Chapter

The Heart: Anatomy, Physiology and Exercise Physiology

1

Syed Shah, Gopinath Gnanasegaran, Jeanette Sundberg-Cohon, and John R Buscombe

Contents

1.1 Introduction

The impact of anatomy on medicine was first recognised by Andreas Vesalius during the 16th century [1] and from birth to death, the heart is the most talked about organ of the human body. It is the centre of attraction for people from many lifestyles, such as philosophers, artists, poets and physicians/surgeons. The heart is one of the most efficient organs in the human body and heart disease is one of the commonest causes of morbidity and mortality in both developing and developed countries. Understanding the anatomy and pathophysiology is very important and challenging. With innovative changes in the imaging world, the perception of these has changed radically and applied anatomy and physiology plays an important role in understanding structure and function.

1.2 Anatomy of the Heart

The heart is located in the chest, directly above the diaphragm in the region of the thorax called mediastinum, specifically the middle mediastinum. The normal human heart varies with height and weight (Table 1.1). The tip (apex) of the heart is pointed forward, downward, and toward the left. The (inferior) diaphragmatic surface lies directly on the diaphragm. The heart lies in a double walled fibroserous sac called the pericardial sac, which is divided into (a) fibrous pericardium, and (b) serous pericardium. The fibrous pericardium envelops the heart and attaches onto the great vessels [2]. The serous pericardium is a closed sac consisting of two layers – a visceral layer or epicardium forming the outer lining of the great vessels and the heart, and a parietal layer forming an inner lining of the fibrous pericardium [2–4]. The two layers of the serous pericardium contain the pericardial fluid, which prevents friction between the heart and the pericardium [2–4].

Table 1.1 Anatomical facts about the human heart

Normal human heart varies with height and weight
Weighs approximately 300–350 grams in males
Weighs approximately 250–300 grams in females
Right ventricle thickness is 0.3–0.5 cm
Left ventricle thickness is 1.3–1.5 cm
Divided into four distinct chambers
Composed of three layers (epicardium, myocardium and endocardium)
Contains two atria (left and right)
Contains two ventricles (left and right)
Contains four valves (aortic, mitral, tricuspid, pulmonary)

The wall of the heart is composed of three layers: (a) epicardium; (b) myocardium; and (c) endocardium (Fig. 1.1) [5, 6]. The epicardium is the outer lining of the cardiac chambers and is formed by the visceral layer of the serous pericardium. The myocardium is the intermediate layer of the heart and is composed of three discernable layers of muscle [5, 6] that are seen predominantly in the left ventricle and inter-ventricular septum alone and includes a subepicardial layer, a middle concentric layer and a subendocardial layer. The rest of the heart is composed mainly of the subepicardial and subendocardial layers [7, 8]. The myocardium also contains important structures such as excitable nodal tissue and the conducting system. The endocardium the innermost layer of the heart is formed of the endothelium and subendothelial connective tissue [5, 6].

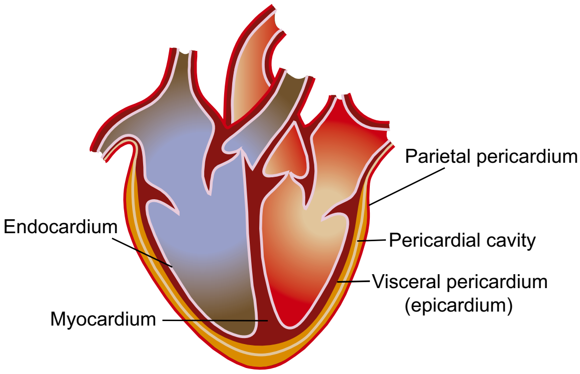

Fig 1.1 Layers of the heart

1.2.1 Chamber and Valves

The heart is divided into four distinct chambers with muscular walls of different thickness [2, 4, 9]. The left atrium (LA) and right atrium (RA) are small, thin-walled chambers located just above the left ventricle (LV) and right ventricle (RV), respectively. The ventricles are larger thick-walled chambers that perform most of the work [2, 4, 9] (Table 1.2). The atria receive blood from the venous system and lungs and then contract and eject the blood into the ventricles. The ventricles then pump the blood throughout the body or into the lungs. The heart contains four valves and the fibrous skeleton of the heart contains the annuli of the four valves, membranous septum, aortic intervalvular, right, and left fibrous trigones [3, 4, 6, 10, 11] (Fig. 1.2, Table 1.3). The right trigone and the membranous septum together form the central fibrous body, which is penetrated by the bundle of His [3, 4, 6, 10, 11]. The fibrous skeleton functions not only to provide an electrophysiological dissociation of atria and the ventricles but also provides structural support to the heart [8, 12, 13]. Each of the four valves has a distinctive role in maintaining physiological stability [3].

1.2.2 Cardiac Cell and Cardiac Muscle

The cardiac cell contains bundles of protein strands called myofibrils. These myofibrils are surrounded by sarcoplasmic reticulum, which contains cysternae (dilated terminals) [6, 10, 11, 14–16]. The sarcomeres are the contractile unit of myofibrils and the T tubules are continuations of the cell membrane located near the Z-lines, which conduct the action potential (AP) to the interior of the cell [6, 14]. The T tubules connect the sarcolemma to the sarcoplasmic reticulum in the skeletal muscle and the cardiac muscle [14, 15].

Cardiac muscle is an involuntary striated muscle, which is mononucleated and has cross-striations formed by alternate segments of thick and thin protein filaments, which are anchored by segments called Z-lines. Cardiac muscle is relatively shorter than skeletal muscle [6, 10, 11, 14–16] and actin and myosin are the primary structural proteins. When the cardiac muscle is observed by a light microscope, the thinner actin filaments appear as lighter bands, while thicker myosin filaments appear as darker bands [8, 12, 13, 15]. The dark bands are actually the region of overlap between the actin and myosin filaments and the light bands are the region of actin filaments [8, 12, 13, 15]. The thinner actin flaments contain two others proteins called troponin and tropomyosin, which play an important role in contraction [6, 14, 15]. Cardiac muscle also contains dense bands (specialised