Ph.D. synopsis of the thesis on

# "MORPHOLOGY OF VARIOUS VALVES, PAPILLARY MUSCLE, LEFT VENOUS VALVE REMNANT, CHIARI NETWORK OF HEART AND THEIR POSSIBLE ROLE IN CARDIAC INTERVENTION - A CADAVERIC STUDY"

**Submitted to**
**The Maharaja Sayajirao University of Baroda**

THE MAHARAJA SAYAJIRAO UNIVERSITY OF BARODA
सत्यं शिवं सुन्दरम्

**For the degree of**
**"DOCTOR OF PHILOSOPHY IN ANATOMY"**
**(Medical)**

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MEDICAL COLLEGE BARODA

**At Department of Anatomy**
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**<u>TITLE OF THE STUDY:</u> "Morphology Of Various Valves, Papillary Muscle, Left Venous Valve Remnant, Chiari Network Of Heart And Their Possible Role In Cardiac Intervention - A Cadaveric Study"**

# 1. INTRODUCTION:-

HEART - GENERAL ORGANIZATION

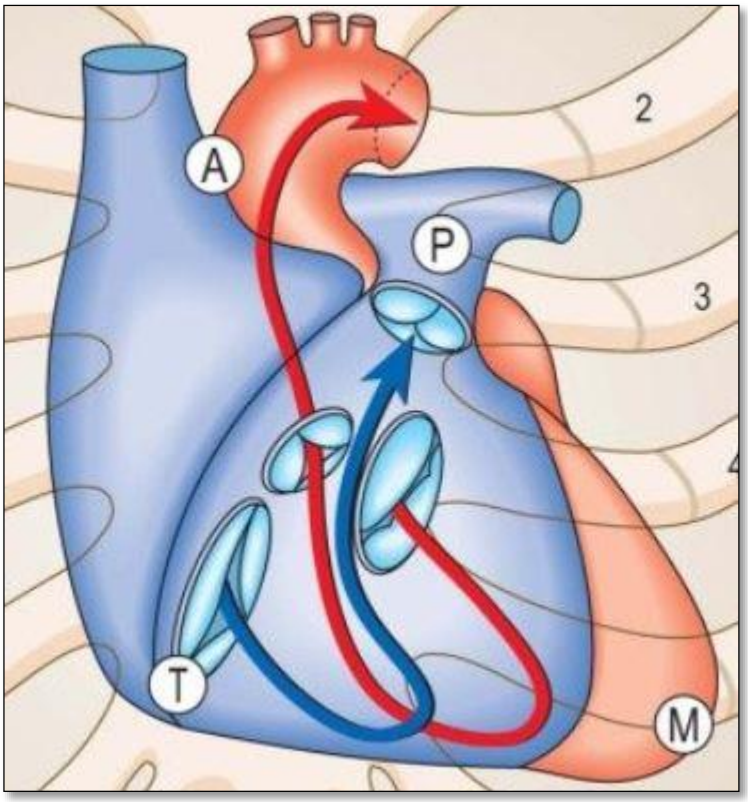


**Figure 1.1 : Heart Organisation**

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. 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 preliminary description emphasizes such difficulties in order to circumvent certain misconceptions, before proceeding to an account of more detailed structure. The sites of the tricuspid and pulmonary valves are widely separated and on different planes, the flat cavity of the right ventricle, which is crescentic in its section, splaying out between them. The inlet to the left ventricle, which contains the mitral valve, is very close to its outlet (the aortic valve.) The left ventricular cavity is narrow and conical, and its tip occupies the cardiac apex.

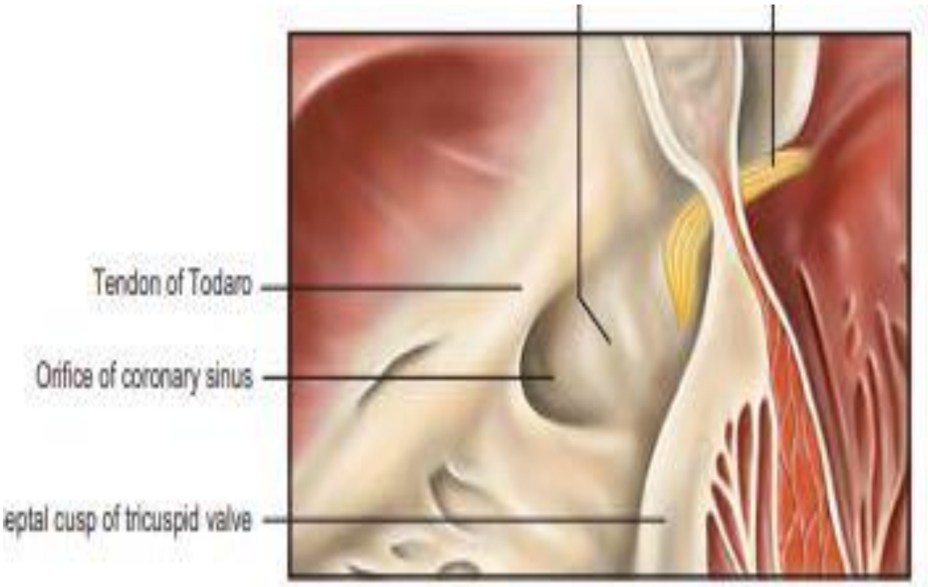

**Figure 1.2 : Coronary Sinus**

The interatrial septum (or atrial septum) is oblique, so the right atrium is both anterior and to the right of the left atrium. The superior vena cava opens into its dome and the inferior vena cava into its lower posterior part. An extensive muscular pouch, the auricle, projects anteriorly to overlap the right side of the ascending aorta. The auricle is a broad, triangular structure and has a wide junction with the true atrial component of the atrium. The junction between the venous part (sinus venosus) and the atrium proper is extending between the right sides of the openings of the two venae cavae, which corresponds, internally, to the terminal crest (crista terminalis). The interior surface of the right atrium can be divided into three regions: a smooth-walled venous component posteriorly that leads, anteriorly, to the vestibule of the tricuspid valve and the auricle. The wall of the vestibule is smooth, but its junction with the auricle is ridged all around the atrioventricular junction. The smooth-walled part receives the opening of the venae cavae and the coronary sinus. It represents the venous component (sinus venosus) of the developing heart. The wall of the vestibule has a ridged surface and that of the auricle is trabeculated. Both are derived from the embryonic atrium proper. The superior and inferior venae cavae open into the venous component. The superior vena cava returns blood from head, neck and upper limb through an orifice that faces inferoanteriorly and has no valve. 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. Anterior to its orifice is a flap-like valve, the Eustachian valve or valve of the inferior vena cava. Of varying size, this valve is found along the lateral, or right, margin of the vein. When traced inferiorly, it runs into the sinus septum (see below), where it is contiguous with the valve of the coronary sinus. The lateral part of the Eustachian valve becomes continuous with the lower end of the terminal crest. The valve is a fold of endocardium enclosing a few muscular fibres. It is large during fetal life, when it serves to direct richly oxygenated blood from the placenta through the foramen ovale of the atrial septum into the left atrium. The valve varies markedly in size in postnatal life; it is sometimes cribriform or filamentous but often is absent. A particularly prominent recess, behind the Eustachian valve, is seen posteroinferiorly relative to the ostium of the coronary sinus. The coronary sinus opens into the venous atrial component between the orifice of the inferior vena cava, the fossa ovale and the vestibule of the atrioventricular opening. The coronary sinus is often guarded by a thin, semicircular valve that covers the lower part of the orifice (known as the Thebesian valve).The ostium of the coronary sinus forms a prominent landmark in the right atrium, and is the conduit for return of most of the venous blood from the heart, although some atrial veins drain directly to the right or left atrial chambers. The coronary sinus begins at the point where the oblique vein of the left atrium joins the great cardiac vein. This smooth, muscular ridge begins on 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, and corresponds externally to the terminal groove. The septal wall presents the fossa ovale, an oval depression above and to the left of the orifice of the inferior vena cava. Its floor is the primary atrial septum, the septum primum. The rim of the fossa is prominent and, although often said to represent the edge of the so called septum secundum, in reality it is merely the in folded walls of the atrial chambers. It is most distinct above and in front of the fossa, and is usually deficient inferiorly. A small slit is sometimes found at the upper margin of the fossa, ascending beneath the rim to communicate with the left atrium. This represents failure of obliteration of the fetal foramen ovale, which remains patent in up to one-third of all normal hearts.

