nerve with which they are associated.

In the superior portion of the posterior mediastinum, the trunks are anterior to the neck of the ribs. Inferiorly, they become more medial in position until they lie on the lateral aspect of the vertebral bodies. The sympathetic trunks leave the thorax by passing posterior to the diaphragm under the medial arcuate ligament or through the crura of the diaphragm. Throughout their course the trunks are covered by parietal pleura.

Branches from the ganglia

Two types of medial branches are given off by the ganglia:

- The first type includes branches from the upper five ganglia.

- The second type includes branches from the lower seven ganglia.

The first type includes branches from the upper five ganglia and is mainly postganglionic sympathetic fibers, which supply the various thoracic viscera. These branches are relatively small, and also contain visceral afferent fibers.

The second type includes branches from the lower seven ganglia and is mainly preganglionic sympathetic fibers, which supply the various abdominal and pelvic viscera. These branches are large, carry visceral afferent fibers, and form the three thoracic splanchnic nerves referred to as the greater, lesser, and least splanchnic nerves (Fig. 3.101).

- The **greater splanchnic nerve** on each side usually arises from the fifth to ninth or tenth thoracic ganglia. It descends across the vertebral bodies moving in a medial direction, passes into the abdomen through the crus of the diaphragm, and ends in the celiac ganglion.
- The **lesser splanchnic nerve** usually arises from the ninth and tenth or tenth and eleventh thoracic ganglia. It descends across the vertebral bodies moving in a medial direction, and passes into the abdomen through the crus of the diaphragm to end in the aorticorenal ganglion.
- The **least splanchnic nerve** (**lowest splanchnic nerve**), when present, usually arises from the twelfth thoracic ganglion. It descends and passes into the abdomen through the crus of the diaphragm to end in the renal plexus.

Anterior mediastinum

The **anterior mediastinum** is posterior to the body of the sternum and anterior to the pericardial sac (see Fig. 3.53).

- Its superior boundary is a transverse plane passing from the sternal angle to the intervertebral disc between vertebrae TIV and TV, separating it from the superior mediastinum.
- Its inferior boundary is the diaphragm.
- Laterally, it is bordered by the mediastinal part of parietal pleura on either side.

The major structure in the anterior mediastinum is a portion of thymus, described previously (see Fig. 3.85). Also present are fat, connective tissue, lymph nodes, mediastinal branches of the internal thoracic vessels, and sternopericardial ligaments, which pass from the posterior surface of the body of the sternum to the fibrous pericardium.

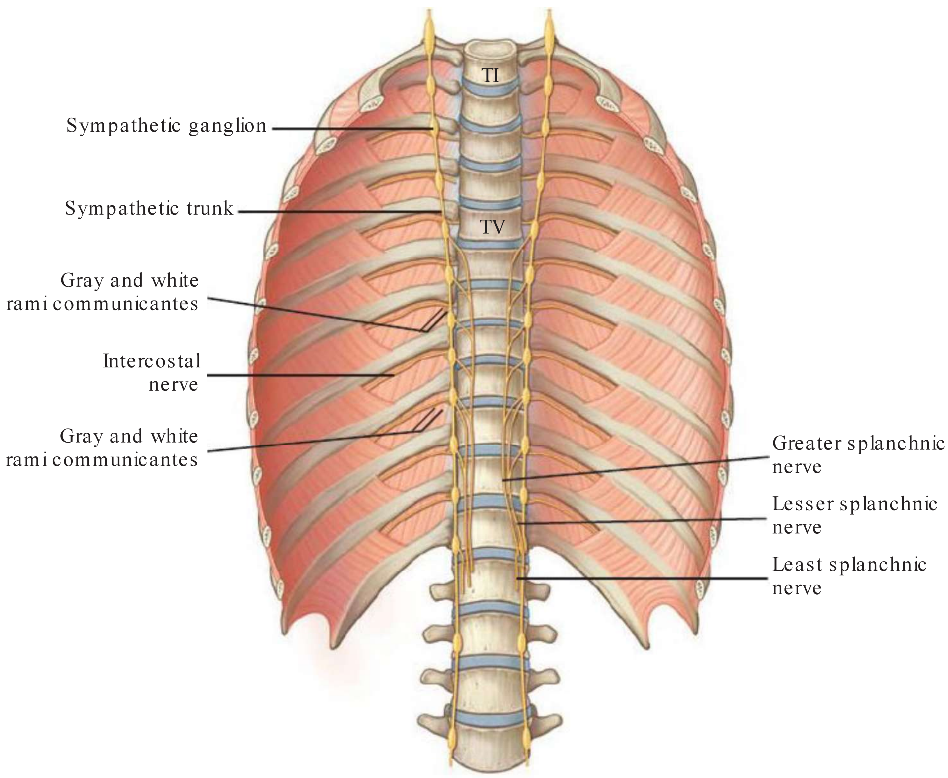
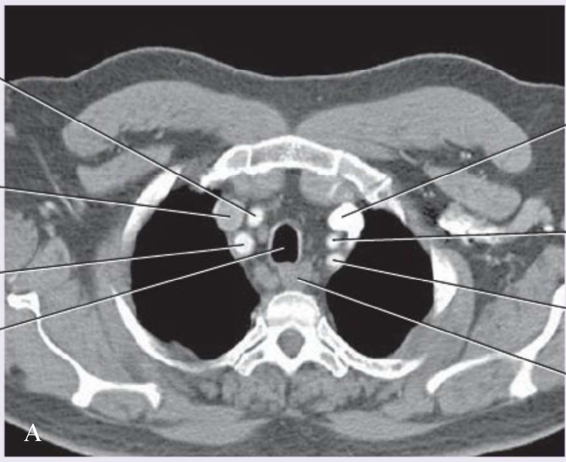


