Review Article

Indian Journal of Anatomy
Volume 12 Number 3, July – September 2023
DOI: http://dx.doi.org/10.21088/ija.2320.0022.12323.1

Structure & Development of Heart Valves

Hrisab Deb[1], Debajit Sarma[2]

How to cite this article:

Hrisab Deb, Debajit Sarma/ Structure & Development of Heart Valves/Indian J Anat. 2023;12(3):95-106.

Abstract

The human heart valves are intricate anatomical structures made up of numerous supporting structures and leaflets. Heart valves' primary function is to ensure that blood flows in a single direction, which is crucial. Malformation and dysfunction of these perplexing designs bring about possibly fatal pathologies. The development, gross anatomy and histology of the four cardiac valves will be discussed in this chapter. These four heart valves can be additionally named two atrioventricular (AV) valves and two semilunar valves; nevertheless, every valve is unique. When subjected to mechanical loading, the leaflets of the two types of valves are supported in different ways. To avoid regurgitation, the AV valves utilize a tension apparatus, which is made out of fibrocartilage containing chordae tendineae (heart strings) and expansions of ventricular myocardium known as papillary muscles. However, the semilunar or ventriculo-arterial valve leaflets are self-supporting, with three leaflets that snap shut on thickened edges. Both the AV and semilunar valve primordia appear early in heart development as acellular swellings between the primitive myocardium and the endocardium. These swellings or pads are loaded up with proteoglycans and glycosaminogly cans making them jelly like consistency. The arrangement of valves during embryogenesis (i.e., valvulogenesis) begins from endocardial cells covering the myocardium. These cells go through an endothelial mesenchymal change, multiply and relocate inside an extracellular grid. In both the atrioventricular canal and the outflow tract, this causes bilateral cardiac cushions to form. Both the cells in the prospective valve and the endocardium are thought to have originated in an embryo. This review will help to get thorough knowledge about the dimensions, morphology and development of the heart valves which is required for planning surgical procedures and manufacturing various types of prosthesis for heart valves.

Keywords: Atrioventricular (AV) Valves; Chordae Tendineae; Myocardium; Endocardium; Valvulogenesis; Embryonic Stem Cells (ESC).

Author's Affiliation: [1,2]Assistant Professor, Advanced Imaging Technology, Kaziranga University, Jorhat 785006, Assam, India.

Corresponding Author: Hrisab Deb, Assistant Professor, Advanced Imaging Technology, Kaziranga University, Jorhat 785006, Assam, India.

E-mail: debajitsarma72@gmail.com

Received on: 18.07.2023

Accepted on: 31.08.2023

INTRODUCTION

The pericardium surrounds the heart, a conical, hollow muscular organ in the middle of the mediastinum. The size is about of a held clench hand and siphons blood to the different parts of the body to meet the nutritive necessities. It is obliquely positioned behind the sternum's body and adjacent costal cartilages, with one third on the right and two thirds on the left of the median plane.[1] There are

four chambers, among them both the atria receive venous blood as weakly contractile reservoirs for final filling of the two ventricles and then provide the powerful expulsive contraction that forces blood into the main arterial system. A sagittal section through the chest taken in the midline shows the right ventricle situated most anteriorly, with the left chamber found posteriorly.[2] The right portion of the heart begins in the right atrium and receives blood from the superior and inferior venae cavae in addition to the coronary sinus, which serves as the main venous in flow into the heart. This fundamental venous blood passes from the right atrioventricular opening which is protected by the tricuspid valve, to enter the delta part of the right ventricle. The apical trabecular component of the ventricle contracts, closing the tricuspid valve and releasing blood into the pulmonary trunk through the muscular right ventricular outflow tract at increasing pressure. The blood then flows through the pulmonary vascular bed, which has a relatively low resistance. The left atrium, which receives all pulmonary oxygenated blood in flow as well as some coronary venous in flow, is where the left portion of the heart begins.[2] After that contracts to fill the left ventricle through the left atrioventricular orifice guarded by its mitral valve. The ventricle is able to eject via the left ventricular outflow tract into the aortic sinuses, the ascending aorta, and the entire systemic arterial tree when the pressure in the apical trabecular component rapidly increases, closing the mitral valve and opening the aortic valve. The larger structural organization of the "left heart" can be explained by the large vascular bed's high peripheral resistance and high metabolic demands, particularly those of the brain's sustained tissues.[3] The ejection phase of the left ventricle is shorter than that of the right, but the fluctuations in pressure is very much greater. Because of its contrasting functional demands, the heart is far from a simple pair of (structurally combined) parallel pumps, even though the right and left ventricles must deliver more or less the same volume with each contraction.

The heart valves prevent blood from regurgitating in the opposite direction and maintain the blood's unidirectional flow. The heart has two pairs of valves: one set of semilunar valves and one set of atrioventricular valves. The right atrioventricular valve is known as the tricuspid valve since it has three cusps. The left atrioventricular valve is known as the bicuspid valve since it has two cusps. The mitral valve is another name for it. The pulmonary and aortic valves are examples of semilunar valves with three semilunar cusps each. The cusps are folds of endocardium, strengthened by an intervening layer of fibrous tissue.[38] The gross structure of all the valves are shown in *Fig. 1.* The purpose of the

