Chapter 1 INTRODUCTION

"The anatomy is not a dead subject, it is living material out of which man……………………builds for the future medicine."

Anatomy is the scientific study of the structure of organisms. Human anatomy is one of the basic essential science of medicine and is a science of facts about structures & their normal anatomical variation. Morphology is a branch of biology dealing with the study of the form and structure of organisms and their specific structural features. This includes aspects of the outer appearance in the form of shape, structure, colour, width, thickness, weight etc.

Dissection is a routine and irreplaceable means to explore existence of these. For every visible, superficial oddity, there may be an invisible internal one. Dissection is the process of disassembling and observing something to determine its internal structure & as an aid to discerning the functions & relationships of its components.

In a disease & injury normal structure is deformed, leading to functional defects in the form of symptoms, viz. pain, swelling, fever, etc. Therefore, it is of paramount importance for clinician and surgeon to have clear knowledge of normal morphology & its normal variations during the period of growth and ageing.

Cardiovascular disease are the leading cause of mortality worldwide; responsible for one –third of all deaths.(Thomar S,2013)

Knowledge of the normal and variant anatomy and anomalies of heart structures is an increasingly vital component in the management of congenital and acquired heart diseases. An increasingly complex cardicac surgical repairs demand enhanced understanding of the basic anatomy to improve the operative outcomes. (Kapana R,2003).

1.1 Gross Anatomy of Heart

- **1.1.1 Structural Organization of Heart:**

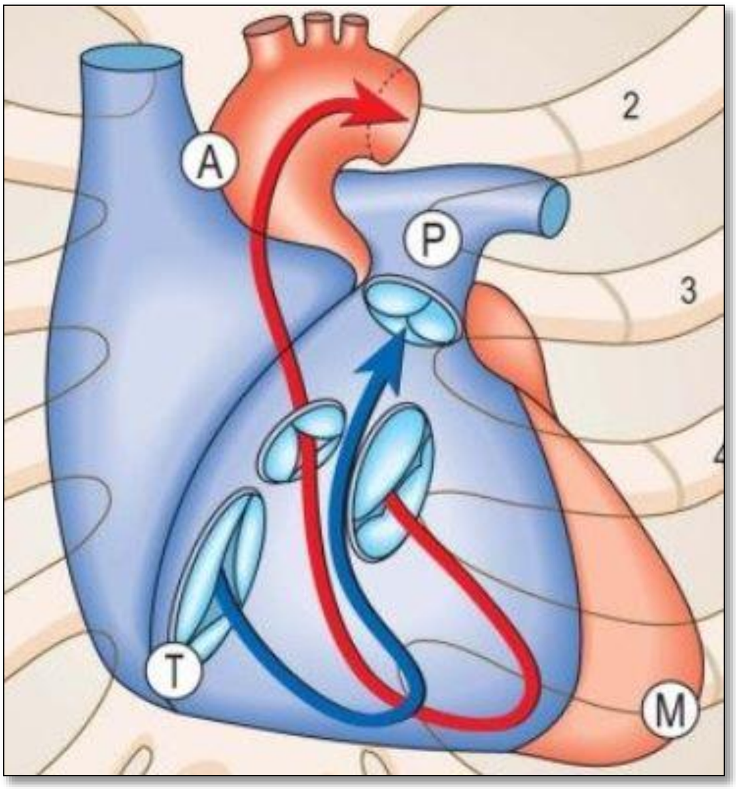

Figure 1.1: Heart Organisation

The heart is a pair of valved muscular pumps combined in a single organ. Despite functional disposition, the two pumps are usually described topographically in parallel. Of the four cardiac chambers, the right heart starts at the right atrium and receives the superior and inferior venae cavae together with the main venous inflow from the heart itself via the coronary sinus. This systemic venous blood traverses the right atrioventricular orifice, guarded by the tricuspid valve, to enter the inlet component of the right ventricle. Contraction of the ventricle, closes the tricuspid valve and, with increasing pressure, ejects the blood through the muscular right ventricular outflow tract into the pulmonary trunk. The blood then flows through the pulmonary vascular bed, which has a relatively low resistance.

