Chapter 4: The thoracic cavity and heart

The thoracic cavity is divided into right and left pleural cavities by a central partition, the mediastinum. The mediastinum is bounded behind by the vertebral column and in front by the sternum; inferiorly it is limited by the diaphragm and above is continuous with the structures in the root of the neck. It contains the heart, larger vessels, oesophagus, trachea and lymph nodes, all embedded in loose areolar tissue. By careful positioning of the person and the use of radiopaque media, many of the organs can be investigated radiologically.

The Heart

The heart is the muscular pump of the systemic and pulmonary circulations. There are four chambers (two atria and two ventricles), which are demarcated on its surface by coronary and interventricular sulci. The direction of flow of the blood is maintained by means of unidirectional valves placed between the atria and the ventricles, and between the ventricles and the large emerging aorta and pulmonary trunk. The heart lies within the pericardial sac, suspended by the large vessels. The organ is the size of a clenched fist, weighs about 300 g and is the shape of a flattened cone, possessing a base and an apex. It lies obliquely across the lower mediastinum behind the sternum.

The base faces posteriorly; it is square in outline and is formed mainly of the left atrium, receiving the four pulmonary veins. The apex is at the left inferior extremity of the heart and is formed by the tip of the left ventricle. The anterior (sternocostal) surface is formed mainly by the right ventricle which is separated by the vertical coronary sulcus from the right atrium above and by the anterior interventricular sulcus from the left ventricle. The surface merges superiorly with the beginning of the aorta and pulmonary artery.

The inferior (diaphragmatic) surface is formed mainly of the right and left ventricles anteriorly and part of the right atrium posteriorly. The inferior vena cava enters the right atrium at the right posterior corner of this surface which rests on the central tendon of the diaphragm. The left surface is formed by the left ventricle and a small part of the left atrium. It is in contact with the left lung. The right surface is formed by the right atrium which receives the superior vena cava above and the inferior vena cava below. It is in contact with the right lung.

The chambers of the heart

The right chambers of the heart pump blood through the lungs, and the left through the systemic circulation.

The right atrium is a thin-walled narrow chamber. Between the superior and inferior venae cavae, it forms the right border of the heart. Superomedially a small projection, the right auricle, overlaps the beginning of the ascending aorta. The posterior part of the wall behind the caval openings is smooth and separates the cavity from the left atrium. It is marked by a shallow oval depression, the fossa ovalis, bounded by a crescentic ridge, the limbus of the fossa ovalis. Anteriorly the wall is thicker and formed of parallel muscular ridges which pass transversely from the right auricle to a prominent vertical ridge, the crista terminalis, between the caval openings.
The superior caval orifice in the upper part of the cavity has no valve; to its left lies
the cavity of the right auricle. The inferior caval orifice is guarded by a thin fold of
endocardium anteriorly, the valve of the inferior caval opening and between them is a smaller
orifice, the opening of the coronary sinus, also with an endocardial flap guarding it.

The right ventricle is a thick-walled elongated chamber projecting forwards and to
the left of the right atrium and forming part of the anterior and inferior surfaces of the heart.
The interventricular septum separates the right from the left ventricle and bulges into the right
cavity, making it crescentic in cross section. The walls of the cavity are covered by
interlacing muscle bands except superiorly where the smooth-walled wide infundibulum leads
to the pulmonary orifice. Near the apex a distinct muscle bundle, the septomarginal band,
often crosses the cavity. The atrioventricular orifice lies postero-inferiorly. It is guarded by
the tricuspid valve which possesses three thin cusps, each attached at its base to the fibrous
ring surrounding the orifice. The cusps consist of a little fibrous tissue covered on both sides
by endocardium. The atrial surfaces of the valve cusps are smooth. Their margins and
ventricular surfaces are rough and anchored to the ventricular walls by fine tendinous cords
which arise directly from the septum or from two small conical papillary muscles situated
on the walls of the cavity. These muscles tighten the tendinous cords and prevent eversion
of the cusps into the atrial cavity during ventricular contraction. The pulmonary orifice is a
fibrous ring lying at the upper end of the smoother infundibulum. It is guarded by a valve
possessing three semilunar valves, one posterior and two anterior. In the middle of the free
margin of each valve is a thickened nodule.