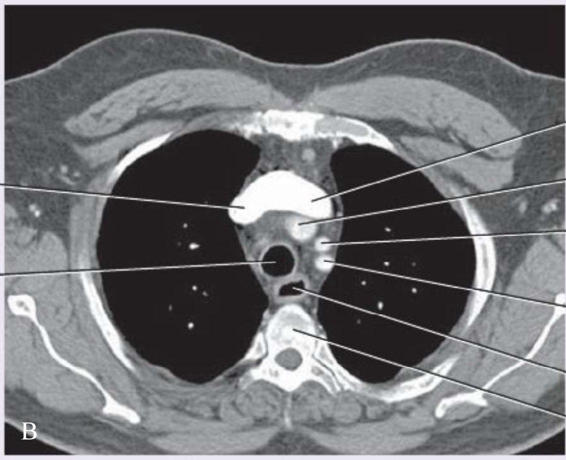
Fig. 3.101 Thoracic portion of sympathetic trunks.

Imaging app

Visualizing the mediastinum in the axial plane
Fig. 3.102A through I

This is a series of images that pass through the thorax from superior to inferior showing the various mediastinal structures and their relationships with each other. CT images, with contrast, in axial plane.





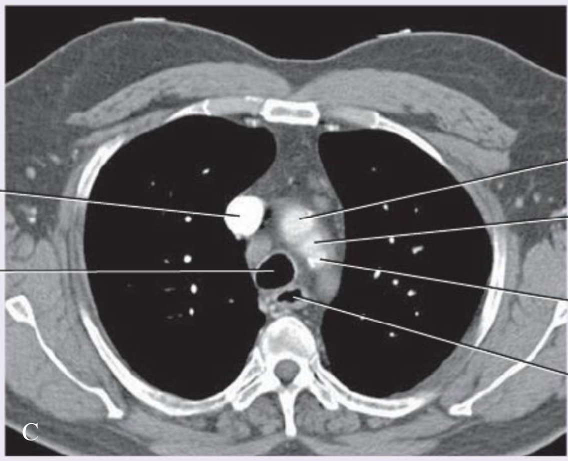
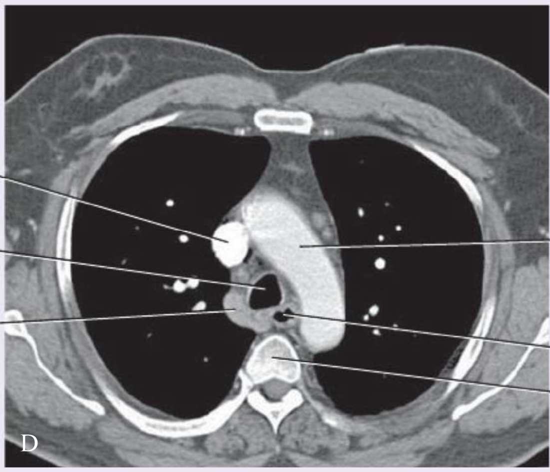
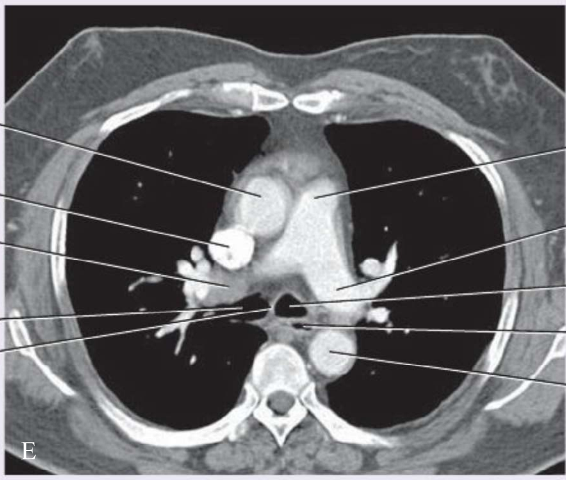


