INTRODUCTION

In the heart, diffuse interstitial fibrosis plays an essential role in the development of a variety of cardiomyopathies and is associated with increased mortality. Previously, endomyocardial biopsy was the principle method used to diagnose myocardial fibrosis. Currently, T1 mapping is a novel and expanding application of cardiac MR imaging and has the potential to depict diffuse interstitial fibrosis in a variety of cardiac diseases ***(Jeremy et al., 2014).***

Cardiovascular Magnetic Resonance (CMR) is increasingly used to differentiate the etiology of cardiomyopathies. Its three-dimensional nature with excellent spatial resolution and high tissue contrast enables accurate measurement of cardiac function and morphology. Recent advances in CMR provide the potential to also assess and quantify myocardial tissue composition ***(Haaf et al., 2016).***

Rapid innovations in CMR now permit the routine acquisition of quantitative measures of myocardial and blood T1 which are key tissue characteristics. T1 quantification requires the acquisition of multiple images to derive the T1 recovery curve which is governed by the exponential time constant for MR longitudinal relaxation, T1. This parameter can be displayed as a pixelwise “T1 map” whereby an estimate of T1 is encoded in the intensity of each pixel. Its quantitative nature permits establishing normal T1 ranges, and T1 values can be assigned colors to simplify visual interpretation ***(Moon et al., 2013).***

Native T1-mapping as well as ECV mapping is currently being explored as a diagnostic tool for a wide range of cardiomyopathies. Native T1 changes are detectable in both acute and chronic MI. Elevated native T1 has also been reported in a number of diseases with cardiac involvement: myocarditis, amyloidosis, lupus and decreases in native T1 have been associated with Anderson Fabry disease, and high iron content ***(Kellman and Hansen, 2014)***.

In chronic MI, there is replacement of myocardial cells by scarring or fibrosis with an increase in extracellular collagen. Importantly, there is no edema, as this has resolved in the initial weeks after MI. Therefore, T1 values are higher than in normal myocardium, but not as high as in acute MI ***(h-Ici et al., 2014).***

Native T1-mapping can display the typical non-ischemic patterns in acute myocarditis, similar to LGE imaging without the need for contrast agents. T1-mapping also detected additional areas of myocardial involvement and identified extra cases beyond T2W and LGE imaging ***(Ferreira et al., 2014).***

A relatively higher pre-contrast T1 value and ECV, and lower post-contrast T1 value were found with T1 mapping in the myocardium of HCM patients, which suggested T1 mapping is better in the evaluation of myocardial fibrosis ***(Liu et al., 2016).***

T1 mapping appears promising to complement LGE imaging in cases of more homogeneously diffuse disease which affect the myocardial extracellular space ***(Kellman et al., 2013).***

We hypothesize that T1 mapping contributes to the characterization of cardiac masses based on the spectrum of T1 relaxation times in tissue consisting of fat, calcium, melanin, blood and simple fluid. Thrombi and myxomas showed intermediate and relatively long T1 times, respectively ***(Saba et al., 2015).***

For T1 mapping, data were acquired in basal, midventricular, and apical SAX planes before and 10 minutes after administration of 0.3 mmol/kg i.v. gadobutrol (Gadovist®). Data were obtained in end-diastole using a cardiac gated, SSFP-based Modified Look-Locker Inversion Recovery (MOLLI) technique ***(Knobelsdorff-Brenkenhoff et al., 2013).***

AIM OF THE WORK

We aim to determine the standard T1 values specific to the Siemens 3 Tesla machine in both normal and diseased myocardia in an Egyptian population.