The left atrium, a thin-walled, rectangular chamber, lies behind the right atrium and
forms most of the base of the heart. Superiorly a small irregular projection, the left auricle
overlies the left side of the pulmonary trunk. The four pulmonary veins enter symmetrically
on the smooth posterior surface, two on each side; their orifices possess no valves. The left
atrioventricular orifice lies in the anterior wall. The posterior wall of the atrium is separated
by the cavity of the pericardium from the oesophagus, left bronchus and descending thoracic
aorta.

The left ventricle extends forwards and to the left from the left atrium and lies mainly
behind the right ventricle. It forms the apex, the left border and surface, and part of the
anterior and inferior surfaces of the heart. Its walls are very thick and covered on the inside
by muscular ridges except for a smooth area just below the aortic orifice, the vestibule. The
conical cavity possesses two orifices, the left atrioventricular posterior and the aortic
superiorly. The left atrioventricular orifice is guarded by the mitral (bicuspid) valve, the two
cusps of which are attached to a fibrous ring surrounding the orifice. Their free margins and
ventricular surfaces are anchored to papillary muscles on the ventricular wall by tendinous
cords. The anterior cusp is the larger, lies between the aortic and mitral orifices, and blood
flows over both its surfaces. The aortic orifice is a fibrous ring lying behind and to the right
of the pulmonary orifice. It is guarded by a valve possessing three semilunar valves (one
anterior, two posterior) which are similar to those of the pulmonary valve.

The position of the interventricular septum is marked on the surface of the heart by
the anterior and posterior interventricular sulci. The right ventricle, into which the septum
bulges, lies anterior, the left ventricle posterior. The septum is very thick except for a thin
membranous portion between the vestibule and the infundibulum.
Blood and nerve supply

Arteries

Right coronary artery

This arises from the anterior aortic sinus and passes forwards between the right auricle and the pulmonary trunk to gain the right coronary sulcus in which it runs, firstly descending the anterior surface and then crossing the posterior surface of the heart where it anastomoses with the left coronary artery.

Branches

(i) atrial and ventricular branches.

(ii) marginal artery - runs to the left towards the apex along the lower border of the heart.

(iii) posterior interventricular artery - runs along the posterior interventricular sulcus towards the apex and anastomoses with the anterior interventricular artery.

Left coronary artery

This arises from the left posterior aortic sinus. It passes forward between the left auricle and the pulmonary trunk to gain the left coronary sulcus.

Branches

(i) atrial and ventricular branches.

(ii) anterior interventricular artery - descends in the anterior interventricular sulcus towards the apex, turns round the lower border and anastomoses with the posterior interventricular artery. It gives off a diagonal branch to the left ventricle.

(iii) circumflex artery - runs to the left in the coronary sulcus and then passes behind to anastomose with the terminal branch of the right coronary artery. It gives off the marginal artery which runs along the left border of the heart.

Generally the right ventricle is supplied by the right coronary artery, the left ventricle by the left, the interventricular septum by both, and the atria in a variable manner.

Although anastomoses between the two arteries are present in the coronary sulcus, near the apex and in the septum, sudden occlusion of a large branch may result in ischaemia of an area of heart muscle. If the area affected includes the conducting system or is relatively large, death of the patient may occur. Lesser degrees of damage decrease the work capacity of the heart and ischaemia pain (angina) may be experienced on exertion. Stenosis in the coronary arteries may be amenable to dilatation, using a percutaneous fine balloon, or the occlusion may be surgically bypassed. In the latter, a length of long saphenous vein is
anastomosed to a punched out hole in the ascending aorta and anastomosed distally to a coronary artery, beyond the occlusion.

Rupture of a papillary muscle may result in incompetence of the mitral or tricuspid valve. This, or other disease of the valve, may be surgically corrected by inserting an artificial valve in place of the defective one.

Veins

These drain mainly via the coronary sinus. The anterior cardiac veins and the venae cordis minima open into the right atrium.

The coronary sinus is formed at the left border of the heart as a continuation of the great cardiac vein. It passes to the right in the posterior coronary sulcus and enters the right atrium near the orifice of the inferior vena cava. It is about 3 cm long.

Tributaries

(i) great cardiac vein - is a large vessel which drains both ventricles. It ascends the anterior interventricular sulcus, turns around the left border of the heart and becomes the coronary sinus. A left marginal vein enters it.

(ii) middle cardiac vein - lies in the posterior interventricular sulcus.

(iii) small cardiac vein - runs to the left in the coronary sulcus and enters the right extremity of the coronary sinus. It is the continuation of the right marginal vein which runs along the lower border of the heart.

(iv) left posterior ventricular vein - runs up the back of the left ventricle and enters the coronary sinus.

