# INTRODUCTION

According to the latest WHO data published in April 2011 coronary Heart disease causes death rate of 174 per 100,000 of population. And it accounts for 33% of total deaths ***(Egypt Public Health Association, 2011).***

Currently, three routinely directions of heart failure treatment are available: medical treatment, heart transplantation, and revascularization. In daily clinical practice, the choice is frequently made between medical treatment and revascularization. From this perspective, assessment of myocardial viability is important to guide management of patients with ischemic left ventricular dysfunction. Patients with viable myocardium may improve in left ventricle function revascularization, whereas patients with only scar tissue will not improve ***(Sigita et al., 2009).***

The global ejection fraction was determined to assess the ventricular function. The patients were divided into 3 groups (as follows: group 1, EF > 50%, group 2, EF = 35% to 50%; group 3, EF < 35%).

Patients with a low EF less than 35%, coronary artery bypass grafting (CABG) has been shown to be superior to medical therapy to improve long-term survival ***(The annals of Thoracic Surgery, 2008).***

The main value of noninvasive assessment of viability is in the more severely and chronically disabled patient, in whom the outcome without intervention is poor with high risk of revascularization ***(Sigita et al., 2009).***

In case of scar formation there is loss of myocytes after myocardial infarction and the myocardium becomes thinned. Therefore, the measurement of end diastolic wall thickness may give information about the viability of dysfunctional myocardium. This is only true for the chronic setting, as in the acute stage, wall thickness may even increase due to interstitial edema ***(Sigita et al., 2009).***

Several noninvasive imaging techniques have been developed to identify dysfunctional but viable tissue: dobutamine stress echocardiography, single-photon emission computed tomography (SPECT) imaging with thallium- 201 or technetium-99m-labeled tracers, and positron emission tomography (PET) metabolic imaging with 18F-fluorodeoxyglucose (18F-FDG). Magnetic Resonance Imaging (MRI) is a superior technique for assessment of myocardial viability ***(Udelson et al., 2007).***

Several cardiovascular magnetic resonance (CMR) techniques have been proposed for the assessment of myocardial viability. These techniques include resting CMR (which provides information on end-diastolic wall thickness, dobutamine stress CMR (which provides information on contractile reserve) and delayed contrast-enhanced CMR (which provides information on scar tissue) ***(Underwood et al., 2004)***.

Testing CMR to assess left ventricular end-diastolic wall thickness is now considered gold standard for the evaluation of left ventricular volume and mass, as well as myocardial wall thickness and thickening. As in other imaging modalities, the LV is divided into 17 segments, each of which can be attributed to a coronary artery **(Fig. 1)** ***(Sigita et al., 2009).***

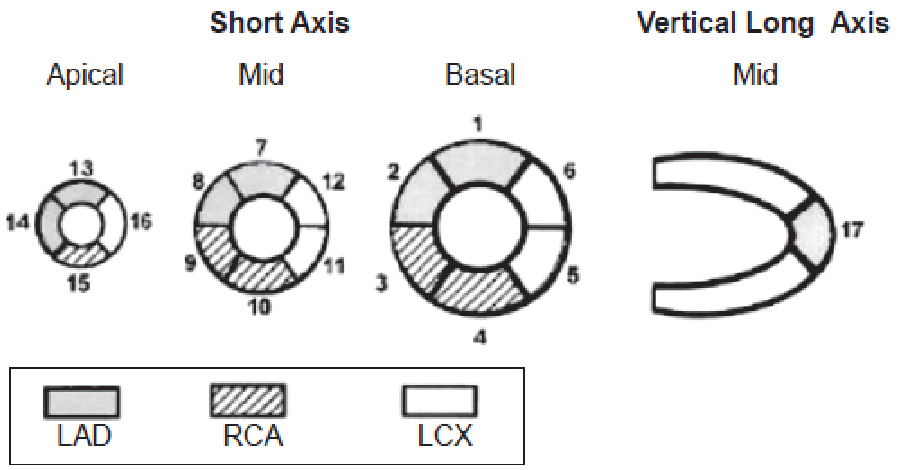



**Fig. (1):** Assignment of the 17 myocardial segments to the territories of the left anterior descending (LAD), right coronary artery (RCA), and the left circumflex coronary artery (LCX) ***(Sigita et al., 2009).***

