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Steps in the Dissection of the Fibrous Skeleton of the Heart

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Abstract

The fibrous skeleton of the heart is best defined as those tissues at the base of the heart which consists of dense collagen fibers which remain stationary with respect to functionally moving parts of the heart namely myocardium, valve leaflets and elastically distensible arteries arising from the heart. So far no clear guidelines are available for dissecting the fibrous skeleton of the heart. The present study evolves the steps in dissecting the fibrous skeleton of the cadaverichearts. Its morphological features such as position, shape and extent are noted. Aim of the study is to dissect the fibrous skeleton of the heart andexplain its dissection steps. Fibrous skeleton is situated at the base of the heart where four functional apertures of the ventricles are crowded together. In fetal life the atrioventricular annuli are in the same plane but in adult they are oblique i.e. at 45^0 and are connected with each other by right and left trigone, which appears as figure of 8. The atrioventricular conducting bundle is only physiological connection between the atria and ventricle across the fibrous ring. The right and left trigone, aortic and pulmonary annuli, conus ligament, membranous septum, tendon of Todaro were dissected and observed. Fibrous skeleton of the heart & its three dimensional views are helpful for both undergraduate and post graduate students of anatomy and cardiology. It would also help cardio-thoracic surgeons in Annuloplasty operations.

Keywords: Fibrous Skeleton of the Heart; Key Stone; Left Trigone; Conus Ligament; Annuli.

Introduction

Operative surgery concerns itself with the production of therapeutically desirable change in the anatomy of the body. The introduction of surgery to any special region of body places it's anatomy in a new perspective. Certain anatomical features are of little interest to surgeons. On the other hand structure, which appear quite insignificant to the pure anatomist frequently are of primary importance to the surgeon.

In order to avoid injury to essential structures, surgeons need recognizable landmarks, which will indicate their presence or proximity. The limited exposure available to him must not hamper his appreciation of these relations. He must, therefore be able to see with his mind's eye structures which are not actually within his visual field.

Any student studying the anatomy of the heart is cognizant of the difficulty in describing this organ in terms, which are meaningful and readily understood. Since the two dimensional picture is most readily available teaching aid, the description of the heart, usually found in the standard anatomical texts, concentrate heavily on the inner and outer chambers.

In addition the heart is in state of incessant motion which cannot even temporarily be ignored or dissociated with its functional anatomy. Such framework is analogous to the skeleton as it is related to soft tissue of the body. At the base of the heart there does exist, in fact, such a structure which has been named by early French anatomist as "Fibrous skeleton of the heart" [1].

The cardiac skeleton, also known as the fibrous skeleton of the heart, is a high density single structure of connective tissue that forms and anchors the valves and influences the forces exerted through them. The cardiac skeleton separates and partitions the atria (the smaller, upper two chambers) from the ventricle (the larger, lower two chambers). This is

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important because it forms the primary channel that electrical energy follows from the top to the bottom of the heart.

The fibrous skeleton of the heart is best defined as those tissue at the base of the heart which consist of dense collagen fibers which remain stationary with respect to functionally moving parts of the heart namely myocardium, valve leaflets and elastically distensible arteries issuing from the heart. There have been no clear guidelines given so far regarding how to dissect out the fibrous skeleton of the cadaveric heart. The present paper evolves the steps for dissecting the fibrous skeleton of the cadaveric heart during routine dissection based on my personal experience. Such frame work is analogous to the body skeleton as it is related to the soft tissue of the body.

Aim

Aim of the study is to dissect the fibrous skeleton of the heart and explain its dissection steps.

Instruments Used

Scalpel, forceps, knife, dissection microscope, cotton, water and gauze piece, Chemicals used Formalin and Glycerin.

Material and Method

So far no clear guidelines are available for dissecting the fibrous skeleton of the heart. The present study evolves the steps in dissecting the fibrous skeleton of the adult cadaveric hearts .

Its morphological features such as position, shape and extent are noted.

The fibrous skeleton of the heart requires integration of three separate method of studies.

1. Gross dissection
2. Observation during the actual and stimulated functions.
3. Histological serial sections.

Before dissection, it is useful to appreciate the anatomy of the fibrous skeleton of the heart.