Chapter 1

GROSS AND MRI ANATOMY OF THE HEART

I. Gross Anatomy:

Anatomy:

The heart is a muscular organ about the size of a closed fist that functions as the body's circulatory pump. It takes in deoxygenated blood through the veins and delivers it to the lungs for oxygenation before pumping it into the various arteries (which provide oxygen and nutrients to body tissues by transporting the blood throughout the body). The heart is located in the thoracic cavity medial to the lungs (***Figure 1&2) (Peate et al., 2015).***

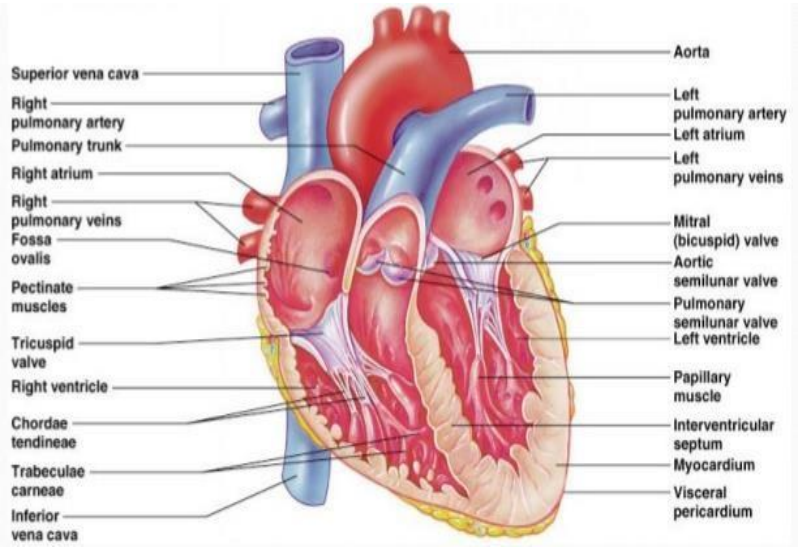

Figure (1): Gross anatomy of the heart frontal view

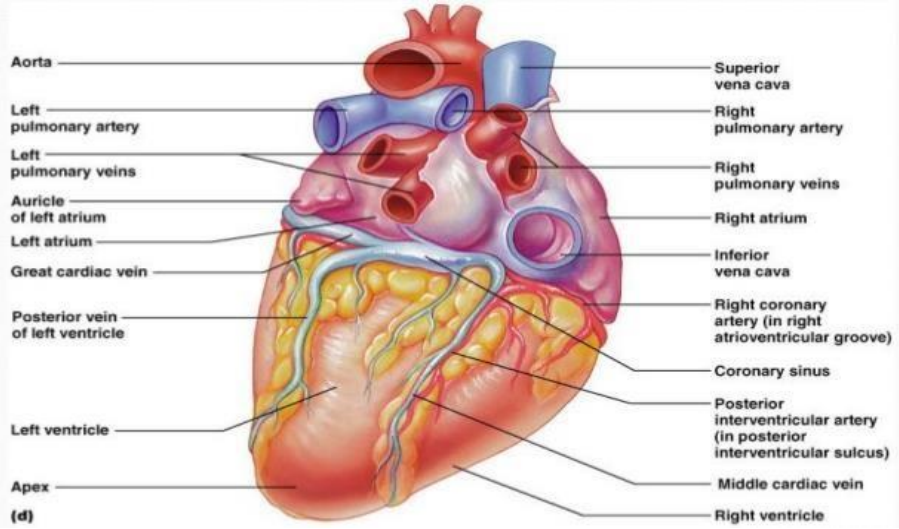

Figure (2): Gross anatomy of the heart, posterior view

Structure of the heart wall

The heart wall is made of 3 layers from outer to inner as follows: epicardium, myocardium and endocardium.

- Epicardium: it is the outermost layer of the heart wall.
- Myocardium: it is the muscular middle layer of the heart wall that makes up the majority of the thickness and mass of the heart wall and is the part of the heart responsible for pumping blood. Below the myocardium is the thin endocardium layer.
- Endocardium: it is the endothelium layer that lines the inside of the heart ***(Peate et al., 2015).***

Anatomy of the coronary arteries:

The Two main coronary arteries are the right coronary artery [RCA], the left main coronary artery {LCA} ***(Figure 3).***