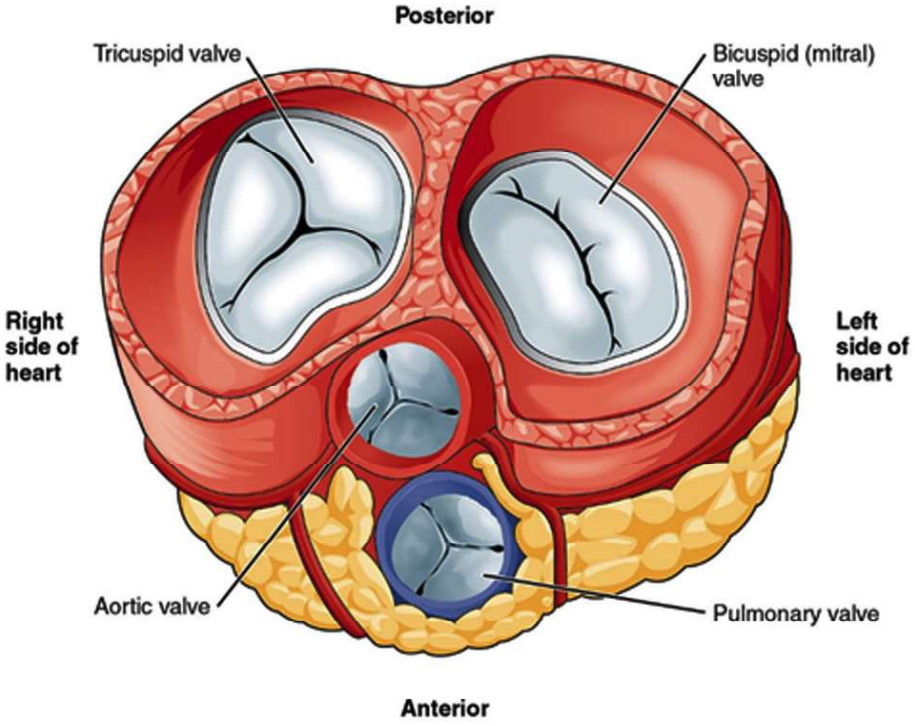

Fig. 1: Valves of the Heart

review is to get thorough knowledge about the structure and dimensions of the heart valves which is very important in diagnosis, prognosis and planning for surgical procedures. This review will also help the vendors in manufacturing different types of prosthetic valves.

Development of Heart Valves

The formation of endocardial cushions in the primitive looped heart tube's AV canal (AVC) and outflow tract (OFT) is the first indication that heart valves are developing during early embryonic development. The endocardial cushions are the source of the valve primordia that are associated with individual leaflets and cusps; however, the precise cushion origins of particular valve components are not well defined. The development process is shown in *fig. 2 & 3.*