Fibrous Skeleton Comprises of (Figure- 1 & 2)

a. Inter valvular fibrosa -Right trigone, Left trigone and Conus ligament
b. Four valvular annuli - Tricuspid, Mitral, Pulmonary and Aortic.
c. Extensions- Tendon of Todaro and Membranous septum Conus ligament: It is the fibrous connection in between the aortic and pulmonary annuli.

Sub-aortic curtain, which is nothing but the continuation of anterior leaflet of the bicuspid valve attached to the aortic annuli in between the non-coronary and left coronary annuli. These annuli are connected with each other at the clinical base of the heart.

Dissection Steps

A. Removal of heart
B. Dissection of heart from superior aspects
C. Dissection of heart from inferior aspects.

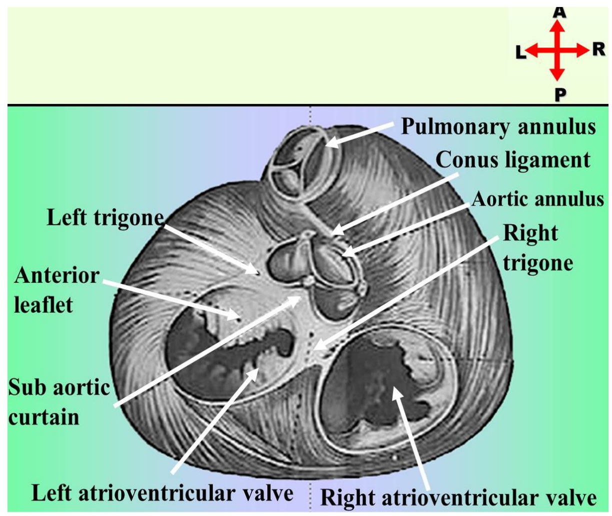

Fig. 1: Fibrous skeleton of the heart (Book Picture from Grey's anatomy)

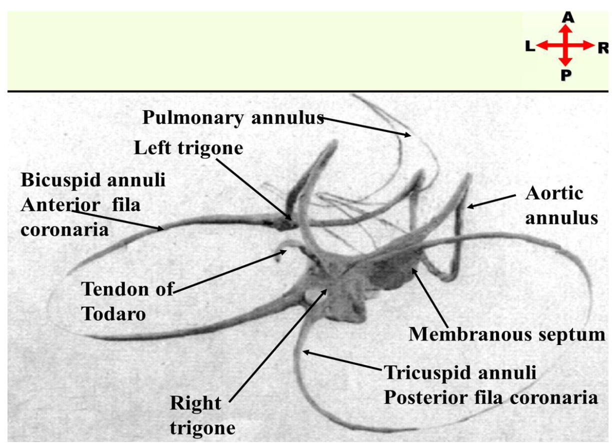

Fig. 2: Fibrous skeleton of the heart from journal of thoracic and cardiovascular surgery by Zocob Zimmerman and Charls Balley

Removal of Heart

Remove the heart from the pericardial cavity by placing the finger in the transverse sinus and cutting through the aorta and pulmonary trunk as they leave the heart, inside of the pericardium. Sever the superior and the inferior vane cave as they enter the right atrium. Identify the four pulmonary veins on the posterior surface of the heart and, working from the oblique sinus, cut each. Review the cut edges of the pericardial reflection both on the heart and on the posterior wall of the pericardial cavity. Carefully examine the removed heart, using borders, ssurfaces, sulci, and great vessels for proper orientation. Heart is removed without cutting the root of aorta, pulmonary trunk, bicuspid and tricuspid annulus. To increase the hardness it is kept in the formalin for 2 to 3 weeks.

Dissection of Heart from Inferior Aspect.

Step I-

Put the heart in anatomical position with left hand and cut with the knife by right hand up to the annulus from inferior aspect.The section of two ventricles with the inter-ventricular septum is seen (Figure- 3).

Step II-

Interventricular septum is cut and with piece meal dissection. Heart is clean with the tap water and the clots are removed the glycerin is added to increase the shining.