Many structural features of the ‘right heart', including its overall geometry, myocardial architecture and the construction and the relative strengths of the tricuspid and pulmonary valves, accord with this low resistance, being associated with comparatively low changes in pressure. The left heart starts at the left atrium, which receives all the pulmonary inflow of oxygenated blood and some coronary venous inflow. It contracts to fill the left ventricle through the left atrioventricular orifice guarded by its mitral valve. The valve is the entry to the inlet of the left ventricle. Ventricular contraction rapidly increases the pressure in the apical trabecular component, closing the mitral valve and opening the aortic valve, enabling the ventricle to eject via the left ventricular outflow tract into the aortic sinuses and the ascending aorta, and thence to the entire systemic arterial tree, including the coronary arteries. Because of its contrasting functional demands, the heart is far from a simple pair of (structurally combined) parallel pumps. The heart has a complicated, spiral, three-dimensional organization which is markedly skewed when compared with the planes of the body. Established terms of anatomical orientation have historically been applied to the heart based on early embryological development prior to axial rotation of the cardiovascular tube. This, together with the traditional study of isolated whole or dissected hearts outside the body, hinders an intuitive understanding of the descriptive relationships between in vivo and surface cardiac anatomy. Terms such as ‘left' and ‘right', ‘anterior' and ‘posterior', ‘superior' and ‘inferior', therefore, do not always assist the descriptions of cardiac anatomy. Another potential source of confusion is the usual study of isolated whole or dissected hearts, with the subsequent difficulty in relating details to the heart as it is positioned within the body. The following description highlights such difficulties in circumventing certain misconceptions before proceeding to describe the structure in more detail. The oblique position of the heart in the thorax can be conceptualized by comparing it to a somewhat deformed pyramid, with the base facing backwards and to the right and the apex forwards and left. A line from the apex to the approximate centre of the base projected posterolaterally appears near the right mid-scapular line. Some surfaces of the cardiac "pyramid" are flat, and others are more or less convex, with these aspects converging along somewhat ill-defined "boundaries". Precise definitions of surfaces and intervening "boundaries" are, therefore, complex. In the following description, official and more generally used terms from clinical practice are alternatively given. The heart has a base and an apex; its surfaces are labelled sternocostal (anterior), diaphragmatic (inferior), and right and left. Its edges are top, bottom (the 'acute' edge or edge) and left (the 'blunt' edge or edge).

The right surface is sometimes called a "boundary" despite its extent. Although the heart is placed obliquely in the thorax, the atrial and ventricular septal structures are practically in line but are inclined forward and to the left at an angle of 45° to the sagittal plane. The planes of the mitral and tricuspid valves are vertical and not exactly coplanar; they are broadly at right angles to the septal plane. Thus, the right atrium is not only right but also anterior and inferior to the left atrium and is partially anterior to the left ventricle. The right ventricle makes up most of the anterior portion of the ventricular mass. Only its lower end is the right part of the left ventricle, while its left upper limb (pulmonary orifice) is to the left and above the aortic valve. The left atrium forms most of the back of the heart, while the left ventricle is only prominent at the bottom and runs along the left margin to reach the apex. The halls are basically to the right of the respective chambers and behind them. These general dispositions are of greatest importance when planning or interpreting radiographs, CT and MRI studies, cardiac angiograms, and echocardiograms. The right heart, while forming the right aspect or "rim", follows a gentle curve and covers most of the anterior aspect of the left heart. The right heart thus forms the most significant part of the front surface; its outflow tract rises until it ends on the left side of the outflow tract from the left ventricle.

