Anatomy of the heart

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Abstract

Despite centuries of writings and research into cardiac anatomy and function, the topic is still advancing, particularly in relation to clinical applications and embryological significance. This article presents the heart with reference to the classical anatomical position and attempts to clarify the nomenclature that is most commonly used by anatomists. We encourage clinicians to use the same terminology. The references are from an excellent compilation on the heart in Clinical Anatomy.

Keywords Atrium; cardiac embryology; chambers; coronary arteries; heart; pericardium; venous drainage; ventricle

The heart is a midline, valvular, muscular pump that is cone-shaped and the size of a fist. In adults, it weighs 300 grams and lies in the middle mediastinum of the thorax. The inferior (diaphragmatic) surface sits on the central tendon of the diaphragm, whereas the base faces posteriorly and lies immediately anterior to the oesophagus and (posterior to that) the descending aorta. The base comprises mainly the left atrium. The left surface (left ventricle) and right surface (right atrium) are each related laterally to a lung and a phrenic nerve in the fibrous pericardium. The anterior surface of the heart lies behind the sternum and the costal cartilages. The constituent parts of the anterior and inferior surfaces are dictated largely by the position of the interventricular septum. Although essentially a midline structure, one-third of the heart lies to the right of the midline and two-thirds to the left.

The interventricular septum bulges to the right because the wall of the left ventricle is much thicker (10 mm) than that of the right ventricle (3–5 mm). It also lies obliquely across the heart, almost in the coronal plane, such that the anterior surface of the heart is two-thirds right ventricle and one-third left ventricle; the proportions are reversed on the inferior surface. The thicker, muscular part of the interventricular septum is formed from the ventricular walls. The muscles of the four chambers and the four valves are attached to, and supported by, a figure-of-eight-shaped fibrous skeleton comprising a central fibrous body and extensions (fila coronaria) that surround the valves. This skeleton both divides and separates the atria electrically from the ventricles and is the remnant of the atrioventricular (AV) cushions. The thinner membranous part of the interventricular septum is formed from the lowest aspect of the spiral valve (neural crest cells), which divides the truncus arteriosus into the aorta and pulmonary trunk.

What’s new?

- The anatomy of the coronary sinus has taken on new clinical importance as a result of the expansion of electrophysiological investigations and interventions. There has been a drive to avoid the ‘Valentine’ approach to cardiac description that has crept into surgical usage and an appreciation of the need to adhere to strict anatomical references.
- The embryology of the heart has been revisited in an attempt to gain more insight into congenital anomalies — the classical concepts of cardiac looping and fate of the original heart tubes have been questioned.
- New and much improved methods of imaging the heart are now available.

Pericardium

The pericardium holds and protects the heart, but provides sufficient potential space for filling and emptying of the chambers. The outer layer is the tough fibrous pericardium, which blends with the adventitia of the aorta, the pulmonary trunk, the superior vena cava and the central tendon of the diaphragm. Within this, there are two layers of serous pericardium:

- a visceral layer, surrounding the heart
- a parietal layer, lining the inner surface of the fibrous pericardium.

These two layers of serous pericardium are continuous with each other as they reflect off the major vessels behind and above the heart. The reflection, posteriorly, between the pulmonary veins is termed the ‘oblique sinus’ of the pericardium. The plane between the superior vena cava and the pulmonary veins posteriorly, and the aorta and pulmonary trunk anteriorly, made by the folding of the heart, is termed the ‘transverse sinus’ of the pericardium.

The visceral layer and the heart itself are supplied by sympathetic nerves from the cardiac plexuses; these in turn carry general visceral afferent fibres to the vertebral levels from which the sympathetic supply arises, which are the three cervical sympathetic ganglia and the T1–5 ganglia — this explains why cardiac pain is referred to the neck, chest and arm.

Features of the chambers

Right atrium

The inferior vena cava passes through the diaphragm at the level of T8 and immediately enters the right atrium, which lacks a true valve. In the fetus, however, there is the so-called valve of the inferior vena cava, a fold of tissue that directs caval blood into the foramen ovale. The superior vena cava enters the superior aspect of the chamber. The fossa ovalis (a remnant of the septum primum) and its overhanging limbus (a remnant of the septum secundum) lie on the smooth, interatrial part of the chamber, which developed from the sinus venosus. This smooth area is separated from the muscular part, with its musculi pectinati, by the crista terminalis internally and the sulcus terminalis externally. The muscular part originated from the fetal atrium and is represented in the mature heart as the right atricle.

Between the opening of the inferior vena cava and the AV orifice lies the opening of the coronary sinus, which is protected...
in some hearts by a small (Thebesian) valve that prevents regurgitation into the coronary sinus during atrial contraction. The coronary sinus empties during systole. The AV node lies between this orifice and the septal cusp of the tricuspid valve.

**Right ventricle**

Blood enters the right ventricle via the tricuspid valve, which has anterior, septal and posterior (lying inferiorly) cusps attached to papillary muscles by fibrous chordae tendineae. The ventricular wall is normally 3–5 mm thick and raised internally by interweaving strands of muscle (trabeculae carneae). Some of this muscle joins the anterior papillary muscle, low on the anterior septal wall, as the septomarginal trabecula (moderator band) and carries part of the right bundle branch of conducting tissue, which ensures that the right ventricle contracts simultaneously with the left. Blood passes superiorly to leave this chamber via the smooth conus arteriosus (infundibulum) and the pulmonary valve, which has two anterior cusps and one posterior cusp (PAPA — Pulmonary—Anterior—Posterior—Anterior).