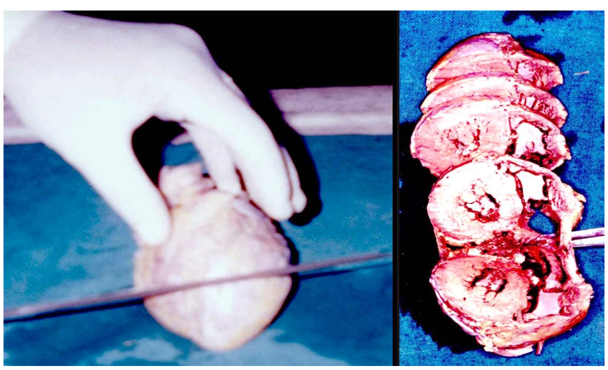

Fig. 3: Step 1: Dissection of heart : inferior aspect

Fig. 4: Step 2: Dissection of Heart: inferior aspect

Step III

Membranous septum of the heart is dissected which is inferiorly semilunar in shape. The annulus gives attachment to the ventricular as well as atrial muscles these muscles are dissected by piecemeal until you get the white fibrous annuli. The fixed part of the leaflets is also cut towards the fibrous ring by scalpel by keeping intact anterior leaflet of the bicuspid valve. Interventricular septum continues with the membranous septum which is the extension of the right trigone and anteriorly it extend up to the aortic annulus so you have to cut the muscular part of the interventricular septum with the scalpel. Dissection of bicuspid and tricuspid annulus both are connected with each other by aortic annulus, right and left trigone (Figure -5).

Dissection of Heart from Superior Aspect

All these annuli are attached to each other at clinical base of the heart Conus ligament is connection between the aortic annuli and pulmonary annuli.

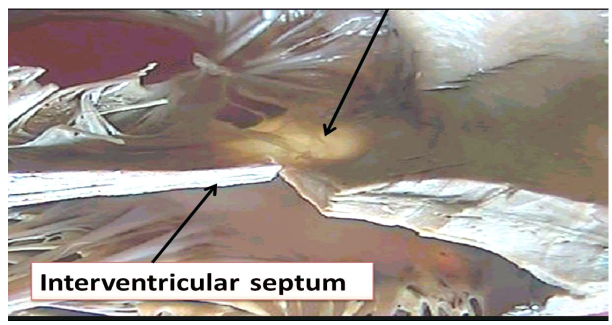

Fig. 5: Step 3: Dissection of heart from inferior aspect Membranous septum of the heart

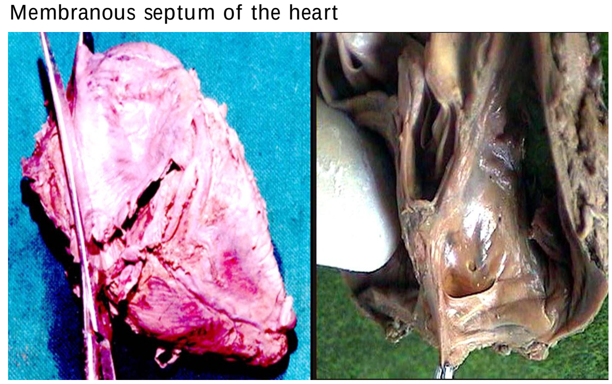

Fig. 6: Step 1: Dissection of heart: Superior aspect inferior of the right atrium with triangle of Koch's

Step I

Right Atrium is cut by passing the seizer in between the superior and inferior vena cava the tricuspid annuli is seen along with the tendon of todaro and right fibrous trigone (Figure 6). Cut the tendon of todaro, which is 1mm in diameter with the scalpel. Cut the atrial muscles and its wall by scalpel and with the forceps with the forceps do piecemeal dissection of tricuspid annuli.

Step II

Left Atrium is cut by passing the seizer in between the pulmonary veins now you can see the bicuspid annuli and right fibrous trigone (Figure 7). Cut the left atrial muscles by scalpel and do piecemeal dissection up to the bicuspid annuli. Now you can see the right and left trigone at the root of aorta. (Figure 8).

Step III

Aortic Annuli is dissected with the scalpel the arterial part of the aorta is cut and simultaneously the aortic leaflet up to the annulus. The aortic annulus looks like as three scalloped lines. The subaortic curtain is kept intact because it is continuous with the anterior leaflet of the bicuspid leaflets. The tendon of todaro is the extension of the right fibrous trigone in right atrium which is subendocardial 1 to 2 mm. in diameter is also dissected by forceps and scalpel (Figure 8).