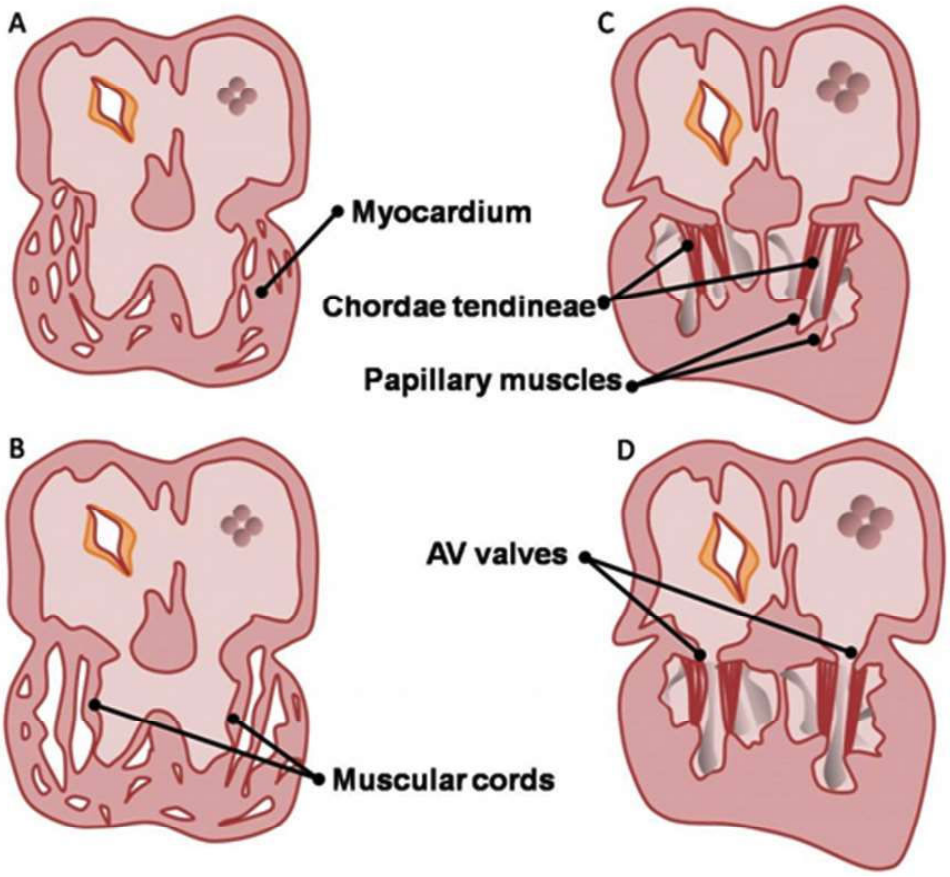

Fig. 2: Development of the mitral and tricuspid valves

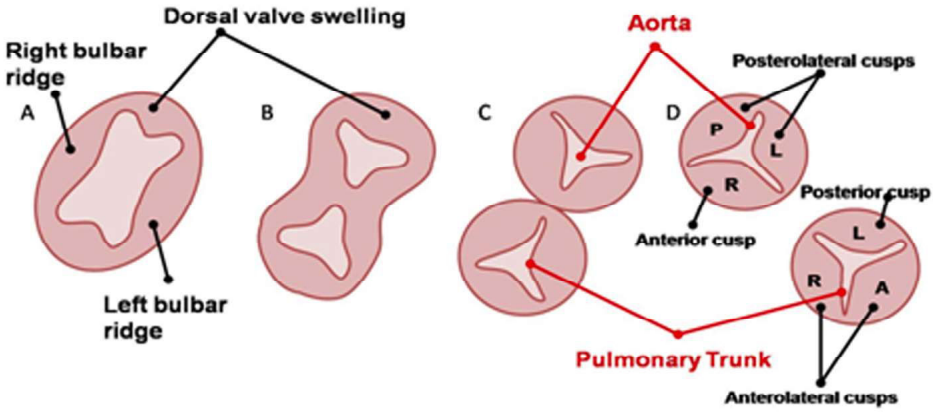

Fig. 3: Development of these milunar valves

Atrioventricular Valves

The fusion of the atrioventricular endocardial cushions marks the beginning of the development of AV valves. Local proliferations of mesenchymal tissue derived from the endocardial cushions surround each atrioventricular orifice. The mural leaflets are derived from mesenchymal cushions that arise laterally in the AV canal, whereas the AV valves and the septal valve leaflets are derived from the fused inferior and superior endocardial cushions that form in the AV canal of the primitive heart tube. Finally, dense connective tissue takes the place of degenerated muscular tissue in the cords. The endocardium covers the connective tissue that makes up the valves. Through chordae tendineae, they are connected to the papillary muscles, which are thick muscular trabeculae in the ventricle wall. Two valve leaflets form in the left atrioventricular canal, forming the bicuspid (or mitral) valve, and three form on the right side, forming the tricuspid valve.[5]

Semilunar Valves

The semilunar valves are developed with the division of truncus arteriosus during development. From the fifth week of gestation, the truncus arteriosus is divided up by the fusion of two truncal ridges across the lumen to form separate channels and become the roots of both the aortic and pulmonary trunks. The truncal ridges grow from the left and right walls of the chamber.

As fusion occurs, small swellings appear on the inferior margin of each of the original truncal ridges where they border each of the newly created channels. These are the primordia of the valve leaflets. In each channel, a third swelling appears opposite those derived from the truncal ridges; this will produce the third leaflet of each of the valves.[6] By convention, the origin of the swelling within the truncus arteriosus determines the name of the valve leaflet in the adult heart:

- Aortic valve:
  - *Left Leaflet:* Derived from the left truncal ridge.
  - *Right Leaflet:* Derived from the right truncal ridge.
  - *Posterior Leaflet:* Derived from a dorsal or posterior swelling within the aortic trunk.
- Pulmonary Valve:
  - *Left Leaflet:* Derived from the left truncal ridge.
  - *Right Leaflet:* Derived from the right truncal ridge.
  - *Anterior Leaflet:* Derived from the anterior or ventral swelling within the pulmonary trunk.

Structure of the Valves of the Heart

Tricuspid Valve

The tricuspid valve is the largest of the four cardiac valves and is located most apically. It is made up of four parts: The leaflets and their relationship to the chordae and papillary muscle play an important role in tricuspid valve closure during systole and may also be integrally related to RV (right ventricle size and function.[8]

Tricuspid Valvular Orifice

The tricuspid orifice is best seen from the atrial aspect. The chordal attachments, the cusps, the papillary muscles, and the annulus (with attached atrium and ventricle). From the septum or atrial wall to the valvular cusp attachment lines, it has a distinct transition line. It is almost vertical, about 45° to the sagittal plane, and slightly inclined, so that it "faces" (on its ventricular aspect) anterolaterally to the left and some what inferiorly. The margins are not exactly in a single plane. Its margins, which are roughly triangular in shape and correspond to the attachment lines of the valvular cusps, are described as anterioro superior, inferior, and septal.[9]

Tricuspid Valve Leaflets

The shape of the cusps are typically semi-circular or three sided and are joined basally to the fibrous annulus. Chordae tendineae insert themselves into the distal quarter of two thirds of the leaflets. The anterior leaflet, also known as the superior leaflet, is typically the largest, most mobile, and shares a boundary with the right ventricle's outflow. The septal leaflet is the least mobile of the posterior and septal leaflets, which are more variable in size and mobility. There are frequently multiple scallops on the posterior tricuspid leaflet.[10] The structure of the leaflets are shown in *Fig. 4.*

The tricuspid valve have three primary papillary muscles, and various little ones which commonly interface with the septal and back handouts. Typically, the largest papillary muscle is the anterior one. It is at the commissure between the anterior and posterior leaflets and arises from the moderator band. The fibrous strands known as chordae tendineae connect the valve cusp to papillary muscles. Essential chordae are connected to the free edge of the leaflets and are most significant in preventing regurgitation. Secondary chordae, on the other hand, insert into the basal portion of the ventricular surface of the leaflet.[11]