The sites of the tricuspid and pulmonic valves are widely separated, and the sickle-shaped flat cavity of the right ventricle extends between them in different planes. Conversely, the left heart is primarily in a posterior position and is covered by the chambers of the right heart when viewed from the front. The inlet to the left ventricle, which contains the mitral valve, is very close to its outlet, surrounded by a wide tract connecting the inlet and outlet components of the right ventricle. The planes of the left ventricular openings, although relatively inclined, are more nearly coplanar than those of the right. The cavity of the left ventricle is narrow and conical, and its tip occupies the apex of the heart. Interior of four chambers of heart is made up of as follows:

- **1.1.2 Interior of Right Atrium:**

The interior surface of the right atrium can be divided into three regions: the smooth-walled venous component located posteriorly leads anteriorly to the vestibule of the tricuspid valve and to the appendage (Fig. 1.2)

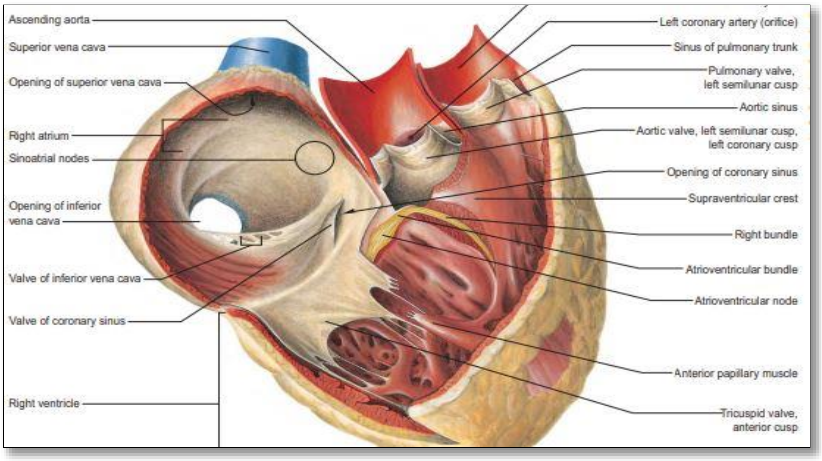

Figure 1.2: Interior of Right Atrium And Tricuspid Valve

The wall of the vestibule is smooth but its junction with the appendage is ridged all around the atrioventricular junction by pectinate muscles. The smooth-walled systemic venous sinus receives the openings of the venae cavae and coronary sinus.

SVC & IVC: The superior and inferior venae cavae, together with the coronary sinus, open into the venous component. The superior vena cava returns blood from head, neck and upper limb through an orifice that faces anteroinferiorly and has no valve; it also receives blood from the chest wall and the oesophagus via the azygos system. The inferior vena cava is larger than its superior counterpart. It drains blood from all structures below and including the diaphragm into the lowest part of the atrium near the septum.

Eustachian Valve: Anterior to orifice of inferior vena cava , and along its lateral or right margin, is the flap-like Eustachian valve, a fold of endocardium that encloses a few muscular fibres and is of varying size.When traced inferiorly, it forms the Eustachian ridge, which runs into the sinus septum , continuous with the valve of the coronary sinus. The lateral part of the valve becomes continuous with the lower end of the terminal crest. The Eustachian valve is large during fetal life, when it serves to direct richly oxygenated blood (from the placenta) from the right atrium through the foramen ovale of the interatrial septum into the left atrium. The valve varies markedly in size in postnatal life; it is sometimes cribriform or filamentous but often absent.

Coronary Sinus & Thebesian Valve: The coronary sinus opens into the venous atrial component between the orifice of the inferior vena cava, the fossa ovalis and the vestibule of the atrioventricular opening. It is often guarded by a thin, semicircular

Thebesian valve that covers the lower part of the orifice. The upper limb of this valve joins the Eustachian valve and its muscular extension, the Eustachian ridge. It also joins a tendinous structure, the tendon of Todaro, running from this commissure into the sinus septum, which is the septum between the coronary sinus and the fossa ovalis. The tendon of Todaro runs forwards to insert into the central fibrous body and is one of the landmarks of the triangle of Koch .