(v) oblique vein - lies on the posterior wall of the left atrium. It is a remnant of the left superior vena cava of the embryo.

Anterior cardiac veins - several small veins which drain the anterior wall of the right ventricle and open into the right atrium.

Venae cordis minima - are small veins draining much of the heart wall. They open directly into the cavities of the heart.

Lymph drainage

This is to the tracheobronchial lymph nodes.

Nerve supply

This is derived from the vagus and sympathetic fibres (upper thoracic segments) through the cardiac plexus. The fibres are distributed with the coronary arteries.
Parasympathetic ganglion cells are found on the heart walls. Sensory fibres subserving reflex activity pass in the vagus, and pain fibres pass in to the spinal nerves (T1-T3). Many pain fibres traverse the sympathetic ganglia before entering the nearby spinal nerves.

**Histology**

The heart wall is composed of three layers; a thin outer epicardium (serous pericardium), a very thick muscular (myocardial) layer and a thin inner endocardium of cubical endothelial cells. The myocardial cells are embedded in areolar tissue. Except for the AV bundle there is no myocardial continuity between the atria and the ventricles; they are separated by a pair of fibrous rings encircling both atrioventricular orifices in a figure-of-eight fashion. To these rings the myocardial muscle fibres are attached and they encircle the heart chambers in complex spirals and whorls. Cardiac muscle consists of branching striated fibres with a central nucleus and transverse intercalated discs at points of meeting of branches. The effectiveness of the heart depends largely on the state of cardiac muscle. Its efficiency as a pump also depends on the state of the valves.

**The conducting system of the heart**

This system is formed of specialised cardiac muscle cells which in man are difficult to distinguish histologically from cardiac muscle. It consists of the sinuatrial (SA) node, the atrioventricular (AV) node, the AV bundle (of His), its right and left branches and a terminal subendocardial plexus (Purkinje fibres). This system initiates the complex cardiac muscle contractions comprising the cardiac cycle, and controls its regularity.

The **SA node** (pacemaker) is a small vascular area of conducting tissue lying in the wall of the right atrium at the upper end of the crista terminalis and to the right of the superior caval opening. Impulses are conducted from it through the atrial wall to the **AV node** which is a similar nodule lying in the septal wall of the right atrium above the opening of the coronary sinus. The **AV bundle** arises from the node, descends across the membranous part of the interventricular septum and divides into right and left branches which are distributed to their respective ventricles. Some of the right branch traverses the septomarginal band to reach the anterior ventricular wall. The branches ramify and form the subendocardial plexus which is distributed to the papillary muscles and ventricular walls.

If the AV bundle is interrupted, for instance by its blood supply diminishing after coronary artery thrombosis, a condition known as total heart block occurs and the ventricles beat slowly at their own rate, independent of the atria which will continue to beat at the rate determined by the SA node.

**The pericardium**

The pericardium is a fibroserous membrane surrounding the heart and the adjacent parts of the large vessels entering and leaving it. It consists of an outer fibrous pericardium and an inner serous pericardium.

The **serous pericardium** is a closed serous sac, invaginated by the heart, possessing visceral and parietal layers and enclosing a narrow pericardial cavity. Visceral pericardium
covers the whole surface of the heart and is continuous with the parietal pericardium lining the inner surface of fibrous pericardium. The lines of reflection from the heart to the fibrous pericardium are shown in the figure. Its irregular form is related to the complex development of the heart. The serous pericardium is derived from the lining of the pericardial part of the coelomic cavity.

Fluid in the pericardium will limit the expansion and contraction of the heart and when this limitation is extreme it may be necessary to aspirate the fluid. A needle is inserted through a wheal of local anaesthetic, between the xiphoid and left costal margin and directed upwards, backwards and medially piercing the central tendon at the diaphragm to enter the distended pericardial sac.

The fibrous pericardium forms a strong flask-shaped sac around the heart and serous pericardium. It blends inferiorly with the central tendon of the diaphragm and with the adventitia of the inferior vena cava, superiorly with the adventitia of the aorta, pulmonary trunk and superior vena cava, and posteriorly with that of the pulmonary veins.

**Development of the heart and pericardium**

The embryonic heart develops from a vascular tube which hangs from the dorsal wall of the pericardial part of the coelomic sac. In its development two main processes are involved: (i) bending and differential growth, and (ii) division into right and left sides.