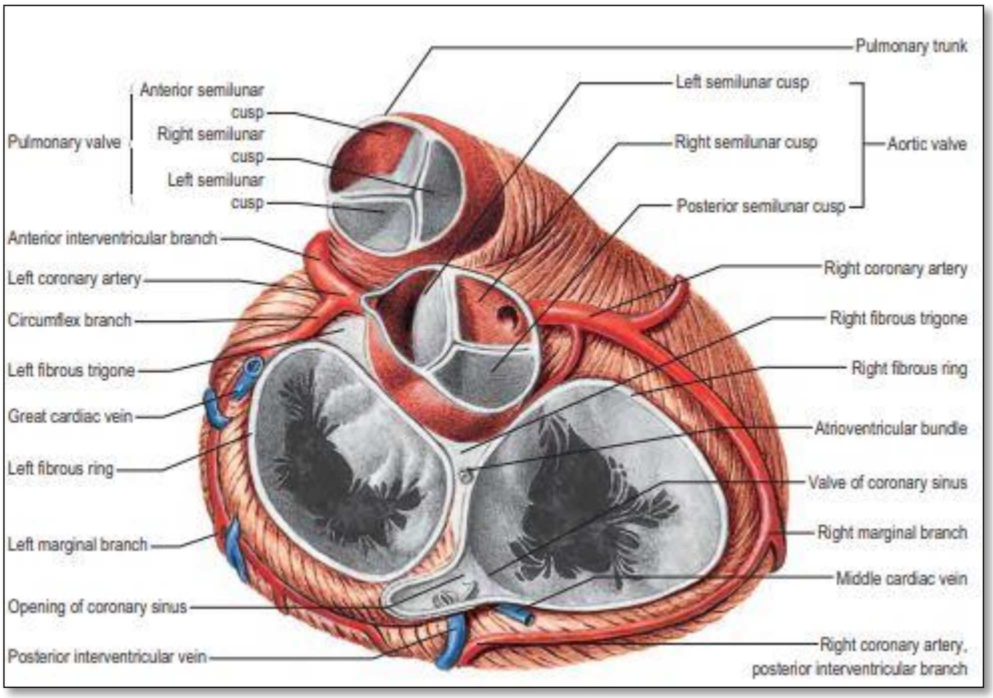


**Figure 1.3 : Superior View Of Valves Of Heart**

The right ventricle extends from the right atrioventricular (tricuspid) orifice nearly to the cardiac apex. It then ascends to the left to become the infundibulum, or conus arteriosus, reaching the pulmonary orifice and supporting the cusps of the pulmonary valve. Topographically, the ventricle possesses an inlet component which supports and surrounds the tricuspid valve; a coarsely trabeculated apical component; and a muscular outlet or infundibulum, which surrounds the attachments of the cusps of the pulmonary valve.The inlet and outlet components of the ventricle, supporting and surrounding the cusps of the tricuspid and pulmonary valves respectively, are separated in the roof of the ventricle by the prominent supraventricular crest (crista supraventricularis). The posterolateral aspect of the crest provides a principal attachment for the anterosuperior cusp of the tricuspid valve. The septal limb of the crest may be continuous with, or embraced by, the septal limbs of the septomarginal trabecula. Other conspicuous protrusions are the papillary muscles, which are inserted at one end onto the ventricular wall and are continuous at the other end with collagenous cords, the chordae tendineae, inserted on the free edge and elsewhere on the free aspect of the atrioventricular valves. Towards the apex, it supports the anterior papillary muscle of the tricuspid valve. The atrioventricular valvular complex, in both right and left ventricles, consists of the orifice and its associated anulus, the cusps, the supporting chordae tendineae of various types and the papillary muscles. Harmonious interplay of all these, together with the atrial and ventricular myocardial masses, depends on the conduction tissues and the mechanical cohesion provided by the fibroelastic cardiac skeleton. All parts change substantially in position, shape, angulation and dimensions during a single cardiac cycle. The tricuspid valve orifice is best seen from the atrial aspect and measures on average 11.4 cm in circumference in males and 10.8 cm in females. It has a clear line of transition from the atrial wall or septum to the lines of attachment of the valvular cusps. Roughly triangular, its margins are described as anterosuperior, inferior and septal, corresponding to the lines of attachment of the valvular cusps. It is usually possible to distinguish three cusps in the tricuspid valve, hence the name. They are located anterosuperiorly, septally and inferiorly, corresponding to the marginal sectors of the atrioventricular orifice so named. Each is a reduplication of endocardium enclosing a collagenous core, continuous marginally and on its ventricular aspect with diverging fascicles of chordae tendineae (see below) and basally confluent with the anular connective tissue. All cusps of the atrioventricular valves display, passing from the free margin to the inserted margin, rough, clear and basal zones. The anterosuperior cusp is the largest component of the tricuspid valve. It is attached chiefly to the atrioventricular junction on the posterolateral aspect of the supraventricular crest, but extends along its septal limb to the membranous septum, ending at the anteroseptal commissure. One or more notches often indent its free margin. The attachment of the septal cusp passes from the inferoseptal commissure on the posterior ventricular wall across the muscular septum and then angles across the membranous septum to the anteroseptal commissure. The septal cusp defines one of the borders of the triangle of Koch, thereby aiding location of the atrioventricular node, which lies at the apex of the triangle, and ensuring that this area can be avoided when operating on the tricuspid valve. The inferior cusp is wholly mural in attachment and guards the diaphragmatic surface of the atrioventricular junction. The chordae tendineae are fibrous collagenous structures supporting the cusps of the atrioventricular valves. False chordae connect papillary muscles to each other or to the ventricular wall including the septum, or pass directly between points on the wall (or septum, or both); they are irregular in numbers and dimensions in the right ventricle. The true chordae usually arise from small projections on the tips or margins of the apical one-thirds of papillary muscles, but sometimes arise from the bases of papillary muscles or directly from the ventricular walls and the septum. They are attached to various parts of the ventricular aspects or the free margins of the cusps. They have been classified into first-, second- and third-order chordae according to the distance of the attachment from the margins of the cusps.