Chiari Network: Occasionally, a reticulated network, Chiari's network, originates from the Eustachian valve and connects to different parts of the right atrium, including the coronary sinus. Often clinically insignificant, Chiari's network has been associated with the pathogenesis of thromboembolic disease, endocarditis, arrhythmias, cardiac flow obstructions, heart murmurs, infective endocarditis, cardiac tumours and entrapment of catheters on percutaneous intervention.

Crista Terminalis: The right atrium and its appendage are separated from the venous sinus by the crista terminalis, a smooth, C-shaped muscular ridge that originates from the upper part of the septal surface and, passing anterior to the orifice of the superior vena cava, skirts its right margin to reach the right side of the orifice of the inferior vena cava. It marks the site of the right venous valve of the embryonic heart, corresponding externally to the terminal groove. The sinu-atrial (sinus) node is located in the superior part of the groove, inferolateral to the orifice of the superior vena cava. The pectinate muscles (musculi pectinati) are almost parallel muscular ridges that extend anterolaterally from the terminal crest, reaching into the appendage where they form several trabeculations. The largest and most prominent pectinate muscle, forming the bridge of the sulcus terminalis internally, is the taenia sagittalis.

Fossa Ovalis & Left Venous Valve Remnant: The atrial septal wall presents the fossa ovalis, an oval depression superior and to the left of the orifice of the inferior vena cava. Some time trabecular, single or multiple thread like structure observed over the fossa ovalis known as left venous valve remnant.

Triangle of Koch: Anteroinferior in the right atrium is the large, oval vestibule leading to the orifice of the tricuspid valve. A triangular zone (of Koch) is defined between the attachment of the septal leaflet of the tricuspid valve, the anteromedial margin of the ostium of the coronary sinus, and the palpable round, collagenous subendocardial tendon of Todaro. Koch's triangle is a landmark of particular surgical importance, indicating the site of the atrioventricular node and its atrial connections. Anterosuperior to the insertion of the tendon of Todaro, the septal wall is formed by the atrioventricular component of the membranous septum, intervening between the right atrium and subaortic outlet of the left ventricle. The bulging atrial wall anterosuperior to the membranous septum, the aortic mound (torus aorticus), marks the location of the non-coronary aortic sinus with its enclosed valvular leaflet.

- **1.1.3 Interior of Right Ventricle:**

Topographically, the ventricle possesses an inlet component that supports and surrounds the tricuspid valve; a coarsely trabeculated apical component; and a muscular outlet or infundibulum that surrounds the attachments of the pulmonary valve leaflets.