**Left atrium**

The left atrium is a box-shaped chamber that lies posteriorly at the base of the heart and receives blood from the lungs via four large, valveless pulmonary veins into the four quadrants of the chamber. The terminology and development of the smooth and muscular parts of the left atrium correspond to those of the right atrium except that the smooth part arises from incorporation of the pulmonary veins.

**Left ventricle**

Blood enters the left ventricle via the mitral valve, which has a larger anterior and smaller posterior cusp, each with chordae tendineae and papillary muscles. The mitral valve is an active valve and not simply a flap of tissue. The muscle wall is about 10 mm thick and roughened by trabeculae carneae. The smooth outflow tract is the aortic vestibule, corresponding to the membranous part of the interventricular septum, leading to the aortic valve with its two posterior cusps and one anterior cusp (APAP — Aortic—Posterior—Anterior—Posterior). The relationship of these cusps to the ostia of the coronary arteries is described below. The trabeculated pattern of the musculi pectinati in the auricles and the trabeculae carneae in the ventricles is an efficient means of gaining power without excessively thickening the wall of the chamber. A single papillary muscle has separate chordae tendineae to two adjacent valvular cusps, which helps draw them together to prevent valvular eversion during systole.

**Conducting system of the heart**

Specialized cardiac muscle fibres form the:

- sinuatrial node (in the right atrial wall between the opening of the superior vena cava and the auricle)
- AV node (in the left wall of the right atrium, at the superior limit of the interventricular septum)
- AV bundle (arising from the AV node and descending in the interventricular septum).

Contractions originating from the sinuatrial node (pacemaker) spread through the atrial walls to reach the AV node, and then the left and right bundles. The plexus of Purkinje fibres allows spread of excitation to the ventricular walls so that the inferior aspects of the ventricles contract first. Further autonomic nervous control is via cardiac branches from each of the cervical sympathetic ganglia and thoracic ganglia T1–5; parasympathetic fibres arise from the superior and inferior cardiac branches of the vagus and from the recurrent laryngeal nerve. All autonomic nerves pass via the superficial and deep cardiac plexuses on the lateral and medial aspects of the aortic arch.

**Blood supply to the heart**

The ostia of the coronary arteries arise in the aortic sinuses superior to the attachment of the base of the relevant cusp — the right from the anterior sinus (also known as sinus 1 or right coronary aortic sinus) and the left from the left posterior sinus (also known as sinus 2 or left coronary aortic sinus). The branches of the coronary arteries are shown in Figure 1 and listed in Table 1. The third sinus is named the right posterior sinus or non-coronary sinus.

**Right coronary artery**

The right coronary artery passes anteriorly from its origin between the right atrial appendage and the pulmonary trunk to enter first the right anterior AV groove and then the right posterior AV groove, where it anastomoses with the circumflex branch of the left coronary artery. In 90% of individuals, it provides a posterior (inferior) interventricular branch as it reaches the posterior interventricular groove on the inferior surface of the heart; this anastomoses with the termination of the anterior interventricular artery (left coronary) in the groove at the apex of the heart.

**Left coronary artery**

The left coronary artery arises from the left posterior aortic sinus and passes anteriorly between the left atrial appendage and

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**Coronary arteries and branches**

- **Left atrial**
- **Right conus**
- **Sinuatrial nodal**
- **Circumflex**
- **Left atrial**
- **Diagonal**
- **Left marginal**
- **Anterior interventricular (anterior descending) and septal branches**

**Figure 1**

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pulmonary trunk, to lie in the left anterior AV groove. Here it divides into the:

- circumflex artery and the
- anterior interventricular artery.

The circumflex artery continues first in the anterior and then in the posterior AV groove, and anastomoses with the terminal branches of the right coronary artery. The anterior interventricular artery (often termed the ‘left anterior descending artery’ or LAD) passes down the same named groove, around the apex of the heart, and anastomoses with the terminal branches of the posterior (inferior) interventricular artery.

The 10% of individuals in whom most of both ventricles and the septum are supplied by the left coronary artery are said to have left cardiac (coronary) dominance. The presence of collateral communications between the right and left coronary systems has been recently reviewed, suggesting that there is more collateral circulation than classically taught. Note that the coronary arteries fill and distribute blood to the heart during diastole when cardiac muscle is relaxed and vascular resistance low.

Venous drainage of the heart
The distribution of the veins of the heart is much more variable than the arteries. Drainage of both ventricles starts with the great cardiac vein in the anterior interventricular groove (Figure 2), which passes to the left in the anterior AV groove, where it collects the left marginal vein. As it runs in the posterior AV groove, it is joined by the oblique vein of the left atrium, the posterior ventricular vein and, finally, the middle cardiac vein, which lies in the posterior interventricular groove and drains the left and right ventricles posteriorly. The confluence of these veins is the 3-cm long coronary sinus, lying in the posterior AV groove. Just before the coronary sinus enters the right atrium, it is usually joined by the small cardiac vein, which drains the right atrium and right ventricle. The small cardiac vein sometimes drains directly into the right atrium. A couple of anterior cardiac veins drain the anterior aspect of the right ventricle and right atrium before crossing the right coronary artery to enter the right atrium. In addition, 20–30% of all drainage is in the venae cordis minimae (Thebesian veins) – small venous channels seen throughout the myocardium that drain directly into the chambers of the heart.

Table 1

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<td>Left marginal vein</td>
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<td>Oblique vein-left atrium</td>
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<td>Coronary sinus</td>
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<td>Anterior cardiac veins</td>
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<td>Great cardiac vein</td>
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Figure 2