When pooled data are compared, the differences in accuracy become more clear. The sensitivity of end-diastolic wall thickness and delayed contrast-enhanced CMR are significantly higher than that of dobutamine stress CMR. Conversely, the specificity of dobutamine stress CMR is significantly higher than that of end-diastolic wall thickness and delayed contrast-enhanced CMR ***(Sigita et al., 2009).***

Finally, by CMR additional information can be provided such as LV function, LV volumes, presence and degree of ischemic mitral regurgitation and LV geometry. This information is needed preoperatively to determine the optimal surgical procedure ***(Wellnhofer et al., 2004).***

# AIM OF THE WORK

The aim of this work is to highlight the role of Magnetic resonance imaging in evaluation of the left ventricular function and assessment of myocardial viability in comparison with other modalities.

*Chapter 1*

# CARDIAC ANATOMY

## Position of the Heart in the Thorax:

The heart is a double, two-chambered pump, usually described in terms of "right-sided" and "left-sided" chambers ***(Standring, 2008)*** **(Fig.2)**.

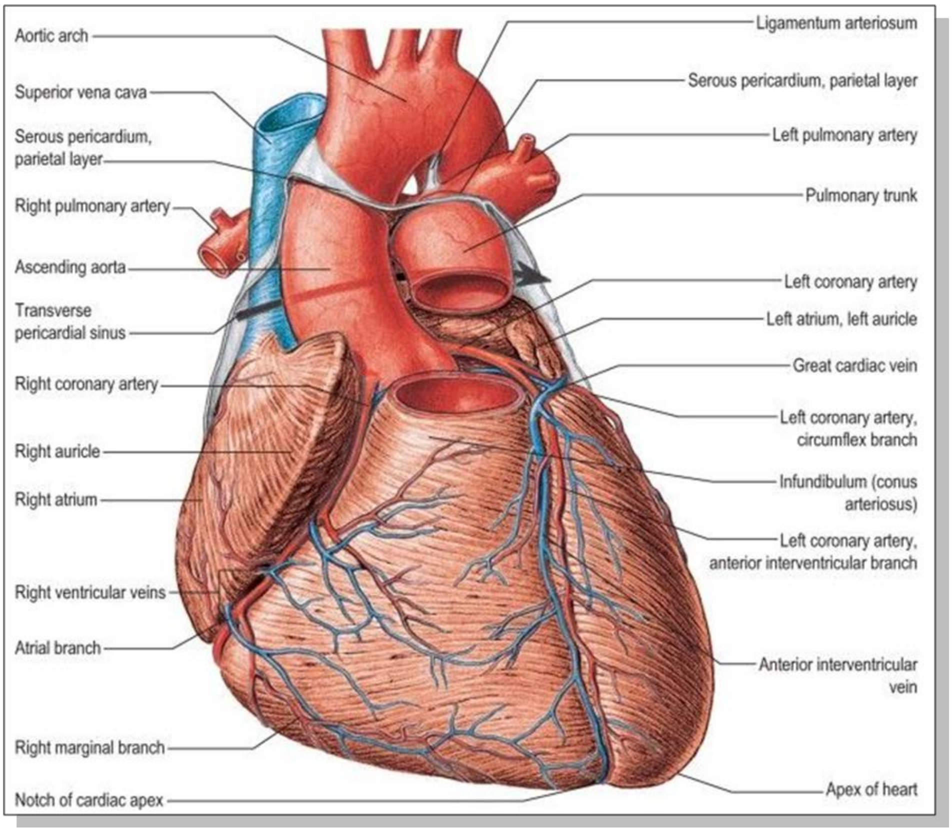
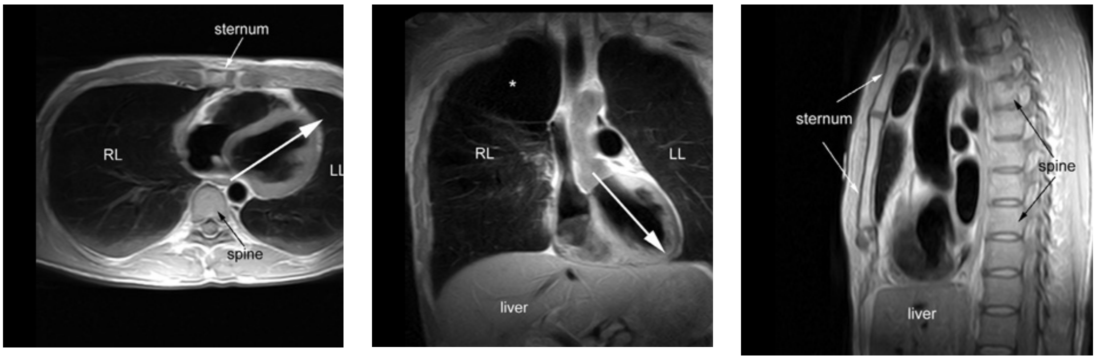