Step IV

The right trigone of the heart is dissected from superior, inferior, right and left aspect by piece-meal dissection. The peripheral parts of the atrioventricular valve were cut along with pulmonary annuli and aortic annuli.

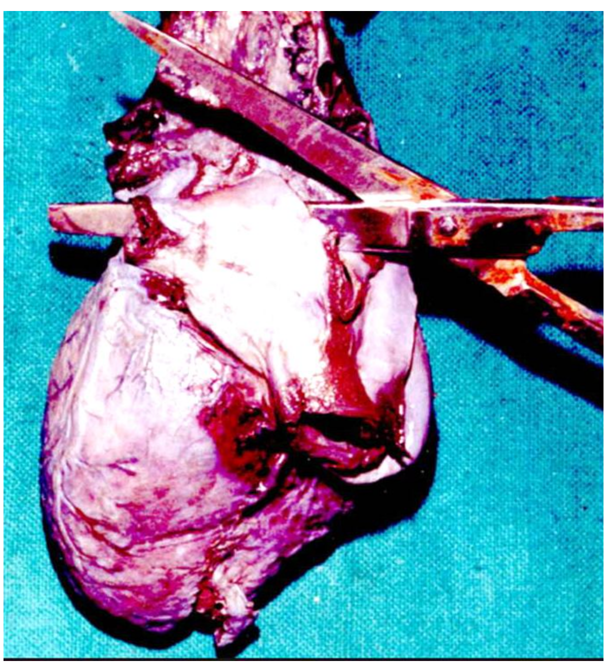

Fig. 7: Step–II Dissection of heart: superior aspect Left Atrium is cut by passing the scissors in between the pulmonary veins.

Fig. 8: Step–III: Dissection of heart: superior aspect Dissection of aortic annulus

Fig. 9: Step –IV: Dissection of heart from superior aspect Figure of -8

The membranous septum and tendon of todaro is kept intact. Two trigones provide anchorage for the structures which partitions the single left ventricular opening into inflow & outflow areas. Two atria & two ventricles attach to a pair of conjoin fibrous ring which is in the form of figure 8 lies in sagittal plane (Figure 7) [3].

Observation

Fibrous skeleton is situated at the base of the heart where four functional apertures of the ventricles are crowded together. The atrioventricular annulus moves forward and to left during systole and retraces the move during diastole.

In fetal life the atrioventricular annuli are in the same plane but in adult they are oblique i.e. at 45^0 and are connected with each other by right and left trigone. The atrioventricular conducting bundle is only physiological connection between the atria and ventricle across the fibrous ring. The right and left trigone, aortic and pulmonary annuli, conus ligament, membranous septum, tendon of todaro were dissected and observed [4].

Tricuspid Annulus

(Right Atrioventricular Annuli)

Largest valvular orifice diameter- 11.4 cm in males and females- 10.8 best seen from atrial aspect. Annulus of the tricuspid valve is an ill-defined term use without uniformity. All four valvular orifices as surrounded by uniform ring of collagenous tissue. These rings were interconnected by dense mass of collagenous ring with mitral and tricuspid valves, precisely at the atrioventricular junctions.

The connective tissue around the orifice of the atrioventricular valve, while serving to separate atrial and ventricular myocardial masses (Figure 1, 2 & 10) [5].

Extending from the right fibrous trigone the component of central fibrous body are a pair of curved, tapered, subendocardial tendons or 'prongs' (fila coronaria) which partly encircles the circumference: the latter is completed by more tendinous, deformable fibroblastic areolar tissue [5]. The tissue within the atrioventricular junction around the tricuspid orifice is less robust than the similar element found at the attachment of the mitral valve.

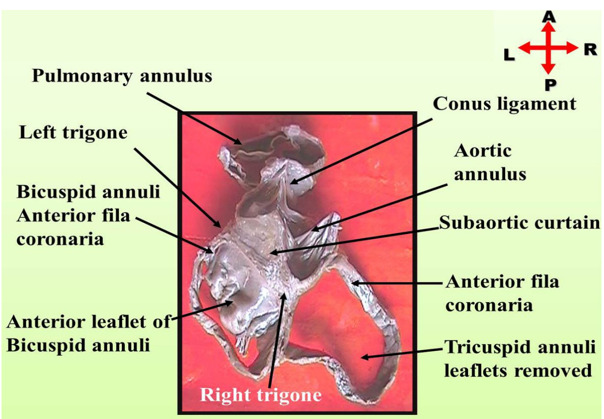

Fig. 10: Fibrous skeleton of the heart (Dissected)

In the tricuspid valve, the topographical 'attachment' of the free valvular leaflet does not wholly correspond to internal level of attachment of the fibrous core of the valve to the junctional atrioventricular connection tissue. It is line of attachment of the leaflet which is the best appreciated in the heart when examined grossly. The extent of fibrous tissue is varies age and sex [6].