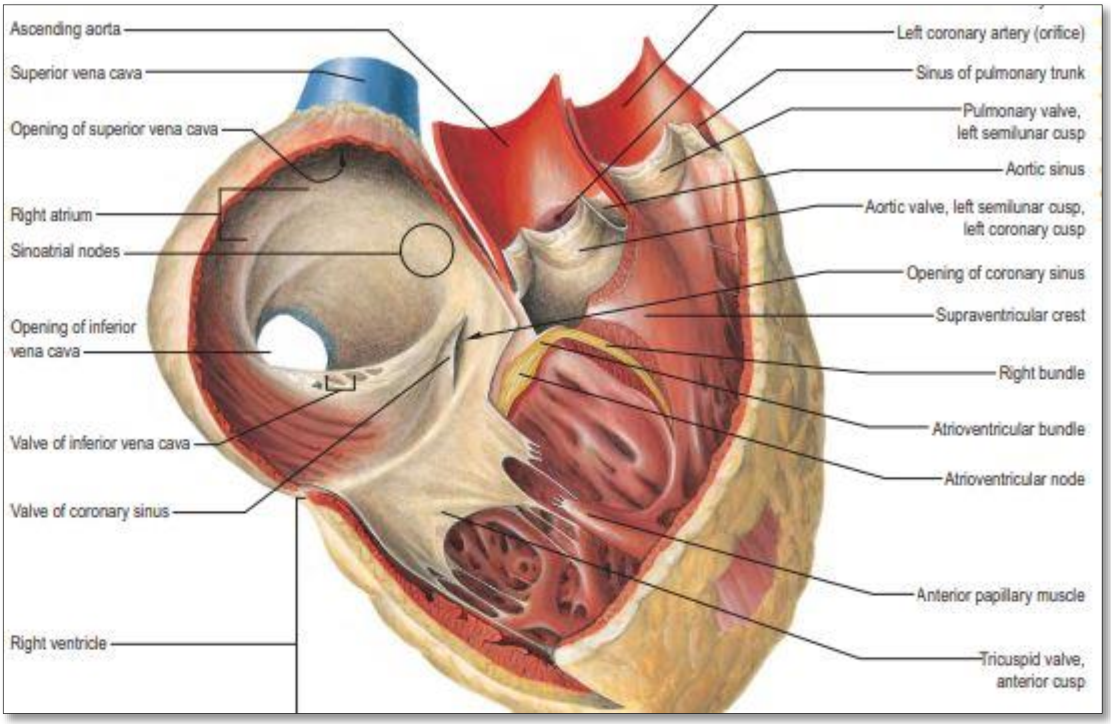


**Figure 1.4 : Interior of Right Atrium and Tricuspid Valve**

The two major papillary muscles in the right ventricle are located in anterior and posterior positions. A third, smaller muscle has a medial position together with several smaller, and variable, muscles attached to the ventricular septum. The anterior papillary muscle is largest. Its base arises from the right anterolateral ventricular wall below the anteroinferior commissure of the inferior cusp and it also blends with the right end of the septomarginal trabecula. The posterior, or inferior, papillary muscle arises from the myocardium below the inferoseptal commissure and is frequently bifid or trifid. The septal, or medial, papillary muscle is small but typical, and arises from the posterior septal limb of the septomarginal trabecula. All the major papillary muscles supply chordae to adjacent components of the cusps they support. A feature of the right ventricle is that the septal cusp is tethered by individual chordae tendineae directly to the ventricular septum; such septal insertions are never seen in the left ventricle. When closed, the three cusps fi t snugly together, the pattern of the zones of apposition confi rming the trifoliate arrangement of the tricuspid valve.

