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Original Research Article

A STUDY OF THE DIMENSIONS OF THE HUMAN TRICUSPID VALVE

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ABSTRACT

Background: With the advent of the prosthetic valves, which are being used by the cardiac surgeons to replace diseased or damaged valves, an accurate knowledge of the dimensions and size of the tricuspid valve will be of immense help. Surgical correction on the heart valves has given a new lease of life to patients. This study, so far has been done mostly on the American and European races. Studies in the Indians, particularly South Indians has been rare. Hence the present study.

Materials and Methods: 96 hearts were studied which were collected from cadavers allotted to undergraduate students for dissection, over a period of time. Hearts were removed by dissection method. The circumference of the tricuspid valve was measured & the diameters of the tricuspid valve are measured in two separate dimensions in two separate perpendicularly oriented planes at the maximally separated points which is described under materials & methods.

Results: The results of the study are as follows: The dimensions of the tricuspid valve annulus range from 5.7 cm – 14.8 cm. No accessory leaflets were found

Conclusions: The study of the dimensions of the tricuspid valve annulus dimensions is important for various cardiac procedures. The knowledge of the annulus of the tricuspid valve is important for the cardiac surgeon in tricuspid valve diseases like stenosis and regurgitation as it will help him plan palliative or corrective surgery in the congenital or acquired heart diseases.

KEY WORDS: Tricuspid valve, Annulus, Leaflets, Prosthetic valves, Stenosis, Regurgitation.

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INTRODUCTION

In most vertebrates, the heart is a single pump made of 3-4 successive chambers separated from one another by valves. These valves maintain unidirectional flow and permit increased pressure to develop in the chambers. The heart valves may be composed of accessory cusps, which may vary in size. The posterior (inferior) cusp may be divided in the right atrioventricular valve and in the bicuspid valve of the left ventricle may have an anterior and posterior cusp or both [1].

According to Hyrtl, the name Valve was first used for the heart valves by Benedictus. The Greeks named them Hymenes, while Vesalius named them membrane. Gallen compared the arterial valves to letter "C" in shape while Heister introduced the name semi lunar for them and the Greeks named the AV valves triglochines and Galen, trisulcas because of their resemblance to a three pointed spear head. Vesalius suggested the name Mitral Valve for the left AV valve because of its resemblance to a Bishop's mitre (hat) [1].

The tricuspid valve consists of three tissue flaps. It separates the right atria and the right ventricle. The tissue flaps of the AV valves (often called Cusps) have tendons known as Chordae Tendinae. These tendons attach the valve cusps into the atria during ventricular contraction. Specialized muscles known as papillary muscles regulate tension in the Chordae Tendinae and contract simultaneously with the ventricular muscle [1].

Louis Green MD et al (1931) suggested that the accurate knowledge of the structure of the valves in the human heart is of prime importance for at least very three practical reasons:

(i) The various anatomical peculiarities in the valve leaflets suggest an explanation for at least some of the mechanical components entering the localization of inflammatory, as well as degenerative (atherosclerotic) processes in these sites. (ii) The insight into pathological processes thus obtained helps one differentiate these lesions from one another. (iii) One is better able to cope with the long disputed question as to whether or not blood vessels or myocardium normally exist in valves [2].

Sanchez Cascos A. et al (1967) reported the finding of a double tricuspid valve in a 11 month old boy and a 17 year old boy and proposed classification of duplication of the atrio-ventricular valves [3].

Bruce Eljenben et al (1968) reported cases of duplication of mitral and tricuspid valves and proposed theories to describe the mechanism of formation of these anomalies [4].

Wafae et al (1990) carried out an anatomical study on 50 human hearts of both males and females. It was observed that the tricuspid valve was not consistently tricuspid, instead it was observed to have 2, 4, 6 cusps in 72% of cases [5].

Victor S and Nayak VM (1994) observed, after studying 100 normal human hearts, that numerous variations are present in the configuration of the cusp tissue and chordal/papillary support of the ventricular wall and these made the interior of the ventricle as unique to each individual as one's finger print [6].