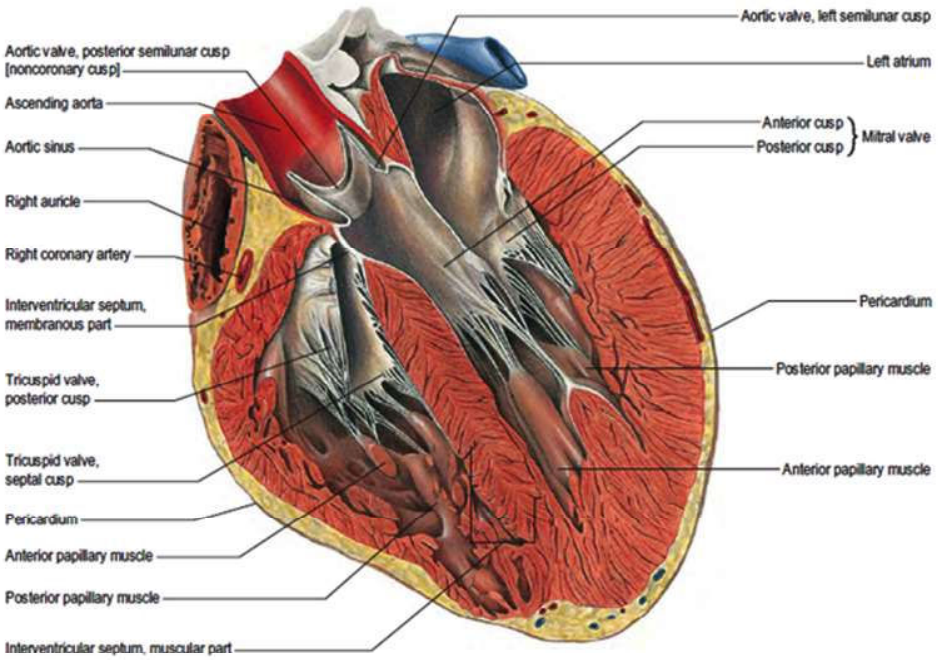

Fig. 4: Leaflets of Tricuspid Valve

Mitral Valve

The valvar complex comprise of the annulus, the cusps, the tendinous lines, and the papillary muscles. The proper functioning of left atrial musculature in required because the leaflets are inserted there and to the myocardium into which the papillary muscles are also inserted. The aortic valve and the mitral valve are connected in a close way due to their oblique location in the heart. Not like the tricuspid valve which is isolated by muscle from its counterpart, the pulmonary valve, the mitral valve is immediately adjacent the aortic valve.[11] The structure is shown in *Fig. 5*.

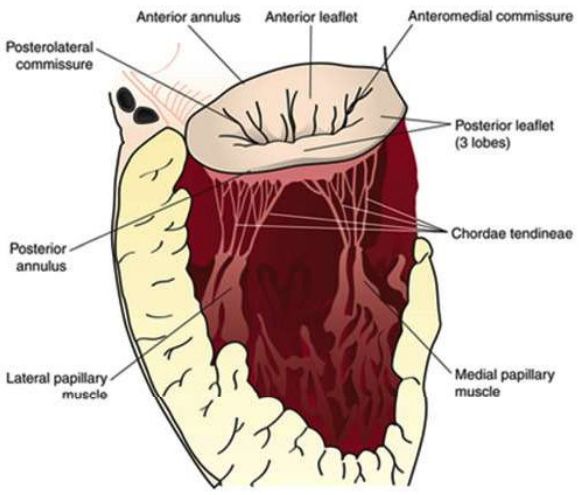

Fig. 5: Structure of Mitral Valve

Mitral Valvular Orifice

The mitral orifice is a well defined transitional zone that connects the bases of the cusps and the atrial wall. It is smaller than the tricuspid orifice. The orifice is roughly circular, almost vertical during diastole, and oriented at 45 degrees to the sagittal plane with a slight forward tilt. The valve's ventricular aspect is oriented anterolaterally to the left and slightly inferiorly toward the apex of the left ventricle.[13] It is nearly at the equivalent plane with the tricuspid opening however fairly postero-superior than it, while it is postero-inferior and slightly to the left of the aortic orifice. The mitral, tricuspid and aortic orifices are intimately connected centrally at the central fibrous body. At the point when the cusps of the mitral valve close, they structure a solitary zone of coaptation, like wise called as commissure. There are two zones on the leaflet atrial surface: a peripheral smooth or body zone and a central rough or coaptation zone. The coaptation zone is thicker and irregular because it has many chordae attached to its ventricular side. The annulus of the valve is not just a simple fibrous ring; rather, it is made up of varying consistency fibro-collagenous elements, from which the cusps' fibrous core is derived. At various stages of the cardiac cycle, these variations permit significant changes in the annulus shape and dimensions to ensure optimal valvular function.[14]

Mitral Leaflets

The shape and circumferential length of the

mitral valve's two cusps are markedly different from one another. The septal cusp is characteristic to the tricuspid valve whereas the posterior cusp is attached to the septum. The anterior cusp is fibrous and is the continuity with the aortic valve. The anterior cusp has a rounded free edge and occupies one third of the annular circumference, whereas the other cusp is long and narrow, lining the remainder of the circumference.[13] The left ventricular inflow and outflow tracts are separated by the anterior cusp, which acts as a curtain. This leaflet is about the same size as the posterior cusp but appears to cover the majority of the atrial floor when the valve is closed. It forms an arc shaped closure line, or zone of apposition, when it meets the posterior cusp and is oblique to the body's orthogonal planes. Each end of the closure line is referred to as a commissure. The free edge of the posterior cusp is often divided into three or more scallops or segments described as lateral, medial & middle. Although three scallops are most common and are unequal in size[15] The cusps are soft, translucent, thin, and pliable. Every cusp has an atrial and a ventricular surface. The insertions of the tendinous cords distinguish between two zones in the anterior cusp and three zones in the posterior cusp. There is a clear area without cordal attachments in both cusps. There are a few irregular, nodular thickenings near the free edge of the atrial surface, which is the thickest part and corresponds to the line of closure and the free margin. On the underside of this area, which is referred to as the leaflet's rough zone, tension cords are attached.[13] The rough zone is broadest at the leaflet's lowest points, but it narrows toward the leaflet's commissure, or periphery, at the closure line. The basal zone that is found exclusively in back cusp is the proximal region that has additions of basal ropes to its ventricular surface. Being far off from the ventricular wall, the foremost cusp doesn't have connections to basal lines. In normal valve closure, the two cusps meet each other with the rough zone and free edge in apposition but at an angle to the smooth zone.[16] When the closed valve is seen the major part of the closure line lies below the plane of the atrioventricular junction rising toward the commissures at the peripheral ends so that the atrial surface of the leaflets has a saddle like configuration Being fastened by the tensor contraption, the line of coaptation in an ordinary valve doesn't reach out over the level of the intersection during ventricular systole.[17]