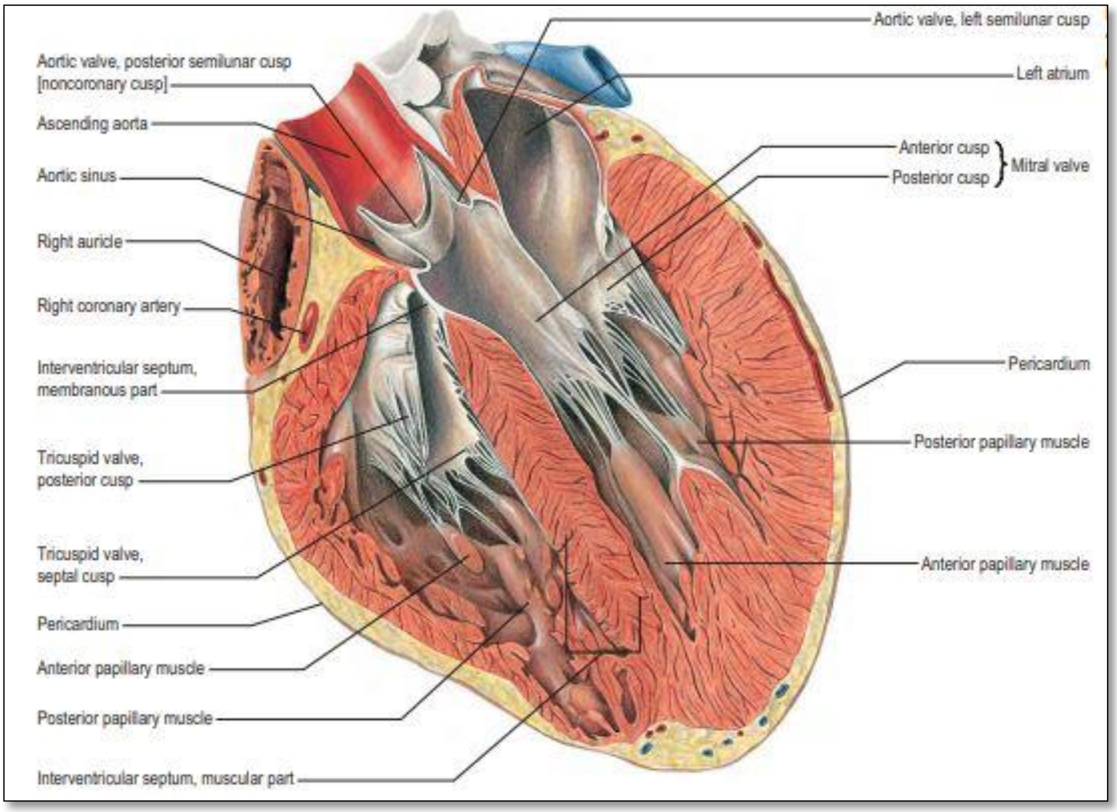


**Figure 1.5: Papillary Muscle and Chordae Of Ventricles**

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. It has three semilunar cusps attached by convex edges partly to the infundibular wall of the right ventricle and partly to the origin of the pulmonary trunk. The line of attachments is curved, rising at the periphery of each cusp near their zones of apposition (the commissures) and reaching the sinutubular ridge of the pulmonary trunk. Removal of the cusps shows that the fibrous semilunar attachments enclose three crescents of infundibular musculature within the pulmonary sinuses, whereas three roughly triangular segments of arterial wall are incorporated within the ventricular outflow tract beneath the apex of each commissural attachment. There is, thus, no proper circular 'anulus' supporting the cusps of the valve, and the fibrous semilunar attachment is an essential requisite for snug closure of the nodules and lunules of the cusps during ventricular diastole. The official nomenclature refers to an anterior, a posterior and a septal cusp, based on their position in the fetus. The position changes with development and in the adult there is one anterior semilunar cusp, and right and left semilunar cusps. Each cusp is a fold of endocardium, with an intervening, and variably developed, fibrous core.Each semilunar cusp is contained within one of the three sinuses of the pulmonary trunk.The left ventricle has an inlet region, guarded by the mitral valve (ostium venosum), an outlet region, guarded by the aortic valve (ostium arteriosum), and an apical trabecular component. The mitral(bicuspid) valve has an orifice with its supporting anulus, cusps and a variety of chordae tendineae and papillary muscles. The mitral, tricuspid and aortic orifices are intimately connected centrally at the central fibrous body. When the cusps of the mitral valve close, they form a single zone of coaptation, sometimes termed the commissure. The mitral valvular cusps have been described as paired structures. Hence, the name 'bicuspid valve' is more explicit, although erroneous (the cusps are not cuspid, or 'peaked', in form) and surely less picturesque than the clinical term 'mitral'. Confusion, controversy and difficulties in quantitation have arisen, however, because small accessory cusps are almost always found between the two major cusps. Its free edge bears several indentations; two are sufficiently deep and however, for these anteromedial and posterolateral extremities to be designated as two independent commissures, each positionally named as indicated. When the valve is laid open, the anterior cusp (aortic, septal, 'greater' or anteromedial) is seen to guard one-third of the circumference of the orifice and to be semicircular or triangular, with few or no marginal indentations. The posterior cusp (mural, ventricular, 'smaller' or posterolateral) usually has two or more minor indentations. Lack of definition of major intervalvular commissures has previously led to disagreement and confusion concerning the territorial extent of this cusp and the possible existence of accessory 'scallops'.Further indentations usually divide the mural cusp into a relatively large middle scallop and smaller anterolateral and posteromedial commissural scallops. Each scallop has a crescentic, opaque rough zone, receiving on its ventricular aspect the attachments of the chordae that define the area of valvular apposition in full closure. The chordae tendineae resemble those supporting the tricuspid valve. False chordae are also irregularly distributed as in the right ventricle. They occur in about 50% of all human left ventricles, and often cross the subaortic outflow. Many contain extensions from the ventricular conducting tissues. True chordae of the mitral valve may be divided into intercusp (or commissural) chordae, rough zone chordae, including the special strut chordae, so-called 'cleft' chordae and basal chordae. Most true chordae divide into branches from a single stem soon after their origin from the apical one-third of a papillary muscle, or proceed as single chordae that divide into several branches near their attachment. Basal chordae, in contrast, are solitary structures passing from the ventricular wall to the mural cusp. There is such marked variation between the arrangement of the chordae in individual normal hearts that any detailed classification loses much of its clinical significance. Suffice it to say that, in the majority of hearts, the chordae support the entire free edges of the valvular cusps, together with varying degrees of their ventricular aspects and bases. There is some evidence to suggest that those valves with unsupported areas of the free edge become prone to prolapse in later life. Two papillary muscles supporting the cusps of the mitral valve also vary in length and breadth and may be bifid. The anterolateral muscle arises from the sternocostal mural myocardium, the posteromedial from the diaphragmatic region. Chordae tendineae arise mostly from the tip and apical one-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 cusps.The smooth left ventricular outflow tract, or aortic vestibule, ends at the cusps of the aortic valve. Although stronger in construction, the aortic valve resembles the pulmonary in possessing three semilunar cusps, supported within the three aortic sinuses of Valsalva. Although the aortic valve, like the pulmonary valve, is often described as possessing an anulus in continuity with the fibrous skeleton, there is no complete collagenous ring supporting the attachments of the cusps. As with the pulmonary valve, the anatomy of the aortic valve is dominated by the fibrous semilunar attachment of the cusps. The cusps are attached in part to the aortic wall and in part to the supporting ventricular structures. The situation is more complicated than in the pulmonary valve, because parts of the cusps also take origin from the fibrous subaortic curtain, and are continuous with the aortic cusp of the mitral valve. Three cusps are conveniently named as right, left and non-coronary, according to the origins of the coronary arteries. Each cusp has a thick basal border, deeply concave on its aortic aspect, and a horizontal free margin. The aortic surface of each cusp is rougher than its ventricular aspect. Currently, three sets of names are used to describe the aortic cusps. Posterior, right and left refer to presumed fetal positions before full cardiac rotation has occurred. Corresponding terms based on the approximate positions in maturity are anterior, left posterior and right posterior. However, as already indicated, widespread clinical terminology links both cusps and sinuses to the origins of the coronary arteries. Thus, the anterior is termed the right coronary cusp, the left posterior is the left coronary, and the right posterior is the noncoronary: these clinical terms are preferable, in the normal heart, because they are simple and unambiguous. The aortic sinuse of Valsalva are more prominent than those in the pulmonary trunk.Coronary arteries usually open near this ridge within the upper part of the sinus, but are markedly variable in their origin.

## 2. AIMS & OBJECTIVES:- Primary objectives of the present work are:

**2.1** To study morphology of normal and variation in tricuspid valve,by measuring various parameters namely: length of cusps, width of cusp, number of chordae attached at each cusp, shape of cusp, annular circumference of valve , number of cleft and scallop present in cusps.

**2.2** To study morphology of normal and variation in bicuspid valve, by measuring various parameters namely: length of cusps, width of cusp, number of chordae attached at each cusp, shape of cusp, annular circumference of valve , number of cleft and scallop present in cusps.

**2.3** To study morphology of normal and variation in aortic valve, by measuring various parameters namely: length of cusps, width of cusp,annular circumference of valve,origin and variation in coronary arteries.

**2.4** To study morphology of normal and variation in pulmonary valve, by measuring various parameters namely: length of cusps, width of cusp, number of cusp, annular circumference of valve.

**2.5** To study morphology of Eustachian valve by measuring various parameters namely: presence or absence of valve. If present so to study structural composition of Eustachian valve.

**2.6** To study morphology of thebesian valve by measuring various parameters namely: presence or absence of valve. If present so to study structural composition , shape ,site of attachment on coronary sinus and how thebesian valve covers coronary ostium.

**2.7** To study morphology of coronary sinus by measuring various parameters namely: craniocaudal diameter, transerve diameter.

**2.8** To study morphology of papillary muscle by measuring various parameters namely: number , length, number of additional head if present, shape of tip, pattern of papillary muscle.

**2.9** To study morphology of chiary network if present,by measuring various parameters namely: structure, attachment of both ends either on inferior vena cava, coronary sinus or on right atrial wall.

**2.10** To study variation in structure of remnant of left venous valve if present.

**2.11** To find out variation in different measured parameters of heart.

## 3. RESEARCH METHODOLOGY:-

**3.1. Data collection procedure:** This was a cross sectional observational study carried out after obtaining approval from ethics committee, at Anatomy Department, Medical College Baroda,Gujarat. Hundred properly embalmed and formalin fixed adult cadaveric hearts specimens which retains its morphological features and in good condition after removal from the cadavers, were selected for the study. Specimens with gross morphological changes and having calcified valves were excluded. Dissection was done under the guidance and supervision and observations were made after dissecting the cadavers.

**3.2 Details of method followed for measurement of various parameters:** Dissection of heart was done using cunnighams volume-2 and interior of heart was seen for tricuspid valve, bicuspid valve, aortic valve, pulmonary valve, thebesian valve, eustachian valve, chiari network, papillary muscle and left venous valve remnant.

Morphological parameter of above mentioned structure were measured as follows:

**3.2.1 Tricuspid valve:** If there were presence of three cusps on right side than it was normal valve and if any missing or additional cusp was there than it was consider as abnormal/variation of valve.

- Length of cusp: Measurement of distance of attachment of each cusp on annulus.
- Height of cusp: From the middle point of length to maximum distance at free margin of each cusp.
- Shape of cusp: Each cusp was observed for either triangular, rectangular or D shape.

- Number of chordae tendon attached to each cusp were calculated.
- Number of papillary muscle attached to each cusp through chordae were calculated.
- Number of clefts and scallops present in each cusp.
- Annular circumference : With the help of cotton thread length of attached margin of vlve was measured and it considered as annular circumference.

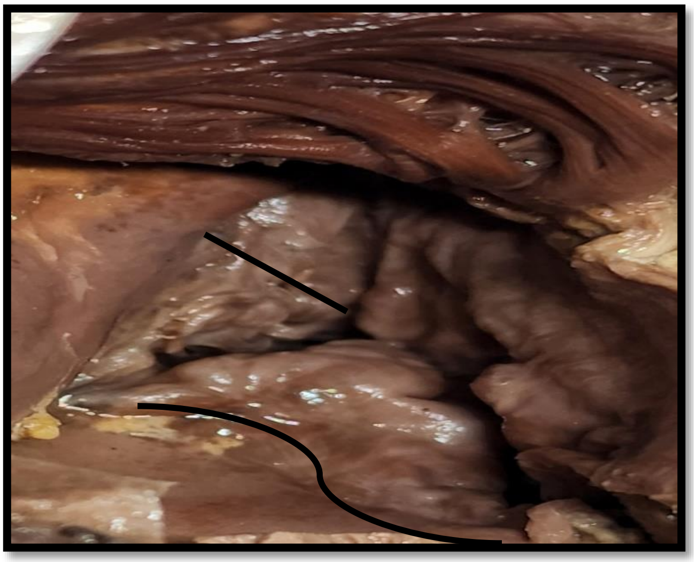

**Figure 3.1 : Length & Width Of Cusp Of Tricuspid Valve**

**3.2.2 Bicuspid valve** : If there were presence of two cusps on left side than it was normal valve and if any missing or additional cusp was there than it was consider as abnormal/variation of valve.

