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MORPHOLOGY OF TRICUSPID VALVE: MYTH AND TRUTH

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ABSRACT

Background and Aim: The tricuspid valve complex has been studied since the beginning of the twentieth century and the variations of its structural orientation have been reported before. Still frequent updates are needed as the additional leaflets pose a major problem during surgeries. **Method:** In this study, 52 adult formalin fixed human hearts were analyzed to assess the number of leaflets and the different morphometric parameters of the valve.

Results: The result showed variations of number of leaflets from its conventional three to less or more cusps. 46.15% specimens showed normal three leaflets. Rests were variable. Minimum and maximum cusps were seen as single and eight respectively. Mean circumference and diameter of annulus was 10.32 cm and 2.94 cm respectively. Basal attachment of septal leaflet was least among three.

Conclusion: It is suggested that multicuspidial form of tricuspid valve raises concern about understanding the functional and physiological significance of the accessory leaflets. Our data may enrich and help the cardiac surgeons and forensic experts. 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.

Key words: heart, tricuspid valve, morphology, morphometry.

Introduction

The dynamic progress of therapeutic and diagnostic cardio-invasive procedures indicates a marked rise in interest in studies of cardiac anatomy. Despite intense interest in cardio-anatomy the tricuspid valve morphology is still an open question. The tricuspid valve, in the light of existing research, is a heterogeneous structure with great variability in its morphology. The number of cusps, their configurations and their sizes are still controversial. The three leaflets of tricuspid valve (TV) referred to as anterior, posterior/inferior and septal as attached to a fibrous

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annulus conform to the sternocostal, diaphragmatic and septal walls of right ventricle respectively.[1] The three-dimensional (3D) shape of this tricuspid annulus (TA) is complex and does not conform to a flat ring [2]. Tricuspid regurgitation (TR) is the most common pathology affecting the valve. An understanding of the pathological process underlying TR is necessary to determine the optimal management strategy. Usually, TR is secondary to left-sided valvular pathology (mostly mitral valve disease) with pulmonary hypertension and right ventricular dilatation.[3] As TA is a component of the right ventricle, it will dilate also. However it can only lengthen and dilate along the attachment of the anterior and posterior leaflets since the septal leaflet is fixed between the fibrous trigones.[1] The accurate knowledge of the morphology and morphometry of the tricuspid valve is also of importance for differentiating between functional and organic tricuspid diseases. Unfortunately, TV evaluation continues to be a major problem in the surgical decision-making process as its position and structural complexity adds to the challenges in its assessment by radiological techniques in living human beings.[4] The task of cardio-surgeons is to regain the original mechanics of the valvular complex in order to maintain the natural circulation after repair of the diseased valve. With the rapid progress in the field of interventional cardiology and new valvuloplasty methods, study of morphometric measures of tricuspid valve complex on cadavers is the crucial need of time. It is also seen in different studies that a broad racial and ethnic disparities exist in the epidemiological records on the incidence and prevalence of cardiovascular diseases.[5] Existing controversies, its' clinical significance and lack of studies on Eastern Indian population necessitates extensive study on the anatomic variations of tricuspid valve in the population of this region. This baseline data will enrich the previous records and will be helpful for the cardiothoracic surgeons as well as prosthesis manufacturers during replacement or repair of valves in this population.