Mitral Chordae Tendineae (Tendinous Cords)

The structure of chordae tendineae are similar to the tricuspid valve. There are numerous false chordae which are unpredictably conveyed in the right ventricle. They frequently cross the sub-aortic outflow and are found in approximately 50% of all human left ventricles. These can frequently be distinguished by cross-sectional echocardiography.[17] The true chordae of the mitral valve can be broken down into inter-cusp (or commissural) chordae, rough zone chordae, which include the special strut chordae, so-called "cleft" chordae, and basal chordae. These chordae are the true chordae of the mitral valve. The majority of true chordae either continue as single chordae that divide into several branches near their attachment or divide into branches from a single stem shortly after their origin from the apical third of a papillary muscle.[17] Basal chordae are isolated structures that connect the mural cusp to the ventricular wall. In most of hearts, the chordae support the whole free edges of the valvular cusps, along with changing levels of their ventricular angles and bases. In later life, valves with unsupported free edge areas are more likely to prolapse.

Papillary Muscles

There are two muscles that support the cusps of the mitral valve. These muscles can be bifid and vary in length and breadth. The posteromedial muscle comes from the diaphragmatic region, while the anterolateral muscle comes from the sternocostal mural myocardium. 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.[18]

Pulmonary Valve

The semilunar valve that separates the right ventricle from the pulmonary trunk is the pulmonary valve. Anatomically, the annulus (ring like connective tissue) of this valve delimits the right ventricle chamber at the intersection of the pneumonic blood vessel trunk. The structure that connects the pulmonary valve to the cardiac fibrous skeleton and is necessary for anchoring all of the heart valves in the myocardium is called the annulus.[19] There are three cusps in the pulmonary valve; right, left, and anterior cusps. Every one of these cusps is isolated from each other by a commissure. To ensure adequate lumen closure, the free margin below these cusps overlaps by about several millimetres. The area of overlap is known as a lunula. Local fibrous thickening forms a nodule (nodule of Arantius) in the central portion of the lunula to maximize lumen closure. A tough,

fibrous annular ring surrounds the cusps, which are made of a thin layer of endocardium.[20] Compared to the aortic valve, the pulmonary valve is thinner and more delicate. Unlike the atrioventricular valves (mitral and tricuspid), the pulmonary valve does not have a connection to papillary muscles or chordae tendinae. The pressure gradient across the valve determines when the valve opens and closes. At the superior border of the pulmonary valve, there is a pocket formed by the valve cusp and the adjacent arterial wall is called as sinus of Valsalva.[21] The schematic diagram is shown in *Fig. 6.*

Aortic Valve

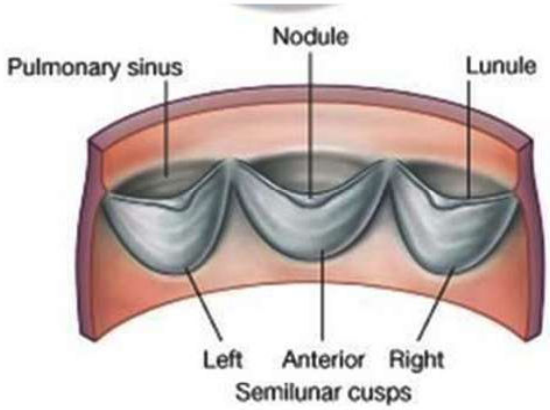

Fig. 6: Structure of Pulmonary Valve

The aortic valve is a sophisticated structure that plays important functions resulting in the unidirectional flow of blood out of the left ventricle, the optimising of coronary blood flow, and preservation of myocardial function. The aortic valve, which sits wedged between the left and right atrioventricular annuli and the bulging thick left ventricular myocardium, is the part that connects the left ventricle to the ascending aorta.[22] the annulus, commissures, inter leaflet triangles, sinus of Valsalva, sinotubular junction and cusps. The "aortic root" is the name given to the entire aortic valve complex, which is situated between the left ventricle and the ascending aorta. A crown shaped annulus is attached in a semilunar pattern to the valve cusps.[23] The boundary between the valve and the ascending aorta is marked by a small ridge known as the sinotubular junction at the highest point of the attachment, where the adjacent cusps (the commissures) are closest together. The annulus bulges to form three "pockets," or sinuses of Valsalva, at the base of each cusp's attachment. Two of the sinuses of Valsalva have ostia that bring about the left and right coronary corridors. Left, right, or non-coronary are the names given to the sinuses and cusps based on whether or not a coronary artery originates there.[25] The aortic root serves as the anatomic boundary between the left ventricle and the aorta, supporting the aortic valve. However, this boundary is distinct from the leaflet-based hemodynamic junction that connects the left ventricle to the aorta. The aortic valve's competent seal is involved in closing areas on individual cusps and preventing blood flow regurgitation. Arantius nodules are made of bundles of fibrous tissue and are located in the middle of each cusp's free edge. The two bow moulded edges of every cusp (known as lunulae), which are situated along the free edge between the commissures and the knob of Arantius, structure a capable seal during diastole through contact with the comparing locale of the touching cusps. Apart from the closing area, the "belly" region of the cusp represents the cusp's primary load-bearing region when closed during diastole. The arterial pressures apply to all structures distal to the hemodynamic junction, whereas the ventricular pressures apply to all proximal parts. [25] The structure is shown in *Fig. 7.*