- Length of cusp: Measurement of distance of attachment of each cusp on annulus.
- Height of cusp: From the middle point of length to maximum distance at free margin of each cusp.
- Shape of cusp: Each cusp was observed for either triangular, rectangular or D shape.
- Number of chordae tendon attached to each cusp were calculated.
- Number of papillary muscle attached to each cusp through chordae were calculated.
- Number of clefts and scallops present in each cusp.
- Annular circumference : With the help of cotton thread length of attached margin of vlve was measured and it considered as annular circumference.

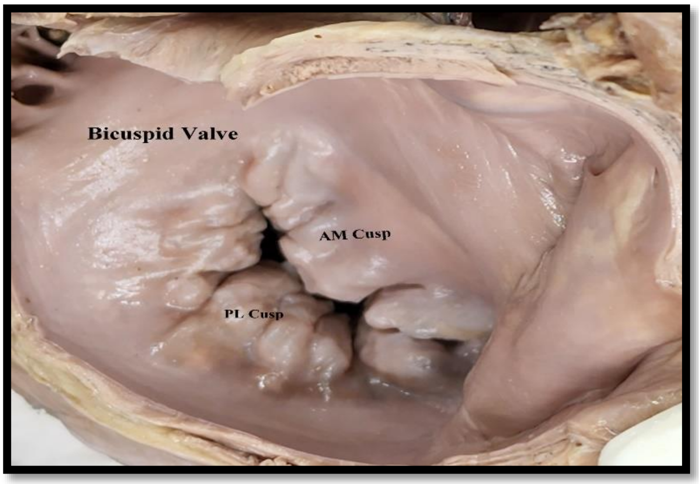


**Figure 3.2 : Bicuspid Valve Cusp-AM-Anteromedial, PL-Posterolateral**

**3.2.3 Aortic valve:** If there were presence of three cusps than it is normal valve and if any missing or additional cusp was there than it was consider as abnormal/variation of valve.

- Length of valve: Measurement of distance of attachment of each cusp on annulus.
- Width of valve:Width will be measured at commissural level.
- Annular Circumferance of valve: Measured at annulus of valve.

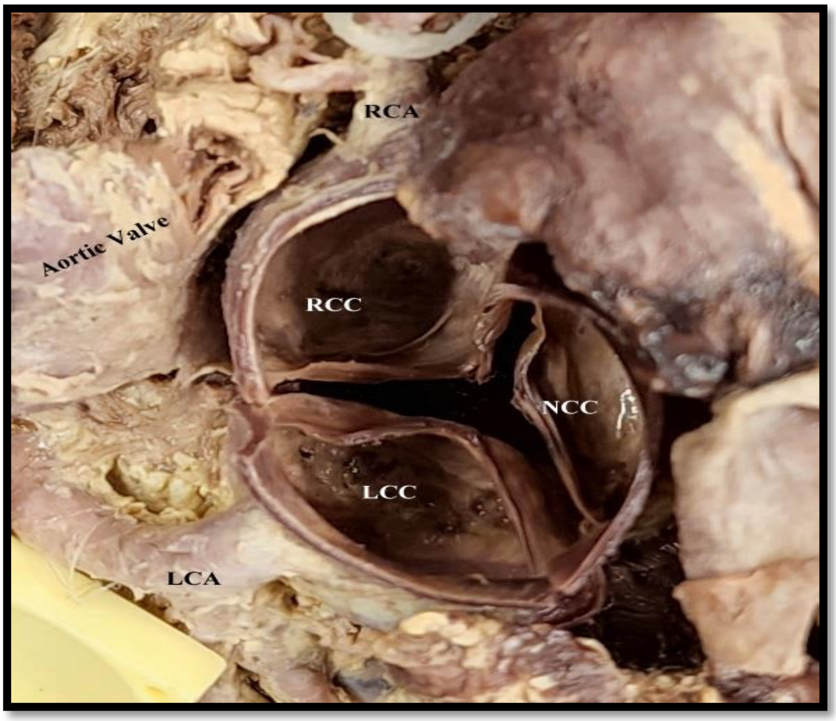


**Figure 3.3 : Aortic Valve-RCC-Right Coronary Cusp, LCC-Left Coronary Cusp, NCC-Non Coronary Cusp**

**3.2.4 Pulmonary valve**: If there were presence of three cusps than it is normal valve and if any missing or additional cusp was there than it was consider as abnormal/variation of valve.

- Length of valve: Measurement of distance of attachment of each cusp on annulus
- Width of valve:Width will be measured at commissural level.
- Annular Circumferance of valve: Measured at annulus of valve.

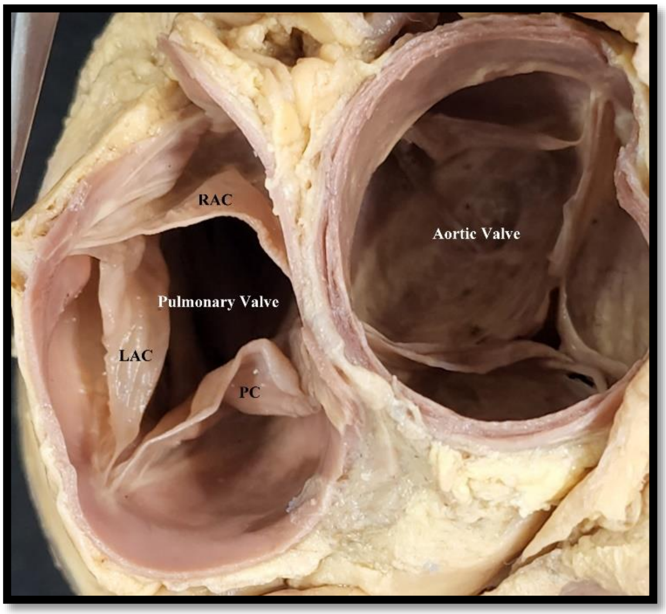


**Figure 3.4 : Pulmonary Valve- RAC-Right Anterior Cusp, LAC-Left Anterior Cusp, PC-Posterior Cusp**

**3.2.5 Papillary Muscle:** Number of papillary muscle, shape of papillary muscle,group of papillary muscles, additional or missing papillary muscle were recorded. Measurement of papillary muscle was taken as follows.

- Length of papillary muscle: From tip to basal attachment.

**3.2.6 Eustachian valve:** If this valve was present than shape , compostion and site of attachment was observed and recorded.

**3.2.7 Thebesian valve:** If this valve was present than shape , compostion and site of attachment was observed and recorded.

**3.2.8 Chiari network:** If present than its trbeculae, reticular threads, extent to nearer structure,how it covers it was observed and recorded.

**3.2.9** L**eft venous valve remnant:** If present than its trbeculae, extent to nearer structure, association with chiari network was observed.

**3.2.10 Coronary sinus:** Craniocaudal and transverse diameter of coronary sinus was recorded.

## 3.3. Data analysis: -

- The data was measured by using digital vernier caliper in millimeters (mm) & relevant photographs of the dissected specimen were taken using a digital camera.
- Data entry was done and analysed in Microsoft Excel.

## 3.4 Expected Outcome:-

Morphological variation of tricuspid valve, bicuspid valve, aortic valve, pulmonary valve, pailllary muscle, eustechian valve, coronary sinus, chordae tendinae, thebesian valve,chiari network and left venous valve remnant.

## 4. RESULTS:

Total hundred adult human cadaveric hearts were dissected with unknown gender. All measurements, shape, structural composition, number were taken & observed in the Department of Anatomy, Medical College, Baroda. Data was measured by using digital vernier caliper. Recorded observation & partial result is enlisted below in detail in tables.