Objectives of the study: With the advent of the prosthetic valves, which are being used by the cardiac surgeons to replace diseased or damaged valves, an accurate knowledge of the dimensions and size of the tricuspid valve will be of immense help.

Surgical correction on the heart valves has given a new lease of life to patients. The incidence of prosthetic valve dehiscence has decreased over the past 20 years, primarily because of improvements in the technical conduct of valve procedures. However, perivalvular leak secondary to suture line disruption still occurs and may be clinically significant in 1-4% of patients.

Considering the clinical importance of the tricuspid valve, the present work is undertaken to explore the precise morphology and to carry out a morphometric study of the tricuspid atrio-ventricular complex and normal quantitative values and range of dimensions of the tricuspid valve in normal adult human hearts obtained by dissecting cadavers. Hence, the work is undertaken to study their morphology in detail and suggest their correction

MATERIALS AND METHODS

Collection of Specimens: Total number of specimens' studies in the present work is 96 adult hearts which were collected by dissecting cadavers allotted to the undergraduate medical students at Dr. B. R. Ambedkar Medical College, Bangalore, over a period of time. Chemicals used for preserving specimens: 10% formaldehyde in H2O and glycerin

Instruments used: Vernier Calipers, Magnifying lens, Scale (Foot Ruler), Scissors, Malleable aluminum wire.

Method of dissection of the already removed hearts: The method adopted is the base of heart method. This method displays all the four valves at the cardiac base and thus is ideal for demonstrating anatomic relationships between the valves themselves and between the valves themselves and between the valves and the adjacent coronary arteries and the atrio-ventricular conducting system.

Collection of Data: Measurement of the tricuspid valve

1. The circumference is measured with the help of a metallic wire, which is flexible. The wire is placed along the boundary of the annulus conforming to its shape and is cut where the ends of the wire meet and then measured with a ruler after it is straightened. The values are shown in a table.

2. The diameters of the tricuspid valve are measured in two separate dimensions in two separate perpendicularly oriented planes at the maximally separated points are measured with sliding Vernier calipers and the values are shown in another table.

The parameters applied for analysis of the values are (i) Mean Standard deviation, (ii) Median, (iii) p value (iv) Kolmogrove- Smirnov Z test

3. The tricuspid valve leaflets are studied and any presence or absence noted and also presence of any accessory leaflets are noted.

Statistical Methods: Kolmogrove- Smirnov Z test has been used to fit the normal distribution for the study parameters. Reference range has been obtained at 2.5th and 97.5th percentile.

The other methods, which can be employed to measure, the tricuspid valve is as follows:

1. Cast method: This method involves injection of a plastic cast material into the ventricular chambers and filling up the AV valve and cutting open the valve and measuring the circumference of the human hearts.

Some of the methods adopted for measuring the heart valves in general are:

2. Calipers

3. Radiological method: By determining the situation of the tricuspid valve and measuring its dimensions

4. Ultrasonography: Is non-invasive and used to determine the dimensions of the tricuspid valve

5. 2D Echocardiography

5. Angioplastic study

7. Doppler echocardiography

8. M. mode and Doppler echocardiography

9. Cross-sectional echocardiography

Fig. 1: The photograph below show the procedure measuring circumference of the annulus, the picture shows the largest & the smallest measured annulus.