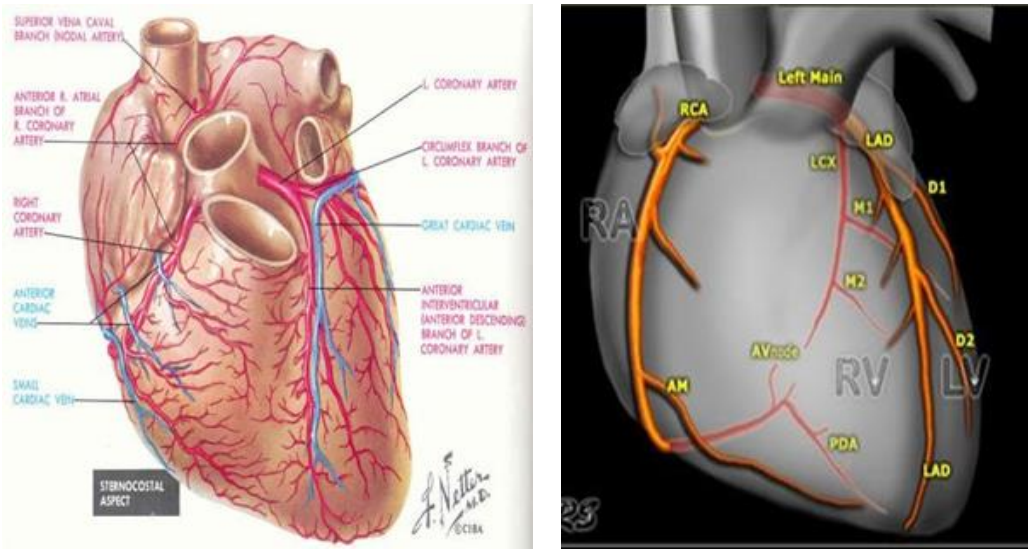

Figure (3): An overview of the coronary arteries and their branches in the anterior projection ***(Wilson et al., 2006).***

Table (1): Coronary arteries and their branches

Left main Coronary artery:	Right coronary artery [RCA]:
1- Left anterior descending [LAD]:	1-Acute marginal branch [AM]
i- Diagonal branches [D1, D2]	2-AV node branch
ii- Septal branches	3-Posterior descending artery [PDA] (in 85% of the population)
2- Left circumflex [LCx] :	
i-Marginal branches [OM1, OM2]	

II. MRI anatomy of the heart:

Cardiac Structures:

A) Atria

Morphological Features of the Right Atrium:

The right atrium forms the right heart border. The terminal crest (crista terminalis) divides the venous component posteromedially from the vestibule laterally ***(Figure 4)***, the venous component receives the inferior and superior Vena cava veins on its posterior surface, and the coronary sinus at the inferior junction with the septal component ***(Anderson, 2010).***

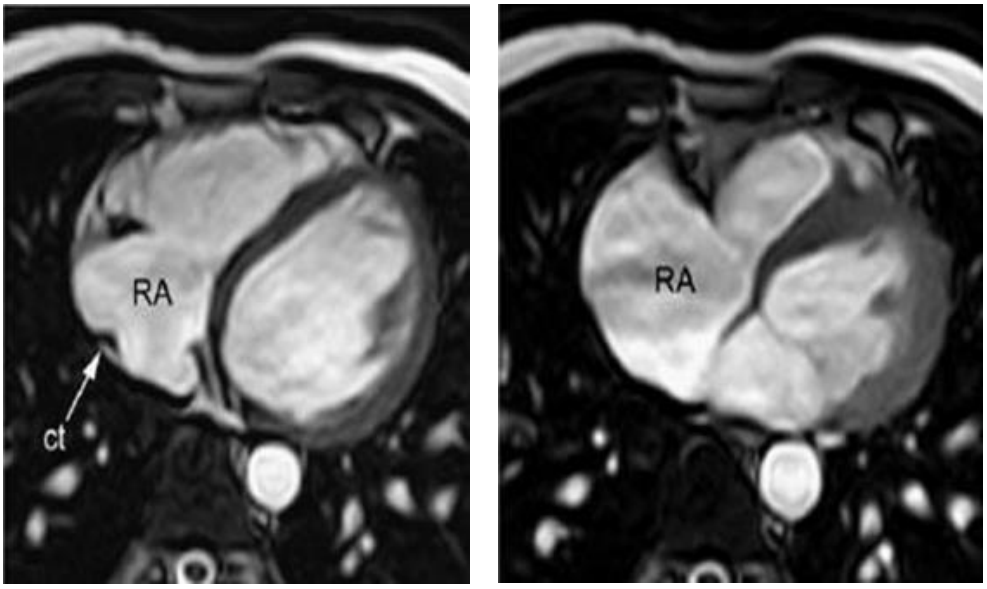

Figure (4): Right atrium at (**A)** diastole and **(B)** end systole. The images are obtained in the four-chamber view, using a balanced steady-state free precession (SSFP) technique ***(Bogaert et al., 2005)***.