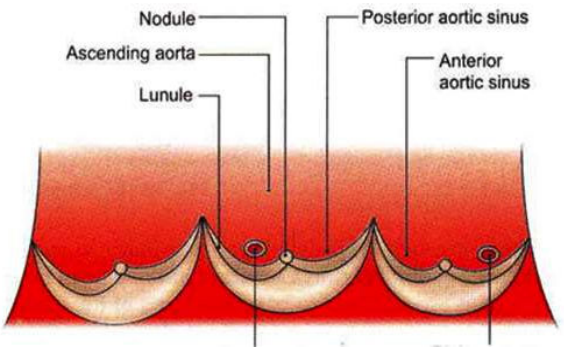

Fig. 7: Structure of Aortic Valve[38]

Microscopic Structure of Heart Valves

In 1931, Gross and Kugel comprehensively described the histology of human heart valves. The fibrosa, which is located on the ventricular aspect of AV valves and the arterial aspect of SL valves, is primarily composed of fibrillar collagens (types I and III) that are circumferentially oriented and provide tensile stiffness. The mature valve structure is made up of highly organized ECM (extra cellular matrix) that is compartmentalized into three layers, the fibrosa, spongiosa, and ventricularis/ atrialis for semilunar valves (SL) & also for atrio-ventricular valves (AV) valves respectively.[25] The atrialis layer of the AV valves and the ventricularis layer of the SL valves are composed primarily of radially oriented filamentous elastic fibres that facilitate tissue motion. Since elastic fibres do not run the entire length of a valve, they only extend

from the closing edge to the hinge of the valve. During the cardiac cycle, the atrialis/ventricularis layer facilitates valve tissue movement by allowing the valve to extend and retract.[27] The spongiosa is located in the middle of the body and is mostly made of proteogly cans with collagen fibres scattered through out. Proteoglycans are the predominant matrix component of the middle layer of the valve. They provide tissue compressibility and integrity by forming an interface between the orthogonally arranged fibrosa and atrialis/ventricularis layers. In AV (atrio-ventricular) valves, cusps are connected to the ventricular myocardium by chordae tendineae, whereas in SL (semilunar valve) valves, cusps are anchored directly to the arterial roots. The annulus, which is mostly made of fibrous collagen, serves as a buttress for the distribution of forces. Tissue stabilization necessitates the tethering of the free edges of the cusp.[28] The redundant tissue that serves as the functional closure of the valve cusps at the tips of both the AV (atrioventricular) and SL (semilunar) valves.[32] The ECM (extra cellular matrix) composition of the mature valves is dependent on the synthetic activity of the valve interstitial cells (VIC). The stratified extracellular matrix (ECM) of the valve leaflets is associated with the VICs' expression of genes encoding fibrillar collagens, chondroitin sulfate proteoglycans, and elastin during valve remodelling.[32] The confined articulation of explicit ECM (extra cell lattice) proteins normal for various connective tissue cell types recommends that there are various subpopulations of VICs in the separated valves, yet this has not yet been conclusively illustrated. During valve maturation, some additional ECM (extracellular matrix) remodelling enzymes, like matrix metalloproteases (MMPs), tissue inhibitors of matrix metalloproteases (TIMPS), and cathepsins, are expressed.[28] VICs from remodelling valves are highly synthetic, and cell proliferation is lower than in endocardial cushion cells. The baseline levels of ECM gene expression that are necessary for valve homeostasis are maintained by the VICs in normal adult valves, which are largely dormant and exhibit little or no cell proliferation.

Microscopic Structure of Tricuspid Valve

Annulus

The tricuspid valve's annulus is not a flat ring and has a complicated three-dimensional shape. It goes through unique changes during the cardiovascular cycle and has a bigger opening contrasted and the mitral annulus. The leaflets are attached to the annulus which has a closed relationship to the right fibrous trigone and the membranous part of the ventricular septum. The annulus additionally assembled piece of the triangle of Koch along with the coronary sinus and the ligament of todaro. The annulus of the tricuspid valve is fibrous in nature.

Leaflets

The endocardial surface and a fibrous skeleton make up the tricuspid valve's leaflets. The surface of the atrial layer of the endocardium is smooth. It is a monolayer of endothelium. These cells are inter connected in various fashions. They show either a straight border inter locked with each other or they show 'roof tile' like overlaps. These arrangement is of importance to maintain the structural integrity under maximum stretch. The endothelium is underlined by a basal membrane, composed of an osmiophilic lamina densa and an osmiophobic lamina rara. Connective tissue in a loosely arranged layer makes up the lamina spongiosa. The lamina fibrosa is a solid plane made up of dense collagenous fibers. Sections through the leaflets using electron microscopy show that the fibres are arranged parallel to and vertical to the free margin of the leaflets.[32] The microscopic diagram is shown in *Fig. 8.*

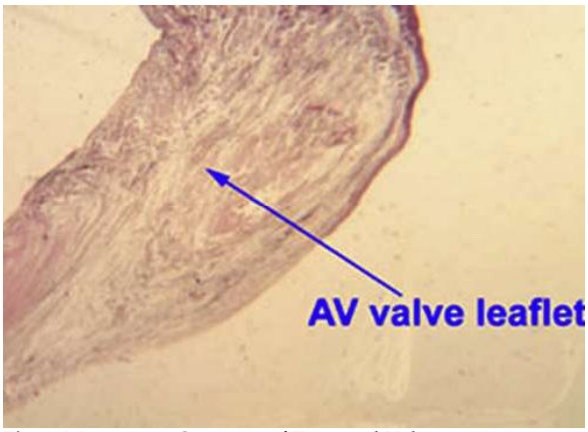

Fig. 8: Microscopic Structure of Tricuspid Valve

Chordae Tendinae

The composition of the chordae tendinae of the tricuspid valve and the mitral valve is comparable. They are like wise made out of an organization of collagen fibrils which fabricated the collagen strands. The strands organized lined up with the long hub of the chordae, these fibrils secure valve ability.[33]