Bicuspid Annulus

(Left Atrioventricular Annuli)

Is not a simple fibrous ring but comprises fibro-collagenous elements of varying consistency from which the fibrous core of leaflets take origin (Figure 1, 2 &10).

The annulus is strongest at the internal aspect of the left and right fibrous trigone. Extending from these structures the anterior and posterior coronary prongs (tapering, fibrous, sub-endocardial tendon) partly encircles the orifice at the atrioventricular junction.

Between the tips of the prongs the atrial and ventricular myocardial masses are separated by more tenuous sheet of deformable fibro-elastic connective tissue. Spanning anteriorly between the trigones, the fibrous core the central part of the anterior aortic leaflet of the mitral valve is the continuation of the fibrous sub-aortic curtain which depends the adjacent halves of the left and non-coronary cusp of the aortic valve [7].

The Right Fibrous Trigone

Shape: It is Triangular in Shape.

Situation: it is situated at the center of the heart, fused together at the medial aspect of mitral, tricuspid and aortic valves.

Apex: is at the base of the heart, it is directed backwards and downwards and slightly towards right side it continues as posterior fila coronaria of the right and left atrioventricular valves.

Base: At the root of the aortic annulus. It is directed upwards and left arising from base of right posterior annulus, it is half centimeter (Figure 11).

Measurements

Anterio-posteriorly 10 mm on length and breadth at base is 5mm. (viewed from above) It feels cartilaginous in palpation and shows two slopes superiorly convex and inferiorly concave. Its extensions are membranous septum, tendon of todaro fibrous tissue to the left trigone of attach to subaortic

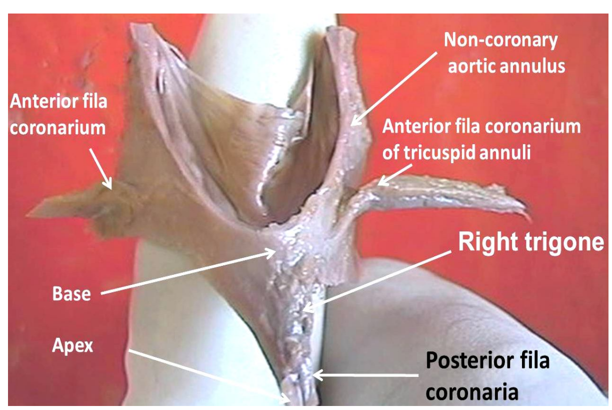

Fig. 11: Right fibrous trigone (Dissected)

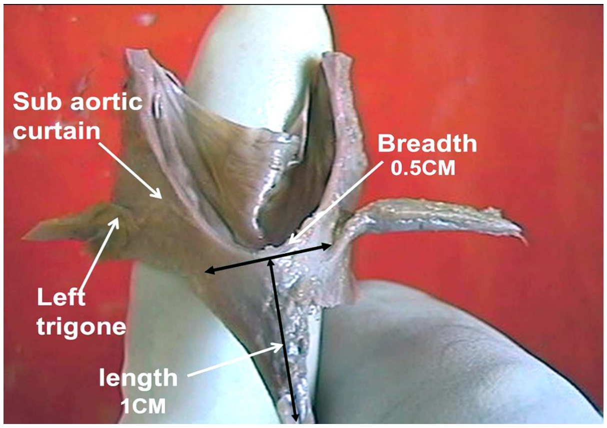

Fig. 12: Right fibrous trigone (Dissected)

curtain and fila coronaria (Figure 12).