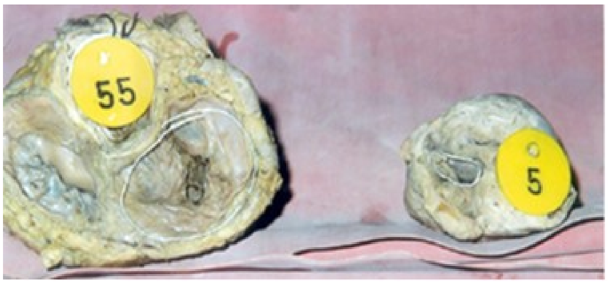
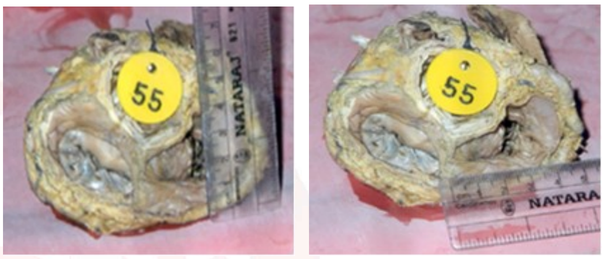


Fig. 2: Photographs below, showing diameters measured in two separate perpendicularly oriented planes at the maximally separated points.



RESULTS AND DISCUSSION

Table 1: Showing reference value for study parameters.

Statistical values	Circumference of Annulus (cm)	Diameter 1 (cm)	Diameter 2 (cm)
n	96	96	96
Mean ± SD	10.01±1.31	2.74±0.78	2.48±0.63
Median	10	2.6	2.45
Kolmogrove-Smirnov Z	0.895	1.22	1.065
Goodness of fit	Normal	Normal	Normal
p value	0.4	0.102	0.207
Reference value	7.15-13.40	1.34-4.57	1.30-3.67

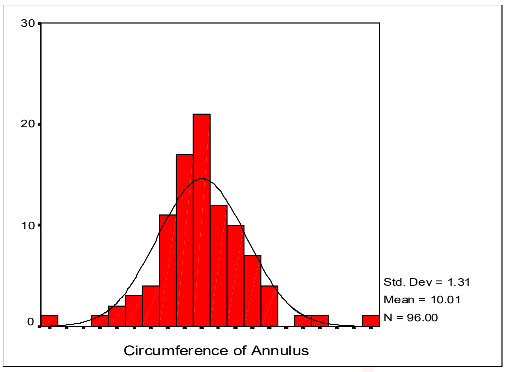
1. n – number of specimens

2. circumference of the annulus: is measured with the help of a flexible metallic wire is measured with the help of a flexible metallic wire. The wire is placed along the boundary of the annulus conforming to its shape and is cut where the ends of the wire meet and then measured with a ruler after it is straightened.

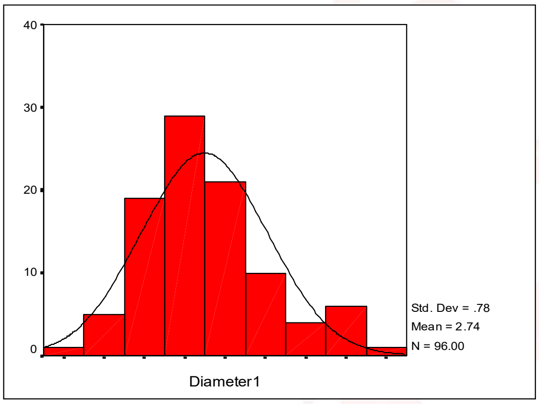
3. The diameters (1 & 2) of the tricuspid valve are measured in two separate dimensions in two separate perpendicularly oriented planes at the maximally separated points are measured with sliding Vernier calipers

4. The parameters applied for analysis of the values are (i) Mean Standard deviation, (ii) Median, (iii) p value (iv) Kolmogrove- Smirnov Z test

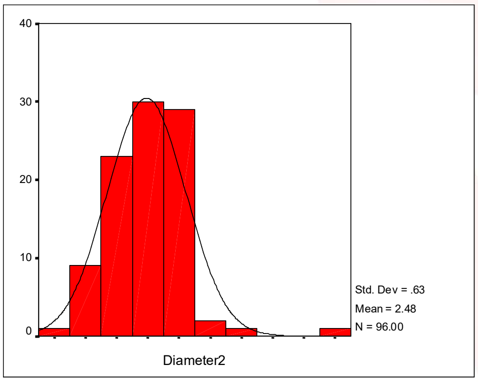
Graphic representation of the circumference of the annulus



Graphic representation of measurement of the diameters in perpendicularly oriented planes



Graphic representation of measurement of the diameters in perpendicularly oriented planes



DISCUSSION

Normal Anatomy of tricuspid valve complex: The atrio-ventricular valvular complex in both right and left ventricles consists of the orifice and its annulus, the cusps, the supporting chordae tendinae of various types and the papillary muscles.