**Fig. (2):** External morphology of the heart ***(Standring, 2008)***.

The heart has a central, ventrobasal location in the thorax and is bordered bilaterally by the lungs, anteriorly by the sternum, and inferiorly by the diaphragm. It has an oblique position in the thoracic cavity, with the cardiac apex in the left hemi thorax. **(Fig. 3).**




**a** **b** **c**

**Fig. (3):** Position of the heart in the thorax. **a)** Transverse image; **b)** Coronal image; **c)** Sagittal image.

The arrow on the transverse and coronal image indicates the longitudinal axis of the heart. LL, left lung; RL, right lung ***(Bogaert et al., 2005).***

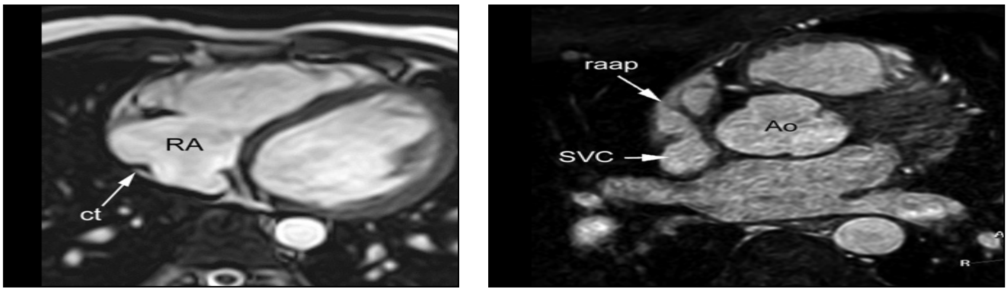
The long axis of the heart is rotated about 45 degree to both the sagittal and the coronal planes. For the most part, the heart is surrounded by the pericardial sac and has no physical connections with the surrounding structures except posteriorly and superiorly where the great arteries originate and the caval and pulmonary veins drain into the atria.

In reality, the right chambers are more anteriorly positioned within the chest, the left chambers more posteriorly, and the ventricles are more inferiorly located than the atria ***(Bogaert et al., 2005).***

## Cardiac Structures:

**1. The Atria:** Both atria can be divided anatomically into a venous component, a vestibule of the atrioventricular valvae, septal component, and an appendage and are separated by the atrial septum.

***a. The right atrium*** **(Fig.4):** forms the right heart border.The venous component receives the inferior and superior caval veins on its posterior surface, and the coronary sinus at the inferior junction with the septal component. Fibromuscular webs attach to the terminal crest in the regions of the openings of the inferior caval vein and coronary sinus. These are the so-called venous valves, the Eustachian valve in relation to the inferior caval vein, and the Thebesian valve at the coronary sinus.