The crista terminalis is readily visualized on both bright and dark blood sequences and appears isointense to the myocardium. A prominent crista terminalis can mimic a mass, as shown in ***Figure 5***. However, the location and signal characteristics on MRI can help confirm that this structure is indeed normal cardiac tissue ***(Daniel et al., 2011).***

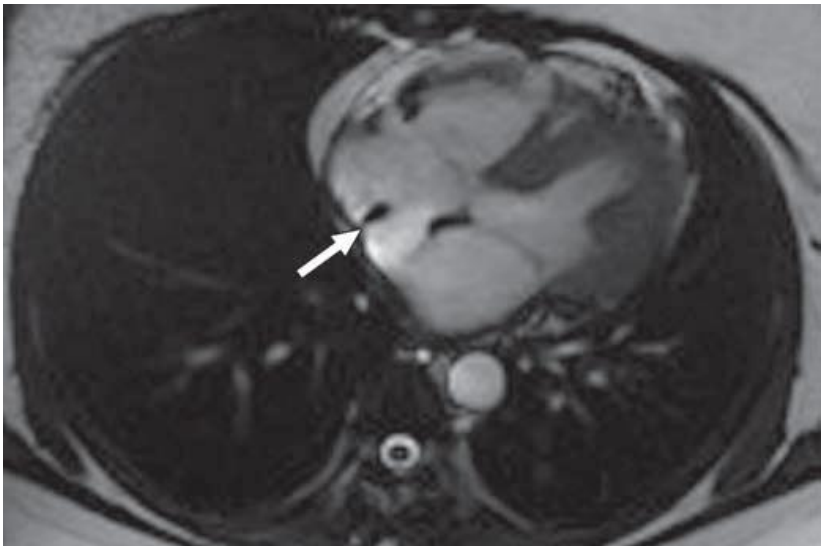

Figure (5): Axial fast imaging employing steady-state acquisition image shows prominent crista terminalis (*arrow*).

Morphological Features of the Left Atrium:

The morphological left atrium forms the upper posterior heart border, with its appendage extending anteromedially. The left atrium extends cranially behind the aortic root and the proximal part of the ascending aorta. The venous component, also posteriorly located and smooth-walled, receives the four pulmonary veins, one at each corner ***(Figure 6) (Bogaert et al., 2005).***

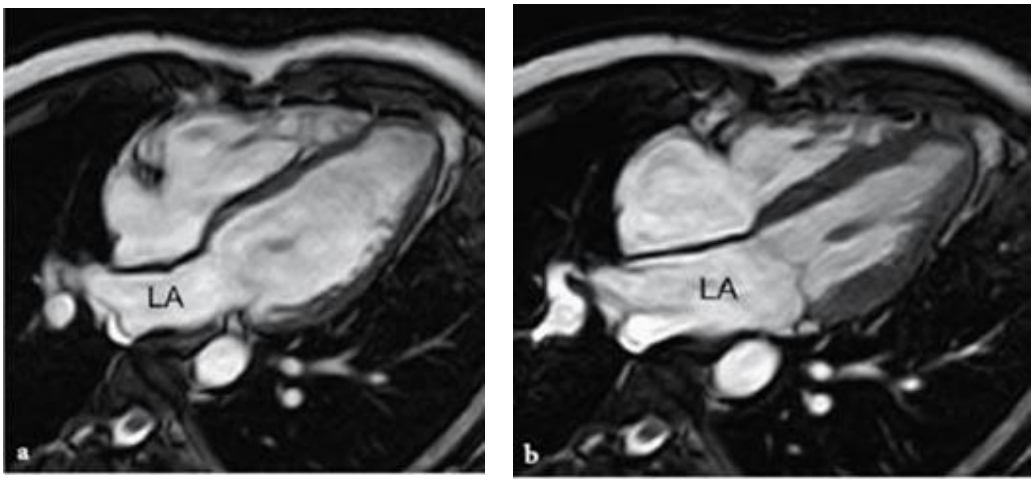

Figure (6): Left atrium at end diastole **(a)** and end systole. **(b)** Horizontal long axis images using a balanced SSFP technique. The entrance of the pulmonary vein from the right lower lobe in the left atrium (LA) can be clearly seen ***(Bogaert et al., 2005).***