Tricuspid valve is made up of six major anatomic components: (i) Right atrial wall (ii) Annulus (iii) 3 Leaflets (iv) chordae tendinae (v) papillary muscles (vi) Right ventricular free wall [7-10].

Harmonious interplay of all these, together with the atrial and ventricular myocardial masses depends on the conducting tissues and the mechanical cohesion provided by the fibro elastic cardiac skeleton [1].

All parts change substantially in position, shape, angulation and dimensions during a single cardiac cycle.

The Right Ventricle is characterized morphologically by its muscular conus, which separates its entry from its exit valves by its coarsely trabeculated septal aspect and by the direct attachment of part of its valve to the septum, either by chordae tendinae or by papillary muscle of the conus [7].

Tricuspid valvular orifice: The tricuspid valve orifice is best seen from the atrial aspect and measures 11.4 cms in circumference in males and 10.8 cms in females. Its margins are not precisely in a single plane. It is almost vertical but at about 45 degrees to the sagittal plane and slightly inclined to the vertical, such that it faces (on its ventricular aspect) antero- laterally to the left and somewhat inferiorly. It is roughly triangular and its margins are described as antero –superior, inferior and septal corresponding to the line of attachment of the annulus of the tricuspid valve.

Elementary accounts often describe all valvular orifices as surrounded as uniform rings of collagenous tissue, the rings interconnected by dense masses of collagen which, in the mitral and tricuspid valves are situated precisely at the atrioventricular junctions (presumed also to separate the atrial and ventricular myocardial masses.

The connective tissues around the orifice of the AV valves, while serving to separate the atrial and ventricular myocardial masses completely except at the point of penetration of the AV bundle vary in density and disposition around the valvur circumference.

Extending from the right fibrous trigone component of the central fibrous body are a pair of curved, tapered, sub endocardial tendons, or “prongs” (Fila Coronaria) which partly encircle the circumference, the later is completed by a more tenous, deformable fibro elastic areolar tissue. The extent of fibrous tissue also varies with age and sex. Nevertheless, the tissue within the AV junction around the tricuspid orifice is less robust than similar elements found at the attachments of the mitral valve. Furthermore, in the tricuspid valve, the topographical attachment of the free valvular leaflets does not wholly correspond to the internal level of attachment to the leaflet which is best appreciated in the heart when examined grossly and this feature is also more readily discerned clinically [1,7,10]. Normally, the tricuspid valve inserts lower on the IV septum than the mitral valve. Occasionally one can see prominent papillary muscles within the RV chamber.8 The atrioventricular complex of the right ventricle consists of the orifice and its associated annulus, the cusps, the supporting chordae tendinae of various types and the papillary muscles.

The valve gets its name because of the three leaflets present in it. More often than not, however, there are only two cusps, and in the literal sense, the use of the term tricuspid is not always apt. These leaflets are located septally, anteriorly and posteriorly [5,6].

Each is reduplication of the endocardium enclosing a collagenous core, continuous marginally and on its ventricular aspect, with diverging fascicles of tendinous cords and basally confluent with the annular connective tissue. Its atrial aspect is smooth and glistening and co-apts during systole, closing the orifice by pressing the distal surfaces of the leaflets together.

The ventricular surface of the valve is roughened by the attachments of the chordate [11]. All leaflets of the AV valves display, passing from the free margin to the inserted margin, 3 zones: Rough zone; (b) Clear zone; (c) Basal zone.