Materials & Methods

The present study was conducted on 52 formalin fixed human adult cadaveric hearts procured from the department of Anatomy, age ranging from 20-80 years. Sex could not be ascertained as we included some previously collected departmental specimen also for our study material. The hearts which were injured before or during autopsy, having evidence of any disease, burnt or decomposed were not included in the study. The hearts were dissected with least destruction of valves after cleaning thoroughly under the tap water. The first incision was given from right aspect of inferior vena cava to the superior vena cava and the right atrium was opened to expose the tricuspid valve to observe the variations of the leaflet and measured the diameter and circumference of it. The second incision was given along the inferior border of the heart to the inferior margin of anterior interventricular groove i.e. along the acute margin of the heart. The walls were carefully retracted and the interior was thoroughly washed under running tap water to remove the clots. The shape of the tricuspid valve was observed. The tricuspid valve was then opened by cutting through the annulus at the junction of anterior and posterior leaflet. Then again the heart was thoroughly washed. Excessive water was soaked with a clean cotton cloth. The fibrous annular ring and attachment of the valve leaflets along its anterior, posterior and septal margins were examined. Variations of leaflets were noted and photographs were taken. A single curtain present along the total annular circumference with no complete indentation (which reaches up to the fibrous annular ring) for differentiation of anterior, posterior or septal leaflets are considered as mono-cuspid valve.

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By using digital Vernier Calliper (Mitutuyo, with measurement resolution 0.01 mm) and malleable millimeter ruler following measurements were taken.

1. Annular diameter.
2. Circumference of annulus of tricuspid valve (Rusted et al.[6] suggested that this measurement technique results in a measurement error of no more than 0.02-0.03 cm).
3. Basal/annular attachment length of Anterior, Posterior & Septal Leaflets.
4. Maximum height of the anterior, septal and posterior cusp- measurement of distance from tip of cusp to its annular attachment.

The data were summarized using descriptive statistics like frequency, mean, standard deviation, range and 95% confidence interval. All the statistical calculations were performed using Statistica Software. Goodman fit test was done to see the distribution of data and the results were tabulated. P value <0.05 is considered as significant.

Results

In present study, classical tricuspid valve was present in24 specimens (46.15%). Rests 28 specimens were variant with cusps either less or more in numbers. Single and double cusp were seen in 2 specimens (3.85%) and 11 specimens (21.15%) respectively. More in number like four cusps were present in 8 specimens (15.38%), five in 4 specimens (7.69%), six in 2 specimens (3.85%) and maximum eight cusps in 1 specimen (1.92%). Accessory cusps were frequently present on anterior (88.89%) than posterior (55.5%) aspect of annulus; no accessory cusps were found on septal aspect. All the parameters were showing normal distribution by Goodman-fit test. Mean annular diameter and circumference was 2.94±0.49cm and 10.32±1.46cm respectively. It was notified that variations of number of cusps were linked with different ranges of valve circumference. In smaller circumference (from 7.3cm to 9cm) no accessory cusps were present whereas circumferences between 10.6cm -12.7cm were represented with predominant accessory cusps. Mean basal length of anterior, posterior and sepal cusps were 4.68 ± 0.8cm, 3.51 ± 0.97cm and 2.02 ± 1.31cm respectively. Mean ratio of basal attachment of anterior, posterior (including accessory cusp) and septal cusp with the annular circumference were 0.46±.054 cm, 0.34±0.09 cm and 0.25±0.063cm respectively indicating that maximum annular attachment by anterior cusp and minimum by sepal cusp. Mean height of anterior cusp was 1.97±0.43 cm, posterior cusp was 1.31 ±1.3 cm and septal cusp was 1.14±0.69 cm. Morphometry of annular diameter and circumference, height of the three cusps, basal attachment of cusps and its ratio with total circumference of annulus were depicted in Table 1.Figure 1, 2, 3represents variations of cusps present in this study. Percentages of variable cusps associated with different range of valve circumference have been shown in Figure4.