Microscopic Structure of Pulmonary Valve

Annulus

The pulmonary valve's caudal margin joins the

myocardium of the right ventricular outflow tract rather than a leaflet of an atrioventricular valve, making it distinct from the annulus of the aortic root. The pulmonary leaflet attachment line lacks a clearly defined fibrous annulus, and the annulus is only loosely connected to the tight collagenous tissue of the right ventricular myocardium.[25]

Leaflets /Cusps

The pulmonary valve's cusps are the most extensively studied structures. These collagenous and elastic fibres carry the most load Light microscopy examinations reveal five layers of the leaflet between the ventricular and arterial endocardial layers. They are known as: lamina spongiosa, lamina fibrosa, lamina arterialis, and lamina ventricularis, respectively. The lamina ventricularis is the layer beneath the ventricular endothelium. Only a few rare, thin collagenous and elastic fibres make up this layer, which is made up of a tightly knit network of reticular fibres. The next layer, the lamina radialis, is made up of collagenous and elastic fibres that are oriented in a radial direction. Some reticular fibres are situated in between the elastic and collagenous fibers.[34] From here, this layer enters the ventricle's endocardium and subendocardial layer. The lamina spongiosa is made up of reticular fibres that are loosely arranged and have bundles of collagenous and some elastic fibres. Large numbers of the collagenous filaments emanate from the lamina radialis and lamina fibrosa into this layer, which in some cases make this layer hard to distinguish. The lamina fibrosa is made up of collagen fibres that are arranged in circles.[34] The layer that lies beneath the endothelium on the arterial side is called the lamina arterialis. Electron microscopy demonstrates that the endothelial cell layers are bordered by a basal membrane. Endothelial cells of the pulmonary leaflets interdigitate or over lap. The pulmonary leaflet endothelial cells over lap or interdigitate. Pinocytic vesicles further define them, indicating an active transport system. The microscopic structure is shown in *Fig. 9.*

Collagen fibroblasts are more than collagenous fibrils in the subendothelial reticular tissue. Collagenous fibrils are arranged in tightly packed bundles in the lamina fibrosa. There are numerous, lengthy processes on the fibroblasts within these fibrils. It has been demonstrated that the pulmonary valve leaflets, like all of the other heart valves, have distinct patterns of neuronal innervation. The innervation is localized to the ventricular layer and lower region of each leaflet and originates from the ventricular endocardial plexus.[32]

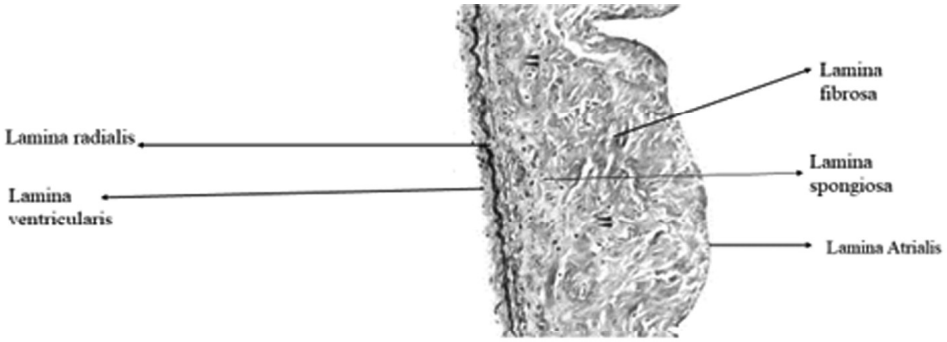

Fig. 9: Microscopic Structure of Pulmonary valve leaflet

Microscopic Structure of Mitral Valve

Annulus

The mitral valve's annulus is fibrocartilaginous in nature. The leaflets are anchored to the myocardium in the transition zone known as the annulus. The elastic and collagenous fibres radiate into the myocardium in this region. The thickness of the atrial endocardium in the "hinge" zone increases the number of elastic fibres in this region. As a loose, three-dimensional network, collagenous fibres radiate from the atrial wall into the annulus fibrosus and atrial membrane.[35]

Leaflets /Cusps

The mitral leaflets have an endocardial surface and a fibrous skeleton. A lamina spongiosa (facing the atrial side) and a lamina fibrosa make up the architecture of the mitral valve leaflet layers, as demonstrated by light microscopy. The endothelium itself consists of a single layer of thin cells which are either simply attached or inter

locked with each other. The lamina spongiosa of subendocardial connective tissue typically consists of collagenous fibres, histiocytes, and fibrocytes. The fibrocytes that are situated in between the fibrils have the appearance of tendons' winged cells. The leaflet's "backbone" is made up of collagenous fibres with diameters ranging from 150 to 350 Å. Geometric changes and the distribution of collagen fibres angles have been described in the transition zone between leaflet strut chordae. The particular pressure appropriation might assume a significant part in the strength of valve capability. Mitral valve leaflets, as all other heart valves, have been shown to possess distinct patterns of innervations that comprise both primary sensory and autonomic components. Nerve density is twice as high in the anterior leaflet as it is in the posterior leaflet. The nerves extend over the leaflet's proximal and medial portions and are located in the atrial layer.[35] The microscopic structure is shown in *Fig. 10.*