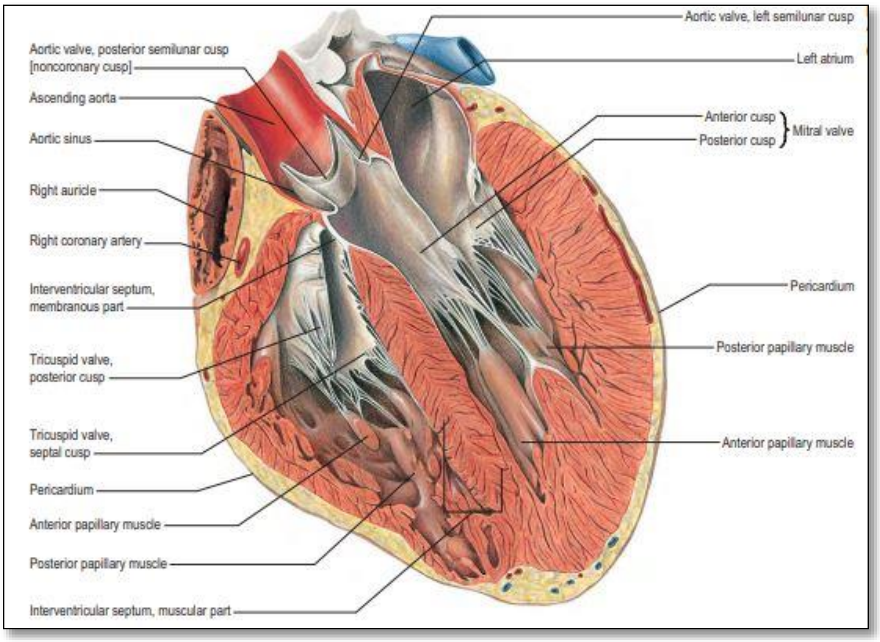

Figure 1.3: Interior of Ventricles of Heart

The inlet and outlet components of the ventricle, supporting and surrounding the leaflets of the tricuspid and pulmonary valves, respectively, are separated in the roof of the ventricle by the prominent supraventricular crest (crista supraventricularis) (Fig.1.3). The crest is made up predominantly by the inner heart curvature, bounded on the epicardial aspect by the rightward margin of the transverse sinus. The crest is a thick, muscular, highly arched structure, extending obliquely anteriorly and to the right from a septal limb high on the interventricular septal wall to a mural or parietal limb on the anterolateral right ventricular wall. The posterolateral aspect of the crest provides a principal attachment for the anterosuperior leaflet of the tricuspid valve. The septal limb of the crest may be continuous with, or embraced by, the septal limbs of the septomarginal trabeculation. The inlet and outlet regions extend apically into and from the prominent coarsely trabeculated component of the ventricle. The inlet component itself is also trabeculated, whereas the outlet component (infundibulum) has predominantly smooth walls. The trabeculated appearance is caused by a myriad of endocardial, lined, irregular muscular ridges and protrusions collectively known as trabeculae carneae. These protrusions and intervening grooves impart great variation in wall thickness; the protrusions vary in extent from mere ridges to trabeculations, fixed at both ends but otherwise free.

Moderator Band: One protrusion in the right ventricle, the septomarginal trabeculation or septal band, is particularly prominent, reinforcing the septal surface where, at the base, it divides into limbs that embrace the supraventricular crest. Towards the apex, it supports the anterior papillary muscle of the tricuspid valve and, from this point, crosses to the parietal wall of the ventricle as the moderator band. The role of the moderator band as part of the conduction system of the heart involves the right atrioventricular bundle, as conduction through cardiomyocytes move towards the apex of the ventricle before entering the anterior papillary muscle.The moderator band may be short/thick, long/thick, short/thin, long/thin: it is occasionally absent.

Atriventricular Valve : The atrioventricular valvular complex, in both ventricles, consists of the orifice and its associated anulus, the leaflets, the supporting chordae tendineae of various types and the papillary muscles. Harmonious interplay of all of these, together with the myocardial mass, depends on the conduction tissues and mechanical cohesion provided by the cardiac skeleton. All parts change substantially in position, shape, angulation and dimensions during the cardiac cycle.(Fig.1.4)