B) Ventricles:

Morphological Features of the Right Ventricle:

The morphological right ventricle can be identified externally by its pyramidal shape and by its coronary distribution pattern, which is distinctive and typical. The left anterior descending coronary artery (LAD) demarcates the right from the left ventricle. The right ventricle possesses an inlet component, an apical trabecular component, and an outlet component ***(Figure 7) (Anderson, 2010).***

The muscular trabeculations of the right ventricle are relatively coarse, few, and straight, tending to run parallel the right ventricular inflow and outflow tracts. The papillary

muscles of the right ventricle are relatively small and numerous, and they attach both to the septal and to the free wall surfaces ***(Bogaert et al., 2005).***

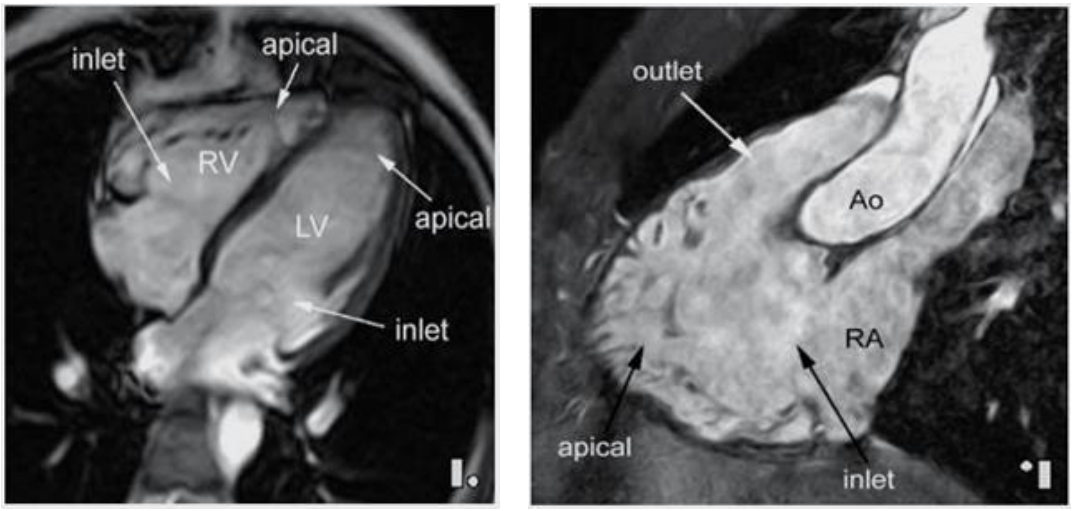

Figure (7): Components of the right ventricle. Horizontal long-axis image (a), RV inflow and outflow tract image (b) using a balanced-SSFP technique. The inlet, apical and outlet part of the right ventricle are indicated on the different images. Ao, Aorta; LV, left ventricle; RA, right atrium; RV, right ventricle ***(Bogaert et al., 2005).***

Morphological Features of the Left Ventricle:

The morphological left ventricle in a normal heart is a thick-walled chamber that forms the apex and lower part of the left and posterior heart border. Internally, the left ventricle is demarcated by its fine trabeculations, which are numerous, fine muscular projections. Like its morphological right counterpart, the morphological left ventricle also possesses an inlet, an apical trabecular, and an outlet portion. The inlet component contains the mitral valve (or LV valve) and extends from the

atrioventricular junction to the attachments of the prominent papillary muscles ***(Figure 8) (Beg et al., 2004).***