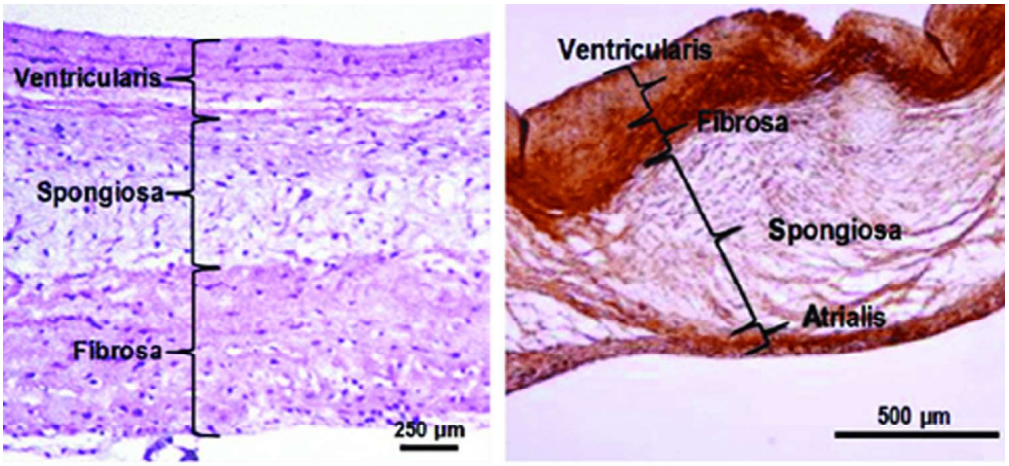

Fig. 10: Microscopic Structure of Mitral valve

Chordae Tendinae

The mitral valve's chordae tendinae are made of collagen and elastic fibres and are arranged in a network of branching chordae. The versatile components have been displayed to return the collagen strands to its wavy design. A network of collagen fibrils makes up collagen fibres themselves. They are arranged parallel to the chordae tendinae's long axis. The thinner chordae had a lower average fibril diameter than thick chordae but a greater average fibril density.[29]

Microscopic Structure of Aortic Valve

Annulus

The aortic valve cusps, are connected to the sinus wall by means of an exceptionally thick collagenous mesh work known as the annulus. Cutting through this construction in the non-coronary sinus, where no myocardial muscle up holds the sinus, gives the impression of a cartilaginous design. In this region, the leaflet layers display a particular arrangement. The intermediate collagenous layer has a cuneiform structure, and the ventricular and arterial layers separate. The arterial layer extends into the sinus wall, whereas the ventricular layer continues as the endocardial layer. Small vessels are situated in the connective tissue layer.[30]

Leaflets/Cusps

The aortic valve cusps are covered by a continuous layer of endothelial cells with a smooth surface on the ventricular side and numerous ridges on the arterial side. Elastic and collagenous fibrils are present within the annulus.[30] The cells are joined to each other by intersections like those present on endothelial cells like different pieces of vascular framework. The arrangement of the endothelial cells are not in line with the direction of flow[30] Between the ventricular and aortic surfaces, there are five layers of connective tissue: lamina ventricularis, lamina radialis, lamina spongiosa, and lamina fibrosa and lamina arterialis. It is simple to identify the first three distinct layers, which are the lamina radialis, lamina spongiosa, and lamina fibrosa. Inside the connective tissue, the flexible and collagen strands show a special plan and direction. They are mechanically connected to one another in a structure that looks like a honeycomb or a sponge. After external forces have been released, this particular arrangement maintains the collagen's geometry and orientation. The blood vessel layer

contains coarse heaps of circumferential collagen filaments, which structure the naturally visible folds lined up with the free edge of the handouts. The arrangement of the fibres is what moves the leaflets' weight to the aortic root wall, where the interstitial cells are located in between the extracellular components. Mayo-fibroblasts have been given the name because these cells resemble fibroblasts and smooth muscle cells. In any case, having similar contractile properties as fibroblasts or smooth muscle cells, these phones might assume a functioning part in the typical capability of the aortic valve and go through mathematical adjustments during the cardiovascular cycle.[25]

The thorough knowledge about the dimensions and morphology of the heart valves is important in the diagnosis, prognosis and planning for surgical procedures. It will also help in manufacturing various types of prosthetic valves. By frequent follow up and with timely interventions, morbidity and mortality rates can be reduced in patients with valvular lesions. The microscopic structure is shown in *Fig. 11.*

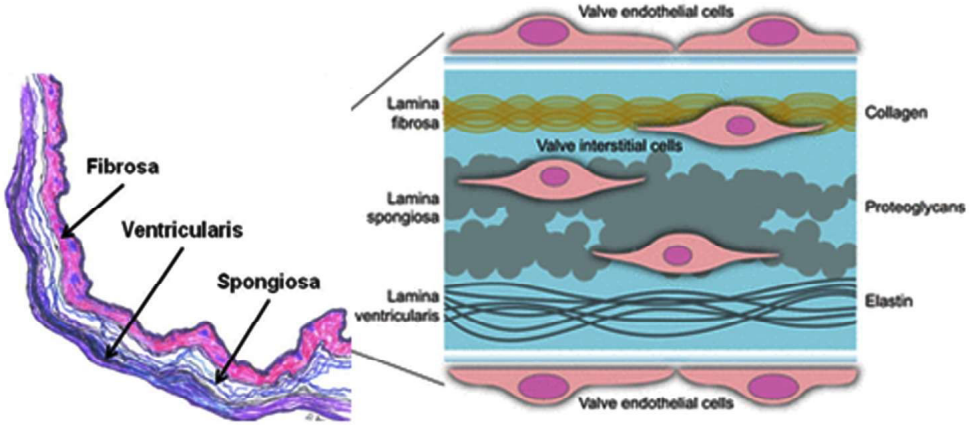

Fig. 11: Microscopic Structure of Aortic valve

CONCLUSION

Heart valve diseases are common and has been increasing in numbers gradually. In developing countries due to inflammatory disease, and in industrial countries due to mainly degenerative valve disease. The normal morphology and microscopic structure of heart valve complex will help the healthcare professionals to understand and treat the diseases related to heart valves. Analysis of the structural elements of the heart valves will give important inputs into tissue engineering principles.

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