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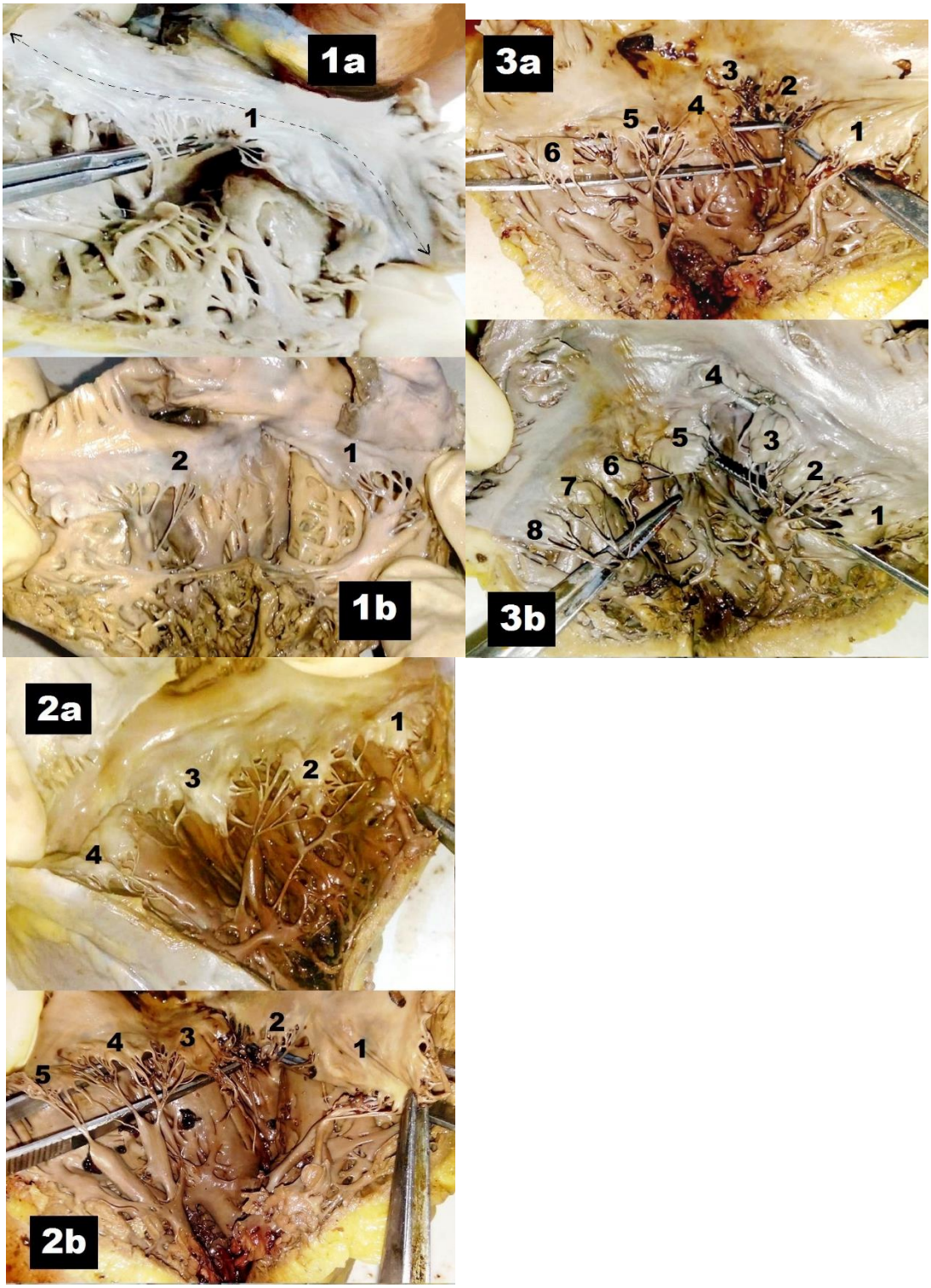

Figure 1: a - monocuspid valve; b – bicuspid valve; c – tetracuspid valve; d - pentacuspid valve; e – hexacuspid valve; f – octacuspid valve

Figure 2: Bar diagram represents number of cusps variation with circumference of valve