Conus Ligament

It is the ligament, which is, attached to the aortic annulus to the subvalvular span of pulmonary annulus facing towards the aortic annulus (Figure-1&2). Its function is to prevent the separation of both the annuli during the ventricular ejection. It is wider at the aortic annulus narrower at the pulmonary annulus

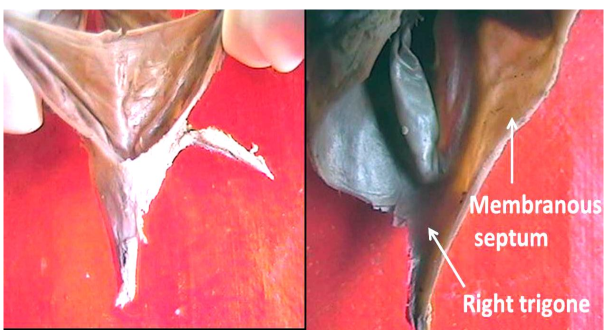

Fig. 13: Right fibrous trigone (Superior aspect) (Inferior aspect)

Aortic Annulus

It consists of three collagenous scallops anterior, posterior right and posterior left.

Each scallop presents a concavity distally. It provides attachment of the inner surface to the base of aortic cusp. The ascending limb of the adjacent scallops meets together at summit that corresponds with the intercuspid commissure.

The bottom of the right posterior aortic annulus forms the fibrous body known as right fibrous trigone. It continues as posterior fila coronaria of the mitral annulus and tricuspid annulus. The bottom of the left posterior aortic annulus forms the fibrous body known as left fibrous trigone. It continues as anterior fila coronaria of the mitral annulus (Figure13 &14) [2].

Shape: In transverse section it is triangular in shape.

Thickness: 1 to 2mm thickness.

Base: Is outer aspect it gives attachment Superior to the arterial part of aortic wall inferiorly it forms subaortic curtain

Apex: Inner aspects to the aortic leaflet.

Pulmonary Annulus

It consists of three collagenous scallops. Plane of pulmonary annulus faces posteriorly, left and Superior towards the left midscapula (Figure 1 & 2).

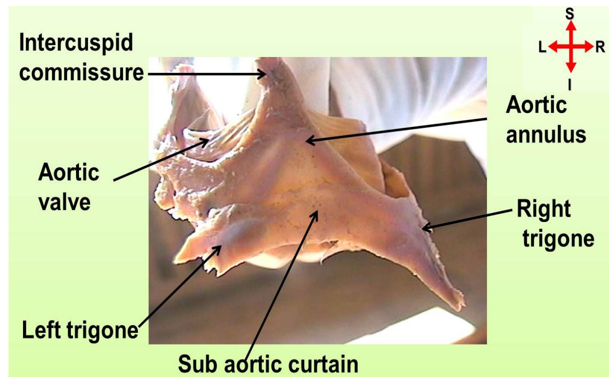

Fig. 14: Aortic annulus (Dissected)

Fig. 15: Aortic annulus (Superior aspect) (Inferior aspect)

It is Triply Scalloped

In fetal life: Anterior, posterior & septal

In adult: Right, left & posterior

Situation: Anteriosuperior & right angle to aortic annulus

Attachment: Inner surface gives attachment to bases of pulmonary cusps.

Sub-valvular Spans: Are intervals between the two scallops and continuous with the myocardium of the infundibulum.

In section it is triangular in shape, apex directed upwards and base is directed downwards

Membranous Septum

It appears to the necked eye arising from aortic annulus between the non-coronary and right coronary annulus

Situation: At the summit of the muscular part of the inter-ventricular septum.

Apex: Triangular and pointed attach to aortic annulus.

Base: Semilunar in shape attach to muscular septum.

Functions: Supports the right and non-coronary aortic cusp.

Measurements: 1 cm. from above downward and anteroposterior 1 to 1.8 cm.

Division: Atrioventricular part and inter-ventricular part

Demonstration: It is better seen when the bright light is placed behind it in the left ventricle it is seen to be translucent. When viewed from right ventricle after the septal cusp of the tricuspid valve is removed.