**Bending and differential growth of the heart tube**

The heart is suspended from the dorsal wall of the embryo by a mesentery, the dorsal mesocardium. The caudal (venous) end of the heart tube receives vessels which develop into the superior and inferior venae cavae and the pulmonary veins. These vessels remain enclosed in a common sleeve of pericardium. The cephalic (arterial) end divides to form the aorta and pulmonary artery which similarly remain enclosed in a common sleeve of pericardium. The cephalic part of the tube elongates and descends, becoming S-shaped, the arteries coming to lie in front of the veins. Simultaneously the middle of the dorsal mesocardium breaks down and forms a dorsal communication between the two sides of the pericardial cavity, the transverse sinus of the pericardium. This lies between the folded arterial and venous ends of the tube. In the adult the sinus lies behind the aorta and pulmonary artery, and in front of the superior vena cava and pulmonary veins.

The sleeve of pericardium surrounding the veins is stretched and forms a o-shaped cul-de-sac (the oblique sinus) bounded by two pulmonary veins on the left and two pulmonary veins and the venae cavae on the right. It is separated from the transverse sinus superiorly by a double layer of pericardium.

Four dilatations develop in the primitive heart, the sinus venosus at the venous end, then the atrium, the ventricle and the bulbus cordis (the latter leading into the truncus arteriosus). The atrium is continuous with the ventricle through a narrow atrioventricular canal.
Division into right and left sinus

Longitudinal partitions divide the atrium, ventricle and bulbus cordis into right and left atria, right and left ventricles and the pulmonary and aortic trunks respectively.

Division of the atrium and the atrioventricular canal

Two small projections, the endocardial cushions, unite across the narrow atrioventricular canal dividing it into right and left portions. In the atrial cavity a septum (the septum primum) descends and fuses with the endocardial cushions; it becomes perforated in its upper part. A septum secundum grows down on the right side of the septum primum, overlapping the perforation. The oblique communication which persists between the two cavities is known as the **foramen ovale**. The septum primum acts in a valve-like manner, opening the foramen ovale and allowing blood to flow from the right to the left atrium but not in the reverse direction. The lower edge of the septum secundum forms the limbus ovalis of the adult.

Division of the ventricle and bulbus cordis

The ventricle is divided by the development of a septum which fuses with the endocardial cushions above. The cavity of the bulbus cordis is divided by a spiral septum into the pulmonary and aortic trunks. The ventricular septum and the septum of the bulbus cordis unite with each other in such a way that the right ventricle leads into the pulmonary artery and the left ventricle into the aorta.

In their growth the ventricles incorporate part of the bulbus cordis thus forming the smooth-walled infundibulum and vestibule. The left atrium incorporates the pulmonary veins and the right atrium the sinus venosus and venae cavae, these forming the smooth-walled part of each cavity.

Fetal circulation

Oxygenated blood from the placenta passes through the liver in the ductus venosus and then into the inferior vena cava and right atrium. The angle between the superior and inferior venae cavae directs the placental blood through the foramen ovale into the left atrium. It then passes through the left ventricle into the aorta. Much of the blood goes to the head of the embryo to supply the developing brain. It returns to the heart in the superior vena cava and is directed into the right ventricle and then into the pulmonary artery. Blood in the pulmonary artery is shunted along the ductus arteriosus into the aorta, thus bypassing the lungs, and joins the aortic blood beyond the points of emergence of the cephalic blood flow. The blood in the thoracic and abdominal aorta passes to the rest of the body and much passes to the placenta in the umbilical arteries. The venous return from the body enters the inferior vena cava and mixes with the blood coming from the placenta through the umbilical vein and ductus venosus. At birth, the lungs take in air and there is a much greater flow of blood to the lungs with a subsequent increased venous return. This raises the pressure in the left atrium and so closes the foramen ovale. About the same time the ductus arteriosus and the ductus venosus also close, so establishing the adult pattern of circulation.
Cardiac abnormalities are among the most frequently encountered congenital defects and some are incompatible with independent life. One of the commonest abnormalities is a bicuspid aortic valve, this being usually without symptoms. Other abnormalities such as persistent patent ductus arteriosus, atrial septal defects (where the foramen ovale has failed to close) and ventricular defects may require surgical correction in childhood. Combined defects can also occur, the commonest consisting of a ventricular septal defect, pulmonary valvular stenosis (narrowing) and an aorta which communicates with both the right and left ventricular cavities. If the ductus fails to close, then pulmonary hypertension (high blood pressure in the lungs) results because of shunting of the systemic blood into the pulmonary circulation. Cardiac failure usually follows.