Fig. 3.102





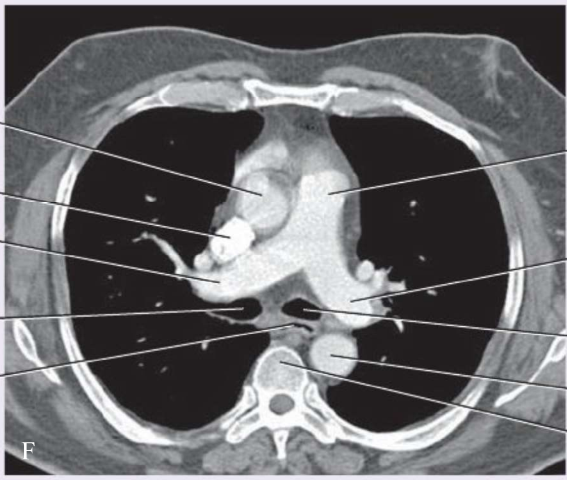


Fig. 3.102, cont'd

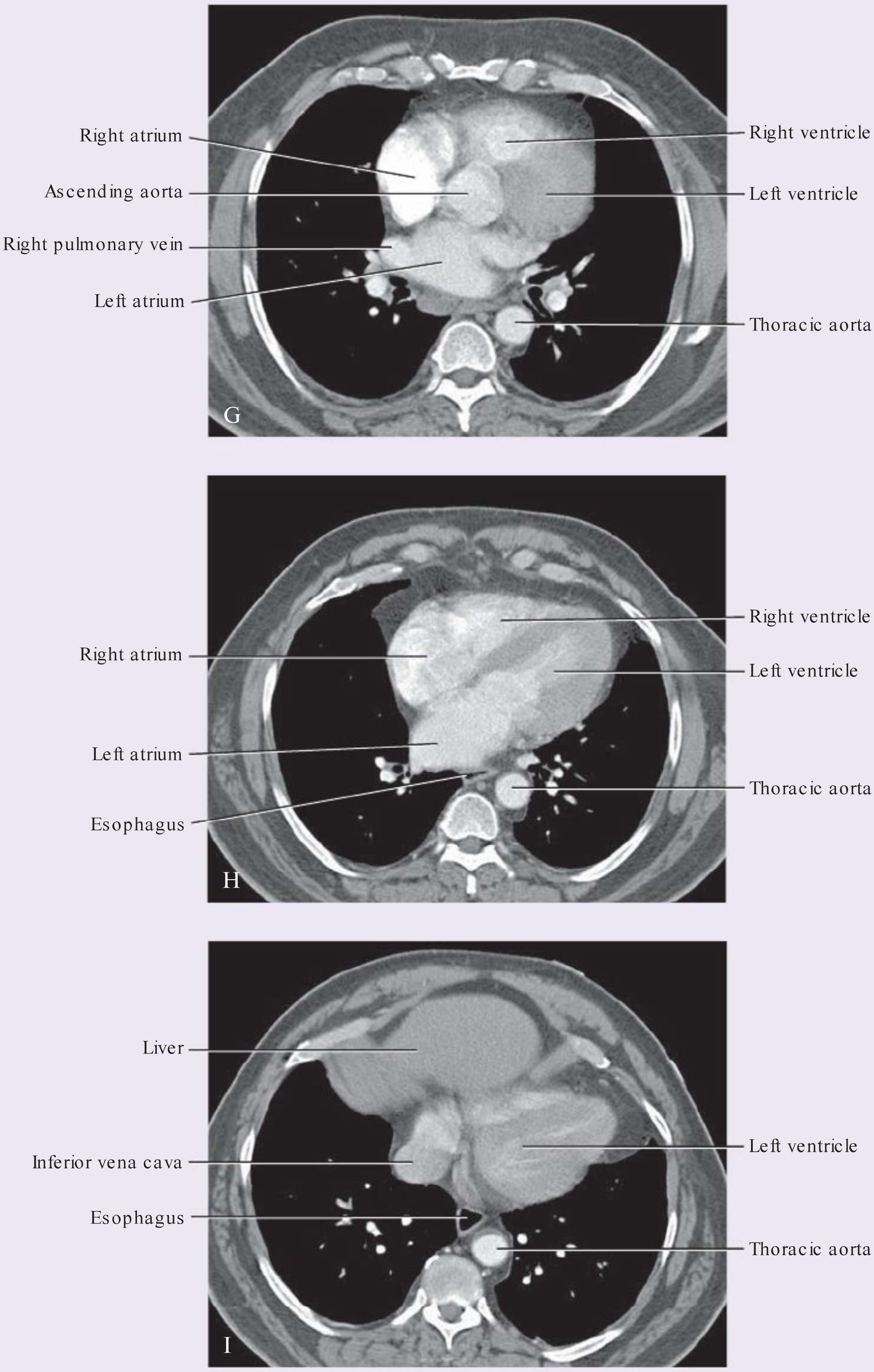


Fig. 3.102, cont'd