Anatomy of the heart

Robert H Whitaker

Abstract

Although the anatomy of the heart remains unchanging, our understanding of its function and development has advanced. This knowledge is increasingly important for modern investigations, which include echocardiological and electrophysiological studies. This article presents the heart as understood by anatomists, and uses the time-honoured nomenclature, particularly for the aortic and pulmonary valves and origins of the coronary arteries. The references are from an excellent compilation on the heart in *Clinical Anatomy*.

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

Key points

- The anatomy of the coronary sinus has taken on new clinical importance because of the expansion of electrophysiological investigations and interventions. The sinus can give access to the left side of the heart and allow detection of ectopic foci from the left atrium
- The embryology of the heart remains highly relevant to our understanding of congenital anomalies
- Left cardiac dominance is an important factor in survival after myocardial infarction

Introduction

The heart is a midline, valvular, muscular pump that is cone-shaped and the size of a fist. In adults, it weighs 300 g and lies in the middle mediastinum of the thorax. The inferior (diaphragmatic) surface sits on the central tendon of the diaphragm, while 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 costal cartilages. The constituent parts of the anterior and inferior surfaces are dictated largely by the position of the interventricular septum. This lies approximately half way between the coronal and sagittal planes 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 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). The thicker, muscular part of the interventricular septum is formed by an up-growth of the ventricular walls. 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. 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.

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Pericardium

This holds and protects the heart, but provides sufficient potential space for expansion 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 lie two layers of serous pericardium:

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

These two serous layers are continuous with each other as they reflect off the major vessels behind and superior to 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. This is important in isolating the major vessels during surgery and placing the patient on cardiopulmonary bypass.

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 – the three cervical sympathetic ganglia and T1–T5 ganglia, which 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 T8 vertebral level 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 originates from the fetal atrium and is represented in the mature heart as the right auricle.

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Between the opening of the inferior vena cava and the AV orifice lies the opening of the coronary sinus. In some hearts, this is protected by a small (Thebesian) valve that prevents regurgitation into the coronary sinus during atrial contraction. 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 3–5 mm thick ventricular wall is 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) that carries part of the right bundle branch of conducting tissue. This ensures that the right ventricle contracts simultaneously with the left. Blood passes superiorly to leave this chamber via the smooth conus arteriosus (infundibulum) and pulmonary valve, which has one posterior and two anterior cusps.

Left atrium

The left atrium is a box-shaped chamber that lies posteriorly at the base of the heart; it 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 leaflet; each has chordae tendineae and papillary muscles. The mitral valve is an active valve and not simply a flap of tissue.[1] The 10 mm thick muscle wall is roughened by trabeculae carneae. The smooth outflow tract is the aortic vestibule, corresponding to the membranous part of the interventricular septum; it leads to the aortic valve with its one anterior and two posterior cusps. 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 trabeculae carneae in the ventricles is an efficient means of gaining power without excessively thickening the wall of the chamber. Each papillary muscle in both ventricles 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:

- sinoatrial (SA) 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 (His) bundle – arising from the AV node, descending in the interventricular septum and extending into the moderator band.

Contractions originating from the SA 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–T5; parasympathetic fibres arise from the superior and inferior cardiac branches of the vagus, and from the recurrent laryngeal nerve.[2] All autonomic nerves pass via the superficial and deep cardiac plexuses on the lateral and medial aspects of the aortic arch.

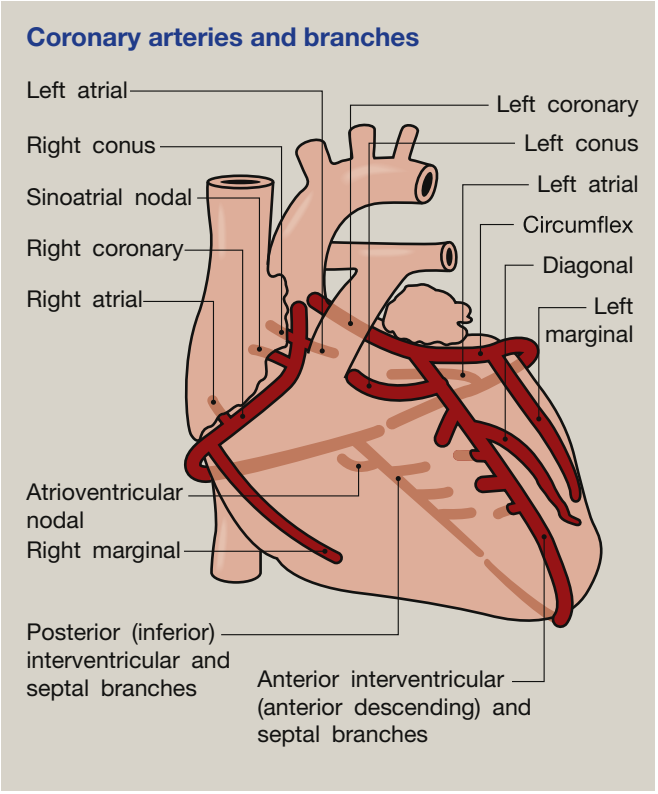

Figure 1

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.[3]

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 (posterior descending artery); this anastomoses with

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