### 4.1 Results On Parameters Of Tricuspid Valve

- In present study mean length of anteriosuperior , septal and inferior cusp was 27.61,27.40,21.73 mm with minimum 10.91,14.2,8.17 mm and maximum 64.92,42.82,32.77 mm respectively.
- In present study mean width of anteriosuperior , septal and inferior cusp was 17.30,13.03,15.59 mm with minimum 8.02,7.12, 6.28 mm and maximum 28.27,23.79,21.79 mm respectively.
- In present study mean annular circumfereance of tricuspid valve was 91.12 mm with minimum 47.01 mm and maximum 132.23 mm respectively.

| **Parameter** | | **Mean (mm)** | **Standard Deviation** | **Minimum (mm)** | **Maximum (mm)** |
|---|---|---|---|---|---|
| **Length Of Cusp** | Anterosuperior | 27.61 | 6.84 | 10.91 | 64.92 |
| | Septal | 27.40 | 4.84 | 14.2 | 42.82 |
| | Inferior(Posterior) | 21.73 | 4.63 | 8.17 | 32.77 |
| **Width (Height) of Cusp** | Anterosuperior | 17.30 | 3.10 | 8.02 | 28.57 |
| | Septal | 13.03 | 3.03 | 7.12 | 23.79 |
| | Inferior(Posterior) | 15.59 | 3.69 | 6.28 | 21.79 |
| **Annular Circumference of Valve** | | 91.12 | 18.65 | 47.01 | 132.23 |

### 4.2 Results on parameters of Bicuspid Valve

| Parameter | | Mean (mm) | Standard Deviation | Minimum (mm) | Maximum (mm) |
|---|---|---|---|---|---|
| **Length Of Cusp** | Anteromedial (Anterior) | 26.77 | 4.16 | 9.08 | 39.82 |
| | Posterolateral (Posterior) | 28.65 | 4.16 | 15.85 | 42.34 |
| **Width (Height) of Cusp** | Anteromedial (Anterior) | 18.44 | 3.04 | 7.31 | 26.31 |
| | Posterolateral (Posterior) | 11.52 | 2.53 | 5.01 | 23.10 |
| **Annular Circumference of Valve** | | 84.11 | 14.25 | 65 | 130 |

### 4.3 Results On Parameters Of Aortic Valve

- In present study mean length of right coronary ,left coronary, non coronary cusp was 30.44,30.73,30.22 mm with minimum 26.36,25.84,23.78 mm and maximum 34.2,34.6,34.86 mm respectively.
- In present study mean width of right coronary, left coronary, non coronary was 4.33,4.89,4.80 mm with minimum 3.4,3.53,3.54 mm and maximum 7.72,8.51,7.85 mm respectively.
- In present study mean annular circumfereance of aortic valve was 75.14 mm with minimum 71.24 mm and maximum 78.89 mm respectively.

| Parameter | | Mean (mm) | Standard Deviation | Minimum (mm) | Maximum (mm) |
|---|---|---|---|---|---|
| **Length Of Cusp** | Right Coronary | 30.44 | 1.37 | 26.38 | 34.2 |
| | Left Coronary | 30.73 | 1.51 | 25.84 | 34.6 |
| | Non Coronary | 30.22 | 1.84 | 23.78 | 34.86 |
| **Width(Height) of Cusp** | Right Coronary | 4.33 | 0.72 | 3.4 | 7.72 |
| | Left Coronary | 4.89 | 0.92 | 3.53 | 8.51 |
| | Non Coronary | 4.80 | 1.43 | 3.54 | 7.85 |
| **Annular Circumference of Valve** | | 75.14 | 1.82 | 71.24 | 78.89 |

### 4.4 Results On Parameters Of Pulmonary Valve

| Parameter | | Mean (mm) | Standard Deviation | Minimum (mm) | Maximum (mm) |
|---|---|---|---|---|---|
| **Length Of Cusp** | Right Anterior | 22.56 | 4.08 | 12.65 | 30.31 |
| | Left Anterior | 23.27 | 4.49 | 12.78 | 34.56 |
| | Posterior | 24.11 | 4.39 | 17.07 | 33.30 |
| **Width(Height) of Cusp** | Right Anterior | 4.69 | 1.08 | 3.05 | 10.87 |
| | Left Anterior | 4.64 | 1.42 | 3.10 | 14.10 |
| | Posterior | 4.71 | 1.03 | 3 | 8.9 |
| **Annular Circumference of Valve** | | 65.06 | 6.85 | 49.28 | 78.71 |

### 4.5 Results On Length Of Papillary Muscle

| Length(mm) | | Mean (mm) | Standard Deviation | Minimum (mm) | Maximum (mm) |
|---|---|---|---|---|---|
| **Right** | APM (n=127) | 13.03 | 2.44 | 8.50 | 20.63 |
| | PPM (n = 150) | 10.09 | 2.89 | 6.58 | 22.17 |
| | SPM (n = 55) | 6.06 | 1.07 | 3.33 | 9.96 |
| **Left** | APM (n=109) | 16.38 | 2.55 | 12.11 | 29.26 |
| | PPM ( n=130) | 21.01 | 2.20 | 8.9 | 26.23 |

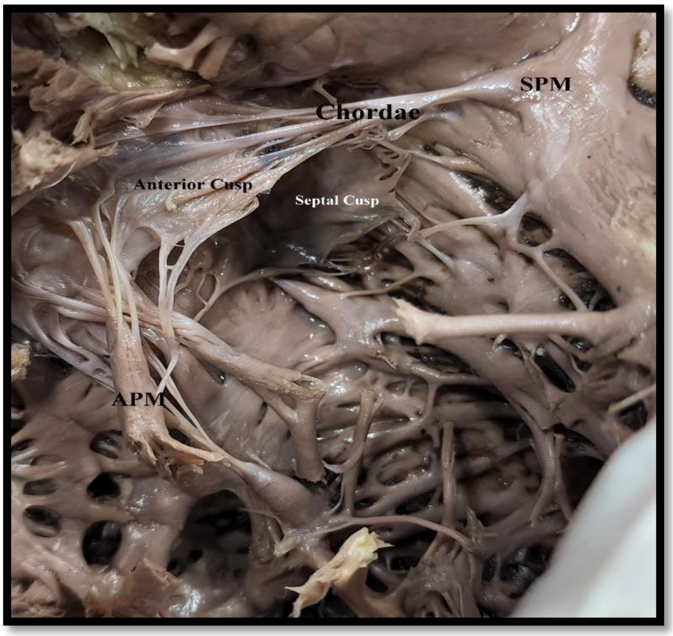


**Figure 4.1 : Anterosuperior cusp,SPM-Septal papillary muscle, APM-Anterior Papillary Muscle**

### 4.6 Results On Parameters Of Coronary Sinus

| Parameter | | Mean (mm) | Standard Deviation | Minimum (mm) | Maximum (mm) |
|---|---|---|---|---|---|
| **With Thebesian Valve ( n=55)** | Craniocaudal Length | 6.84 | 2.85 | 1.11 | 11.44 |
| | Transverse Length | 6.66 | 2.69 | 1.69 | 17.48 |
| **Without Thebesian (n=42) Valve** | Craniocaudal Length | 8.23 | 2.69 | 1.92 | 16.32 |
| | Transverse Length | 8.08 | 2.85 | 3.62 | 18.51 |

### 4.7 Result On Thebesian Valve

In >50% cases thebesian valve was present. In Majority of cases it was membranous type and semilumar in shape. When thebesian valve was present it partially obstruct the coronary sinus outlet. So because of presence of thebesian valve , craniocaudal and transverse diameter was decreased. Fenestrated membranous and biconcave fibrous band like thebesian valve were also observed in present study.