**a** **b**

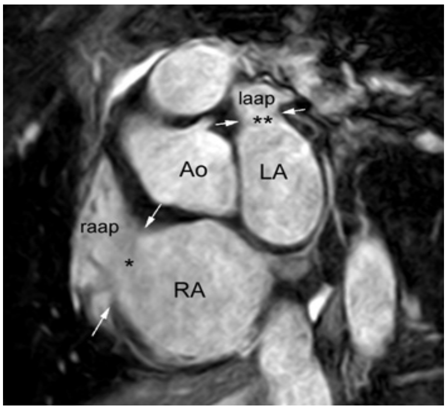
**Fig. (4):** Right atrium, the crista terminalis (CT) divides the venous component (posteromedially) from the vestibule. Right atrial appendage (raap) is located ventrally to the superior vena cava (SVC) and laterally to the ascending aorta (Ao) ***(Broderick et al., 2005)***.

The coronary sinus running through the left or posterior atrioventricular groove opens into the right atrium above the postero-inferior interventricular groove. The junction between the appendage and venous component is particular wide, and the appendage has a broad, triangular appearance, positioned just ventrally to the entrance of the superior vena cava in the right atrium.

The vestibule is smooth walled and supports the attachments of the leaflets of the tricuspid valve. The different components, as well as the relationship to the caval veins and the coronary sinus, can be well appreciated on several imaging planes, including the transverse, coronal, and vertical long-axis or sagittal planes.

The terminal crest is routinely visible on dark-blood and bright-blood MRI as a mural nodular or triangular structure adjacent to the lateral wall that connects both caval veins. This muscular structure can be misinterpreted as an abnormal intra-atrial mass ***(Bogaert et al., 2005).***

***b. the left atrium*** **(Fig.5):** forms the upper posterior heart border, with its appendage extending anteromedially. It lies just beneath the carina and anterior to the esophagus. 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.

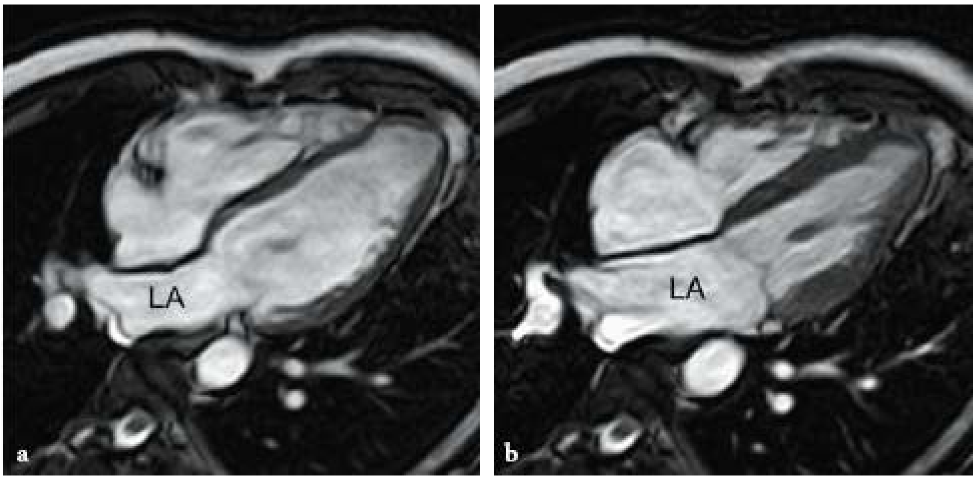

a b

**Fig. (5):** the left atrial appendage (laap) has a narrow junction (two stars) and a long, tubular appearance. Note the relationship of the appendages to the coronary arteries overlies the posterior (or left) atrioventricular groove and the left circumflex coronary artery (lcx). Ao, Aorta; LA, left atrium; lm, left main stem coronary artery; Right atrium (RA); raap, right atrial appendage; pericardial sac (ps) ***(Alicia and Bolooki, 2010).***