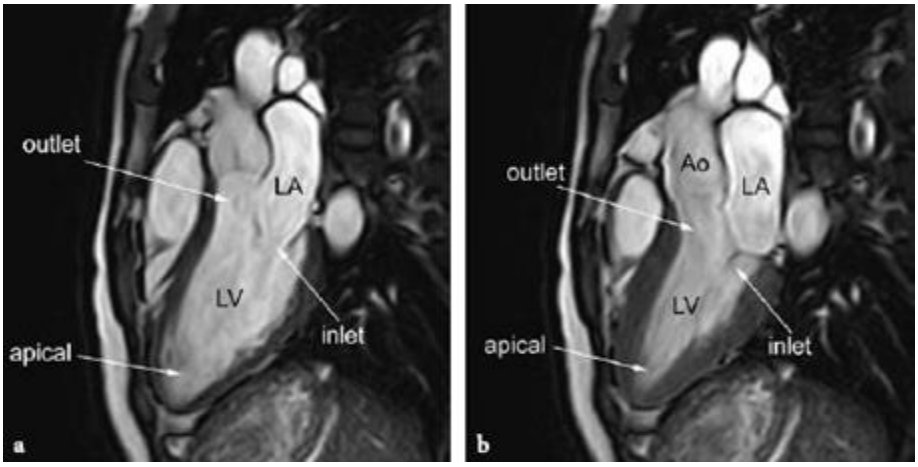

Figure (8): Components of the left ventricle. Left ventricular inflow outflow tract at end diastole (a) and end systole (b), using the balanced-SSFP technique. Ao, Aorta; LA, left Atrium ***(Bogaert et al., 2005).***