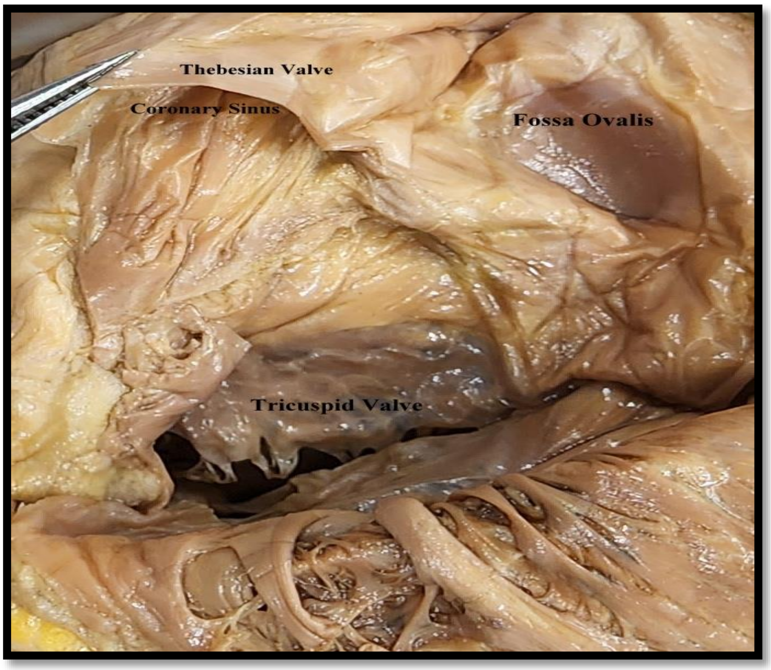


**Figure 4.2: Semilunar membranous Thebsian valve.**

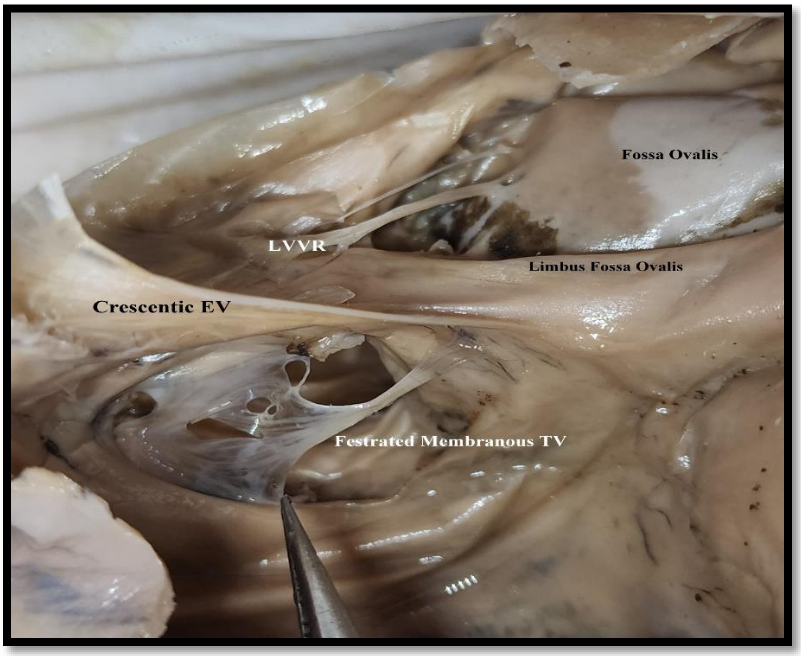


**Figure 4.3: Fenestrated membranous thebesian valve.**

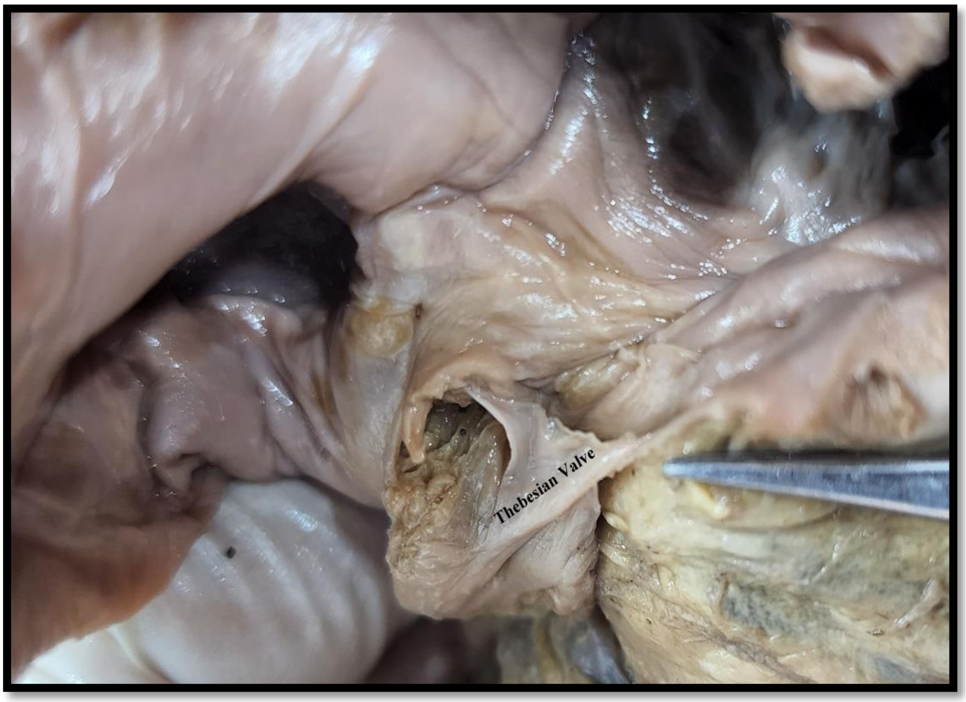


**Figure 4.4 : Biconcave band like thebesian valve**

## 4.8. Result On Eustachian Valve , Chiari Network and Left Venous Valve Remnant

In this study Eustachian valve was present in 10 cases. Among present Eustachian valve 4 cases were associated with presence of chiari network. Majority of eustacian valve was of ridge like but some was of membrous type also observed.

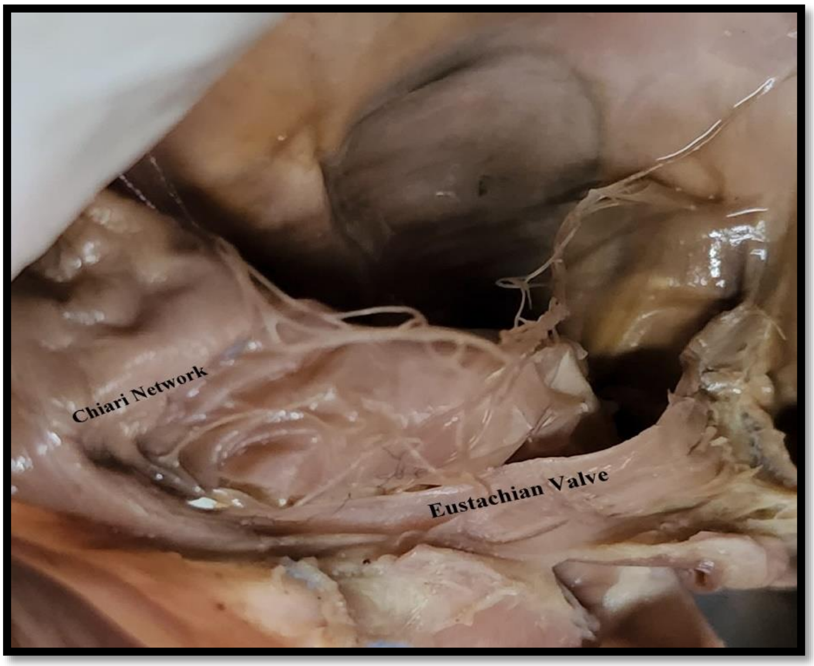

**Figure 4.5 : Eustachian valve(crest like) associated with chiari network- reticular network of fine thread**

In present study there were incidence of presence of chiari network.All the cases were having primary attachment on valve of Inferior Vena Cava,then fine reticular chiri network was either extend upto coronary sinus or towards atrium-wall or cavity.