The vestibule supports the leaflets of the mitral valve and is also smooth-walled. The pectinate muscles, being confined in the appendage, are much less obvious than in the right atrium and never extend around the atrioventricular junction. The appendage, overlying the left atrioventricular groove and left circumflex coronary artery (Lcx), has a narrow junction with the body of the left atrium and has a long, tubular-shaped appearance. Imaging planes for studying the left atrium are similar to those used to study the right atrium ***(Bogaert et al., 2005)***

## Left atrial dimensions:

The normal LA diameter in an adult ranges between 3 and 4cm, while normal left atrial area is 15 cm2/m2 body surface area (**fig.6).**




**a** **b**

**Fig. (6):** Left atrium at end diastole (**a**) and end systole (**b**). Horizontal long-axis images. The entrance of the pulmonary vein from the right lower lobe in the left atrium (*LA*) can be clearly seen ***(Alicia and Bolooki, 2010).***

***c. The atrial septum:*** **(Fig.7)** separates the left from the right atrium. In the atrial septum is an oval depression, the fossa ovalis. The floor of the fossa ovalis is the remains of the septum primum.

The septal surface on its right atrial aspect is made up of the floor of the oval fossa and its postero-inferior rim. The superior rim of the fossa (the so-called septum secundum) is no more than an infolding of the atrial wall between the superior caval vein and right pulmonary veins. The septal surface is roughened on its left atrial aspect, as is the flap of the oval fossa.

The flap valve, superiorly, overlaps the infolded atrial walls (the "septum secundum") so that, even if the two are not fused, there will be no shunting across the septum as long as left atrial pressure exceeds that in the right atrium ***(Taylor et al., 2005).***


**Fig. (7):** Atrial (interatrial) septum. Horizontal long-axis image, RA, right atrium; LA, Left atrium; fo, fossa ovalis ***(Bogaert et al., 2005).***

In most cases the atrial septum can be seen on SE-MRI (Spin Echo MRI) as a thin line separating the two atria, except at the level of the foramen oval, which is often too thin to be seen. This finding should not be misinterpreted as an atrial septal defect.

Bright-blood cine MRI, providing a higher contrast between bright atrial blood and atrial walls, usually depicts this thin membrane very well. The atrial septum is best shown in horizontal and longitudinal planes through the heart (e.g., transverse or four-chamber views) ***(Bogaert et al., 2005).***

## 2. The Ventricles

***a. The right ventricle* (Fig.8):** It is pyramidal in shape and possesses an inlet component, an apical trabecular component, and an outlet component (infundibulum), the presentation of the different components is specific for each ventricle and essential for differentiation of the morphological right from left ventricles. The inlet component (tricuspid valve and atrioventricular septum) surrounds and supports the leaflets and subvalvular apparatus of the tricuspid valve ***(Standring, 2008)***.

It forms the inferior and anterior heart border with the exception of the apex. 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 **(Fig 9)** ***(Bogaert et al., 2005).***