Rough zone: Is relatively thick, opaque and uneven on its ventricular aspect where most tendinous cords are attached. The atrial aspect of the rough zone makes contact with the comparable surfaces of the adjacent leaflets during full closure of the valve.Clear zone: The clear zone is smooth and translucent, receives few tendinous cords and has a thinner fibrous core.

Basal zone: Extends about 2-3 mm from the circumferential attachment of the leaflets, is thicker, contains more connective tissue and is vascularized, containing the attachment of the atrial myocardium [8].

Leaflets

The anterior (superior) leaflet is the largest component of the tricuspid valve. It is attached to the AV junction on the posterolateral aspect of the supraventricular crest, but extends along its septal limb to the membranous septum, ending at the anteroseptal commisure. One or more notches indent its free margins may be scalloped. It forms 3.7 cm of the annulus.

Septal leaflet: It 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.66 It is single. It makes up 3.6 cm of the annulus [10].

Posterior (inferior) leaflet: Is wholly mural in attachment and guards the diaphragmatic surface of the AV junction. Its limits are inferoseptal and antero-inferior commissure [6]. It has a variable number of scallops. It makes up the largest portion of the annulus (7.5 cm) [10]. The posterior cusp may be divided in the AV valve. In the living, the posterior cusp lies below the stream of blood from the atrium, whereas the anterior cusp intervenes between the opening and the conus arteriosus.

The bicuspid valve of the left ventricle may have an anterior or posterior cusp or both. The heart valves may be composed of accessory cusps, which may vary in size [4,6].

DISCUSSION

Carleton Chapman (1964) discussed the various techniques adopted to study the heart at autopsy and their advantages and disadvantages [13].

Pellegrini A. et al (1975) studied the immediate and long-term results of heart valve replacement with artificial prosthesis from Oct 1963 to Dec 1973 and concluded that the most frequent and fearful immediate complication was embolism, while the main late complications were embolism and valve leakage [14].

Louis et al (1993) suggested that the accurate knowledge of the structure of the valves in the human heart is of prime importance for 3 very practical reasons: (i) the various anatomical peculiarities in the valve leaflets suggest an explanation for at least some of the mechanical components entering into the localization of inflammatory, as well as degenerative (athero-sclerotic) processes in these sites. (ii) the insight into the pathological processes thus obtained helps one differentiate these lesions from one another& (iii) one is better able to cope with the long disputed question as to whether or not blood vessels or myocardium normally exist in valves [15].

Singh B and Mohan JC (1994) determined the atrio-ventricular orifice area in 78 healthy subjects aged 2 months to 50 years, by cross sectional and Doppler echocardiography to establish normal values and their relationship with body surface area by the following methods. Mitral valve orifice area was determined (i) by direct planimetry which was 3.37±1.13cm^2, the range being 0.52- 5.6cm^2 and (ii) by continuity equation by which the area was 3.62+/- 1.08cm2 the range being 0.66-7.2cm^2. Tricuspid valve orifice area (4.07±1.5cm^2; range: 0.62–7.20) and by continuity equation had a close correlation with mitral valve orifice area (r-0.76, p<0.001).

Mitral and tricuspid valve orifice areas were significantly correlated to body surface area (r- 0.85 and 0.77 respectively), left and right ventricular outflow diameters n(r=0.90 and 0.79) respectively), and age (r=0.70 and 0.61 respectively). These data provide normal values for AV valve orifice area in normal subjects with a wide range of body surface area and support the practice of indexing valve area by body surface area [16]. Victor S and Nayak(1994) studied 100 normal human hearts and observed that numerous variations were present in the configuration of the cusp tissue and chordal/ papillary support of the ventricular wall and these made the interior of the ventricles as unique to each individual as one's fingerprint [6].