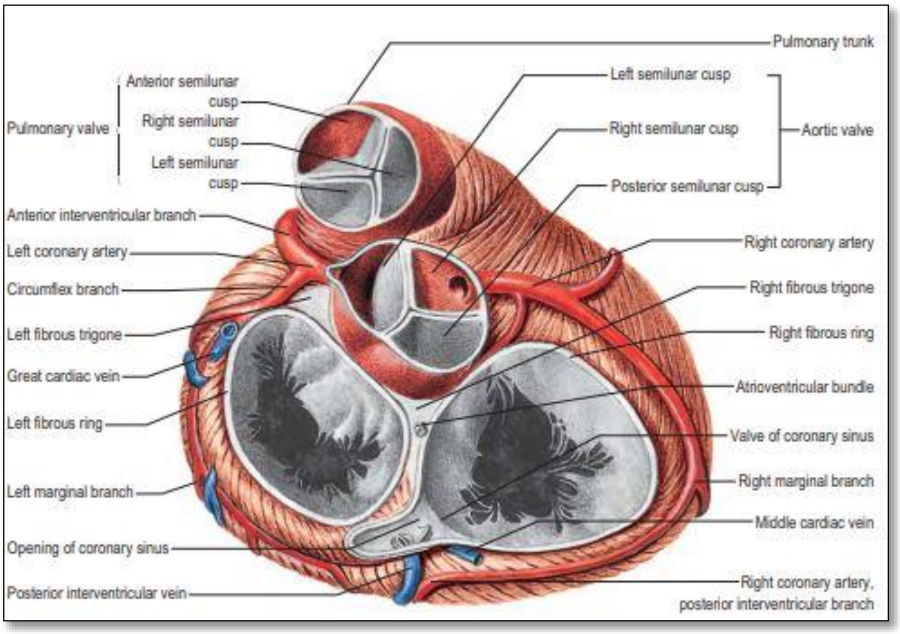

Figure 1.4: Superior View of Valves of Heart

Pulmonary Valve: The pulmonary valve, guarding the outflow from the right ventricle, surmounts the infundibulum and is situated at some distance from the other three cardiac valves.(Fig.1.4)

Papillary Muscle & Chordae Tendineae: A conspicuous protrusions are the papillary muscles, which are inserted at one end on to the ventricular wall and are continuous at the other end with collagenous cords, the chordae tendineae (tendinous cords), inserted on the free edge of the atrioventricular valves.The two major papillary muscles in the right ventricle are located in anterior and inferior positions. A third, smaller muscle lies medially, together with several smaller, variable muscles attached to the ventricular septum. (Fig.1.3)

➢ 1.1.4 Interior of left Atrium:

It possesses a venous component that receives the right and left superior and inferior pulmonary veins, a vestibule and an appendage. Its cavity and walls are formed largely by the proximal parts of the pulmonary veins that are incorporated into the atrium during development. The left atrial appendage is characteristically longer, narrower and more hooked than the right, and is a finger-like extension with more deeply indented margins.

Pulmonary Veins: The four pulmonary veins open into the superior posterolateral surfaces of the left atrium, two on each side (see Figs 57.3, 57.4B). This typical arrangement is present in 20–60% of the population. A common variation includes the presence of a short or long left common venous trunk and multiple pulmonary veins on the right.

- **1.1.5 Interior of left Ventricle:**

The left ventricle is constructed in accordance with its role as a powerful pump for the high-pressured systemic arterial circulation.

Aortic Valve: The aortic root, the anatomical bridge between the left ventricle and the ascending aorta, consists of the aortic valvular leaflets (supported by the aortic sinuses of Valsalva) and the inter-leaflet triangles interposed between their basal attachments. Three aortic valve leaflets are attached in part to the aortic wall and in part to the supporting ventricular structures. The semilunar attachments of leaflets incorporate segments of ventricular tissue within the bases of two of the aortic sinuses. The sinuses(Sinus of Valsalva) and leaflets are conveniently named as right, left and non-coronary, according to the origins of the coronary arteries.

Papillary Muscle & Chordae Tendinae: The two muscles supporting the leaflets of the mitral valve vary in length and breadth, and may be bifid. The anterolateral (superolateral) and posteromedial (inferoseptal) muscle. Chordae tendineae arise mostly from the tip and apical third of each muscle but sometimes take origin near their base. The chordae from each papillary muscle diverge and are attached to corresponding areas of closure on both valvular leaflets.(Fig.1.3)

1.2 Rationale Of The Study

- The study of the morphology of various valves, papillary muscles, remnant of left venous valve, chiari network of heart will provide support to heart anatomy which is necessary for various surgical procedures like valvular reconstructive surgery,cardiac catheterization.
- The dynamic progress of therapeutic and diagnostic cardio-invasive procedures implies a marked rise in interest in studies of cardiac anatomy and it is reasonable, therefore, to research on the morphometry of tricuspid valve,mitral

valve,aortic valve,pulmonary valve,thebesian valve,eustachian valve,papillary muscle,triangle of koch, remnant of left venous valve, chiari network of heart.

- The present study will not only confirm the previous findings on the tricuspid valve,mitral valve,aortic valve, pulmonary valve, thebesian valve, eustachian valve, papillary muscle , remnant of left venous valve, chiari network of heart, but will also study the pattern in the population of Vadodara as there are no such findings available in the current literature.