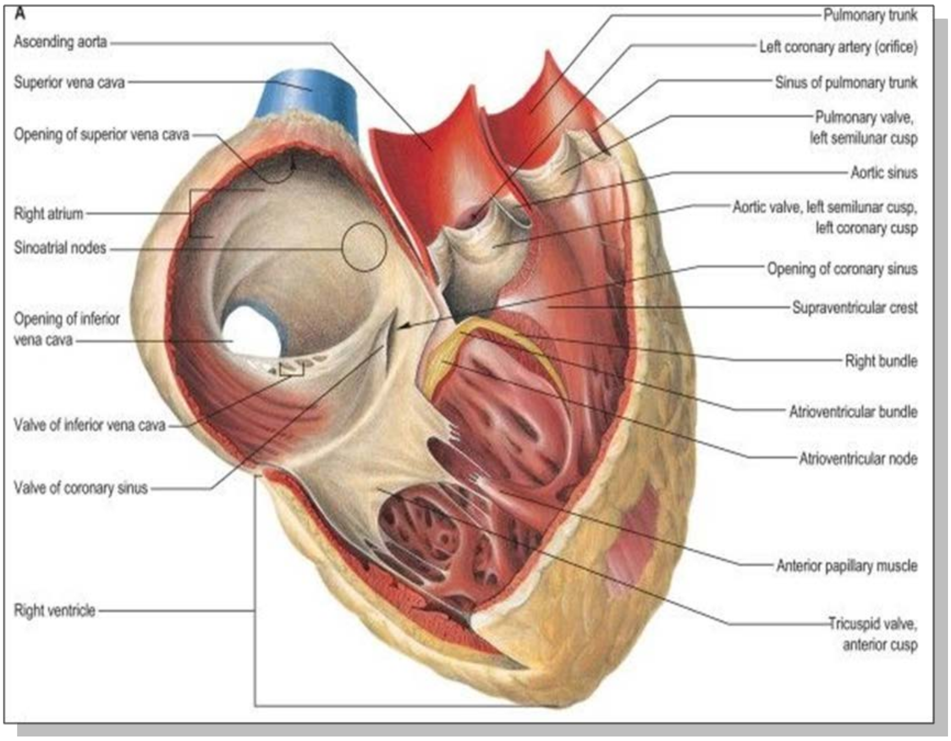



**Fig. (8):** The morphologic right ventricle ***(Standring, 2008)***.

The apical trabecular portion of the right ventricle has characteristically coarse trabeculations. The infundibulum is incorporated into the right ventricle and forms the outflow tract, whereas the right ventricle proper forms the inflow tract. This completely muscular ring supports the three semilunar leaflets of the pulmonary valve. The junction between the infundibulum and the right ventricle is composed of the parietal band, the septomarginal band, and the moderator band. This moderator band, a muscular band that contains the continuation of the right bundle branch, passes from the interventricular septum to the anterior wall and is an essential characteristic of the morphological right ventricle ***(Broderick et al, 2005)***.

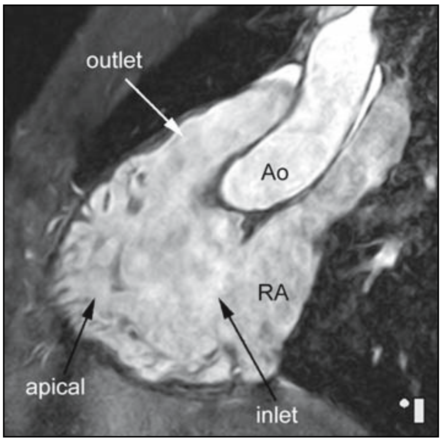



**Fig. (9):** RV inflow and outflow tract. The inlet, apical and outlet part of the right ventricle are indicated on the different images. Ao, Aorta; RA, right atrium; RV, right ventricle ***(Bogaert et al., 2005).***

Only a small part of the infundibulum is a truly muscular septum, while the rest of the posterior margin of the infundibulum, also called supraventricular crest (crista supraventricularis) is caused by an infolding of the roof of the ventricle (also called ventriculoinfundibular fold), and is separated from the aorta by extra cardiac space ***(Broderick et al., 2005)***.

The separation of the tricuspid and pulmonary valves by the crista supraventricularis is another characteristic of the morphological right ventricle. Additional trabeculations, the septoparietal trabeculations, run around the anterior margin of the infundibulum.

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.

The normal right ventricle is a relatively thin wall chamber with an end-diastolic wall thickness of 3–4 mm.

Towards the RV apex, there is often a thinning of the free wall which is not to be mistaken for a wall thinning such as found in arrhythmogenic RV dysplasia.

The complex cardiac anatomy of the morphological right ventricle is best studied using a combination of different imaging planes, i.e., transverse or horizontal long-axis views in combination with short-axis views and/or RV outflow tract views ***(Bogaert et al., 2005).***

**b. The left ventricle: (Fig.10)**

in a normal heart is a thick-walled chamber that forms the apex and lower part of the left and posterior heart border. The exterior of the left ventricle is shaped like a cone. Internally, the left ventricle is demarcated by its fine trabeculations, which are numerous, fine muscular projections

The 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 **(Fig. 11)** ***(Standring, 2008)***.