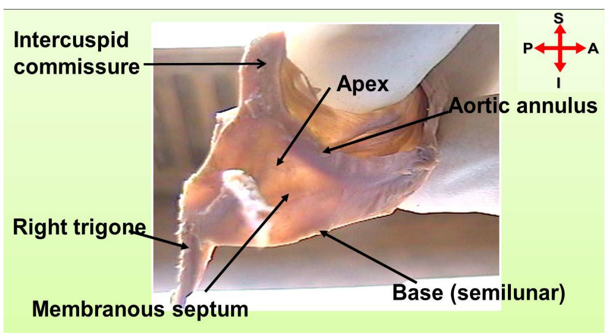

Fig. 16: Membranous septum (Dissected)

Attachment: Septal cusp of the tricuspid valve is attached to right side of the membranous septum. It should be noted that there is no thickening of septum in the line of attachment of cusp.

Tendon of Todaro: It is a small ribbon of connective tissue deeply located not connected to the endocardium. It is an extension of the right trigone of the heart (Figure 17).

Situation: It is situated between the triangle of Koch and fossa ovalis in the right atrium (Figure 18).

Contents: It contains collagen fibres (white glossy).

Shape: It is rounded it may be hook like or straight tendon.

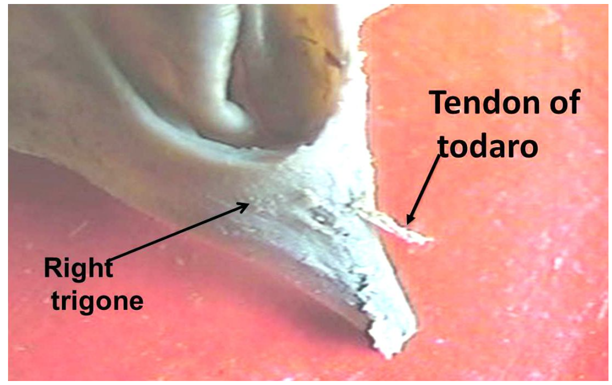

Fig. 17: Tendon of todaro (Dissected)

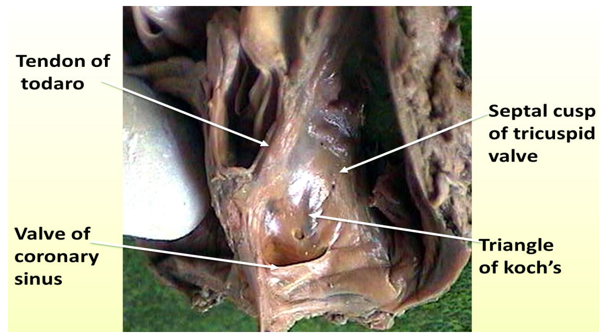

Fig. 18: Tendon of todaro (Dissected) observed in right atrium

Length: 4mm.

Diameter: 1mm.

Staining: Missions method

Importance- it forms superior boundary of triangle of Koch's.

Surgical Application

In general the fibrous skeleton of the heart is capable of holding the sutures securely under the persistent tension.

Suturing and patching up the perforation of the septum restores the heart complete integrity [7].

It is an important landmark for surgical orientation in case of the high ventricular septal defect in the most commonly encountered type these defect occupies the subaortic span between non coronary and right coronary cusp attachment.

Right trigone is the key stone of the skeleton, the rigid fixation to tricuspid, mitral valve and aortic wall to each other and ventricular septum is disrupted.

In mitral stenosis reorganization of the two dimples of the right trigone provide proper orientation for refashioning the distorted valves it may lead to aortic regurgitation. It is also an important landmark for surgical orientation of Surgery for infective endocarditis with para-ventricular abscess and the fibrous body destruction have a highest mortality and morbidity in high surgical risk [2].

Membranous septum is the integral part of the fibrous skeleton it links together three of four chambers and three of the four valves. When it is defective and this by most congenital malformation consequences are not only depend on only the size of the defect but also upon whether it is an isolated lesion or part of complex combination of malformation such as are found in the endocardial cushion defect, tetralogy of Fallot and many varieties of transposition [9].

Fila coronaria can be used for the reduction of the size of atrioventricular passage to produce the competent valve mechanism. Shortening these tendons of myocardium tend to draw the rim of the ventricle with the attached mural portion of the valve closer to the septal component which is attached to the quasi stationary root of aorta [10].

Conclusion and Results

Fibrous skeleton of the heart & its three dimensional views are helpful for both undergraduate and post graduate students of anatomy and cardiology. It would also help cardio-thoracic surgeons in Annuloplasty operations.

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