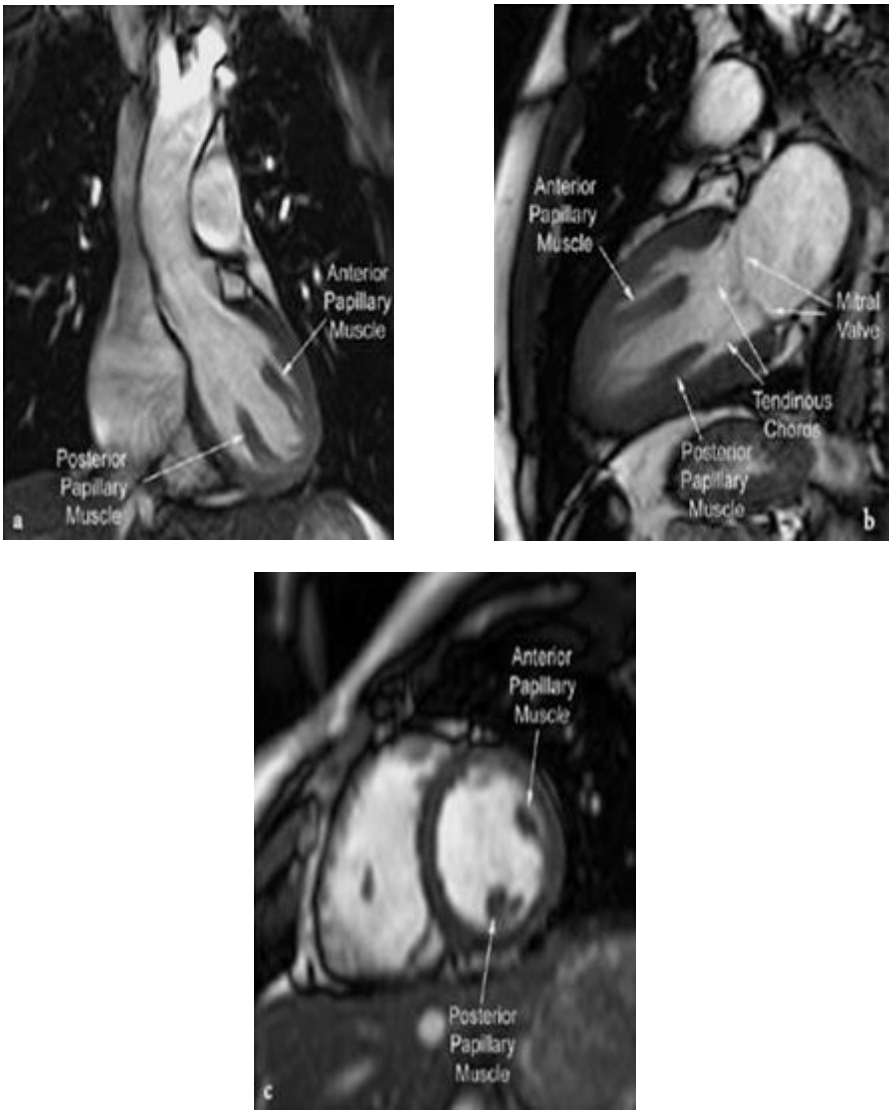

Figure (9): Left ventricular papillary muscles. Left ventricular outflow tract (a), vertical long-axis (b) and mid-ventricular short-axis (c) view, using the balanced-SSFP technique. The papillary muscles are clearly depicted as intra-cavity structures attached to the posterior (medial) and anterior (lateral) LV wall. Their fibrous extensions, i.e., tendinous chords, towards the mitral valve can be seen on high-quality MR images. Note that the LV septal surface on the short-axis view is free of muscular attachments ***(Bogaert et al., 2005).***

The apical trabecular portion is the most characteristic feature of the morphological left ventricle, which contains the fine characteristic trabeculations. The smooth septal surface also helps in identification, since the morphological left ventricle never possesses a septo-marginal trabeculations or a moderator band ***(Bogaert et al., 2001).***

Anatomy on short axis images:

The complexity of segmenting heart chambers and myocardium mainly relies on heart anatomy and MRI acquisition specificity. The LV function consists in pumping the oxygenated blood to the aorta and consequently to the systemic circuit. The LV cavity has a well-known shape of ellipsoid (Fig. 10) and is surrounded by the myocardium, whose normal values for thickness range from 6 to 16 mm. On the contrary, the RV has a complex crescent shape. It also faces lower pressure to eject blood to the lungs and is thus three to six times thinner than the LV, reaching the limit of MRI spatial resolution ***(Shors et al., 2004).***

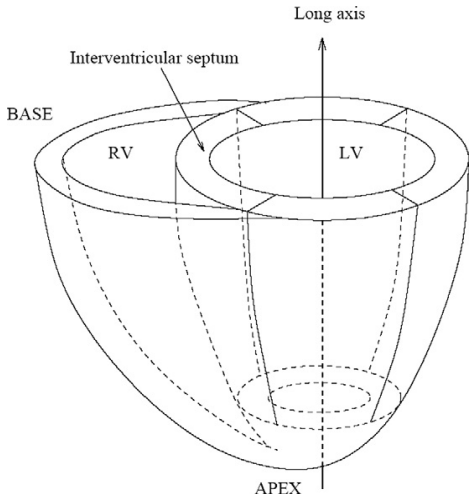

Figure (10): LV and RV geometry

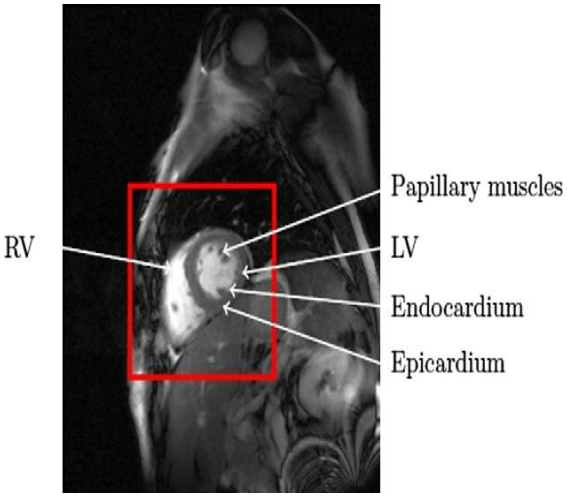

Figure (11): A full size short-axis image

Left Ventricular segmentations and coronary artery territories:

A 17-segment frame of reference is used as proposed by the American Heart Association (AHA). The heart is divided into three segmental area in the short axis plane along the long axis of the LV: basal, mid-cavity, and apical ***(Figure 12) (Bogaert et al., 2005).***