Sutton JP et al (1995) studied 50 hearts to analyze carefully the structure of the right AV valve and to define its component parts. They did cross sectional echocardiography to study the heart valve in closed position. The reported their findings as follows: 62 % had 3 readily identifiable leaflets, 30 % had 2 leaflets while in, 8 % there were 4 leaflets. The cross-sectional echocardiography revealed 3 definite lines of closure in all cases. They were of the view that the eccentric placement of the anterior papillary muscle causes the leaflets to close in three lines of apposition and this makes the valve distinguishable from its mitral partner. They also were of the view that extra scallops in the structure of the right AV valve merely allow better cooptation of the leaflets [17].

John F Secombe et al in 2005, described the morphologic features of the tricuspid valve thoroughly and quantitatively, 24 normal hearts at autopsy from subjects evenly distributed by age and sex, leaflet length, surface area, chordal number and leaflet morphology.

The results were as follows:

Mean tricuspid valve length was – 11.3(+/-) 0.1cm.

Surface area: 21.0(+/-) 1.1cm2

Mean length and surface area for:

Anterior, posterior and septal leaflets: 38- 42 mm and 5.9-7.8cm² respectively.

For a given value, the longest leaflet could be twice the length and thrice the area of the smallest. Calculated valve diameter – 2.13(+/-)0.03 cm /m2.

Chordal density (number of chordae/cm2) was greater in women than men (9.9+/-0.5 vs 7.31 (+/-) chordae/cm2). The septal leaflet had the greatest chordal density and anterior, the lowest [12.7(+/-)0.9 vs 5.9(+/-)chordae/cm2] [18].

Aarti Rohilla et al (2015) studied (a) weight of heart (b) circumference of tricuspid valve (mm), attachment length of leaflets and commissures (mm), and height of the three leaflets (mm). A strong and direct correlation was observed between the circumference of tricuspid valve with the weight of heart, attachment length of leaflets and the three commissures and height of leaflets. Thus in the study they tried to provide the normal data on morphometric parameters of heart and tricuspid valve which will help the cardiac surgeons and forensic experts [19].

Parmatma Prasad Mishra et al (2016) Normal tricuspid valve with three cusps was found only in 51.66% of hearts. Bicuspid, tricuspid valve was present in seven hearts. The number of accessory cusps ranged from one to four. Most of the anterior cusp, posterior cusp and septal cusp was found to be triangular in shape. The anterior cusp was found to be largest in length, followed by septal cusp. The average height of all anterior, posterior and septal cusps was almost same [20].

In the present study, the tricuspid valve orifice area measurements were as follows:

(i) Annulus – circumference – Mean±SD = 10.01±1.31

Kolmogrove- Smirnov Z test – 0.895; p value = 0.400.

(ii) Diameters in two separate dimensions in two separate perpendicularly oriented planes at maximally separated points:

(a) Mean ± SD = 2.74±0.78

Kolmogrove- Smirnov Z test – 0.220; p value: 0.102

(b) Mean±SD: 2.48±0.63;

Kolmogrove - Smirnov Z test - 1.065. p value: 0.207.

The population mean is 10.01.

In the present study (i) was measured with a flexible metallic wire and ruler while (ii) was measured using sliding Vernier calipers.

In the present study the tricuspid valve had three leaflets and no accessory leaflets were present.

CONCLUSION

The study of the dimensions of the tricuspid valve annulus dimensions is important for various cardiac procedures. The knowledge of the annulus of the tricuspid valve is important for the cardiac surgeon in tricuspid valve diseases like stenosis and regurgitation as it will help him plan palliative or corrective surgery in the congenital or acquired heart diseases.

It will also help in the development of the prosthetic valves by preventing various complications of prosthetic valves like thrombosis, leak etc.

Also, the knowledge of the dimensions of the tricuspid annulus helps in distinguishing cardiac from non-cardiac causes of death, at autopsy. It is also useful in determining the sex and age of the individual. Possibly, it can also be used as an important tool in the anthropological studies,for better understanding of surgical anatomy of heart and designing of tissue-engineered cardiac valves

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Conflicts of Interests: None

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