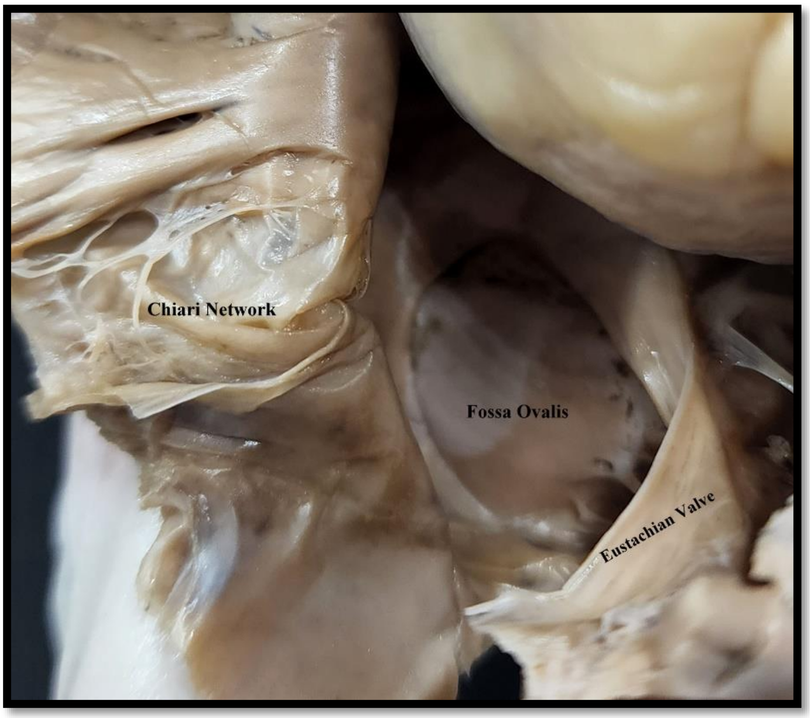


**Figure 4.6 : Chiari network extending from Eustachian valve to atrium.**

Incidance of presence of left venous valve remnant was there in < 10% cases.Left venous valve remant was observed by presence of any trabecular membranous or fibrous single or multiple strands in the ofssa ovalis.In this study there was some incidence presence of left venous valve remnant associated with chiari network.

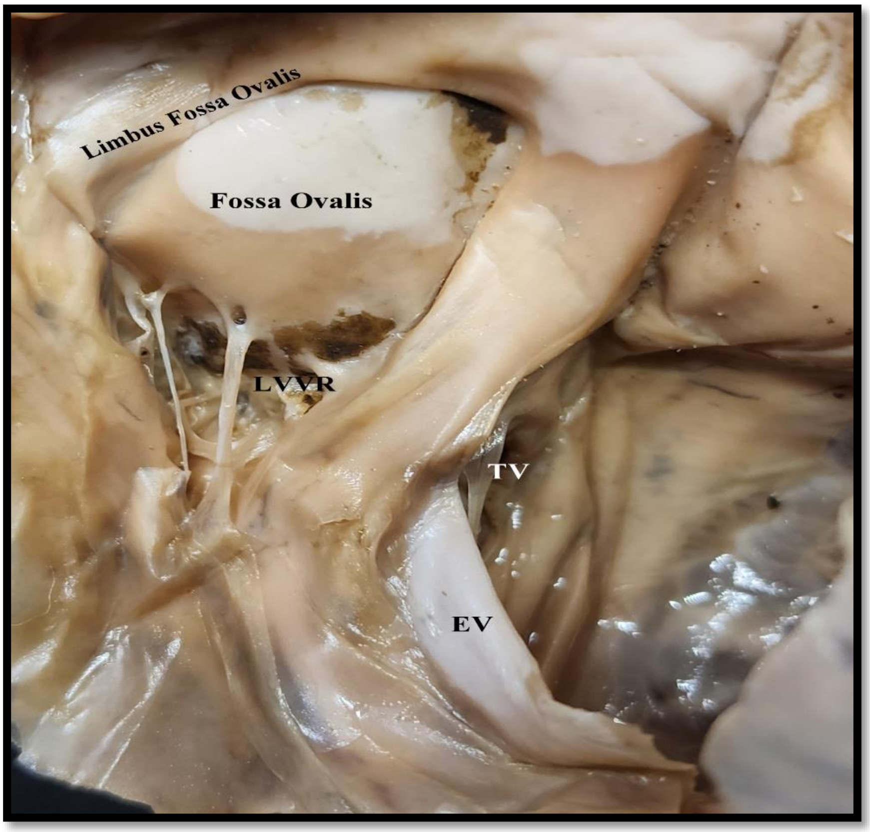


**Figure 4.7: LVVR-Left Venous Valve Remnant with multiple fibrous strand, EV-Eustachian Valve,TV-Thebesian Valve**

## 5. CONCLUSION

- The anatomy of the tricuspid valve is helpful in the practice of cardiac surgery, especially in the partial transfer of leaflets of the tricuspid valve for mitral valve repairs. The right atrioventricular valve region may be involved in severe cardiac malformations. Surgical techniques of tricuspid valve repair have been developed that are equally effective in correcting purely functional and organic valvular incompetence.
- Detailed knowledge about the normal anatomy of heart valve is required for assessing the valve pathologies by imaging modalities, manufacturing prosthetic valves of appropriate dimensions and in surgical correction of damaged heart valves.
- In case of mitral valve replacement for patients who require total excision of the leaflets and the chordae tendineae, mitral allograft is used to restore the annulo–papillary muscle continuity for the resuspension. Morphology of mitral valve and papillary muscles is a guide to the resuspension procedure in mitral valve replacement.

- Advanced invasive and interventional cardiac, diagnostic and management tools involve cannulation of the CS ostium. The presence of obstructive Thebesian valves has been reported to lead to unsuccessful cannulation of the CS.
- Since Chiari network is considered as a remnant of right venous valve, it often prefers the pattern of fetal circulation, thus directing the blood flow towards the foramen ovale. This favors the persistence of patent foramen ovale thus creating cyanosis, atrial septal aneurysm,and paradoxical embolism from right to left atrium resulting to thromboembolic manifestations.
- Chiari network may create turbulent blood flow leading to thrombus formation.
- Cardiac catheter can be entrapped by strands of Chiari network during an attempt to close the atrial septal defect.
- In Eustachian valve associated with patent foramen ovale great attention should be paid while operating ASD as a large Eustachian valve can be mistaken for the lower margin of ASD. Otherwise in such a case, closure of the ASD into the Eustachian valve may then divert the inferior vena cava blood into left atrium permanently.

## 6. UNIQUENESS OF PRESENT STUDY:

- The study would draw the attention of various anatomists, cardiac surgeons, radiologists and interventionists as cardiac anatomy is playing an important role in various heart diseases.
- The cardiac valves are frequently damaged by chronic rheumatic heart disease caused by streptococcal infection and congenital heart diseases. A diseased valve may produce conditions known as stenosis or regurgitation. Important aspect of management of valvular heart disease is replacement of diseased valve by a prosthetic valve surgically (i.e. valvular reconstruction surgery). This needs accurate assessment of various valvular parameters.
- The morphology of chiari network is essential to identify the Chiari network in echocardiography. It has been often observed as the web-like structure with a variable number of thread-like components with characteristic whip-like motion within the right atrium moving with each contraction of the heart.
- The blood flow through the inferior vena cava is guarded by the Eustachian valve. In majority of adults, Eustachian valve is either inconspicuous or appears

as a thin crescentric fold originating at the orifice of IVC. The literature based on cadaveric study of Eustachian valve is scarce.

The findings which are discovered in the present study regarding the morphometry of tricuspid valve, mitral valve, aortic valve, pulmonary valve, thebesian valve, eustachian valve, papillary muscle, remnant of left venous valve, chiari network of heart, are contributing to a better understanding of the same and definitely useful to clinicians in their respective fields.

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