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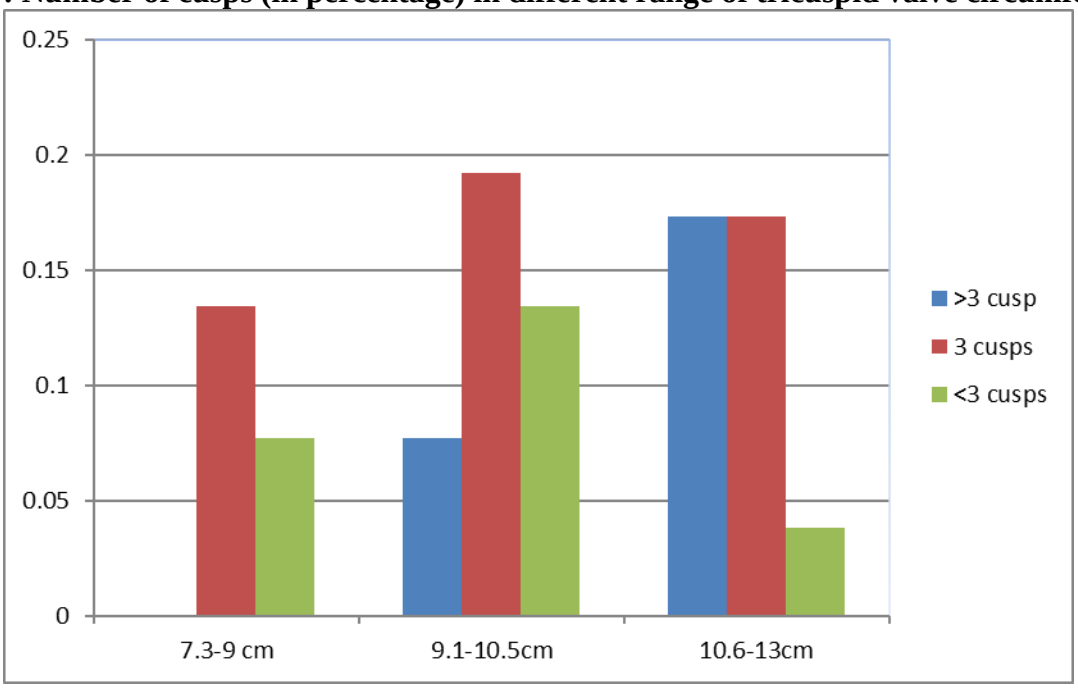
Fig- 4 : Number of cusps (in percentage) in different range of tricuspid valve circumference



DISCUSSION

Although by convention the right AV valve has three leaflets, previous studies [7-10] havesuggested that variations of the number of leaflets are not uncommon. 25% specimens, in our study have less than three cusps which are quite higher in percentage than previousother studies [8-10], but considering accessory cusps, result of present study (28.84% specimens) is much less than previous studies [8,9]. Significant numbers of sample in our study show double cusps, closer only with the findings of Kocak A et al[7].Tetracuspid valve, which we have found in 8 samples only, does not match with the study of Skwarek M et al [8] and Mishra et al [9]. 5 cuspidial structure (including 2 accessory cusps), which is seen only in 5.77% in our study, reported by Skwarek et al[8] in 33.3% cases. Another unusual type of 6 cuspid valve, 3 main and 3 accessory cusps, noted by us in 3.84% sample only, also is much lower than Skwarek M et al [8] study (13.3%). Table 2 shows frequency of tricuspid valve types in different studies. Our analysis yields an assessment of two rarest configurations, 8 cuspidial form and monocuspidal form of the valve which is not reported yet.

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Table 1: Measurement of different parameters (cm) of tricuspid valve.

Parameters		Mean	95% CI		Median	Min	Max	SD
			UL	LL				
ANNULUS	Diameter	2.94	3.07	2.80	2.80	2.1	4.0	0.49
	Circumference	10.32	10.72	9.91	10.50	7.3	12.7	1.46
ANTERIOR CUSP	Height	1.97	2.09	1.85	2.0	1.2	3.1	0.43
	Basal Length	4.68	4.9	4.46	4.45	2.6	7.3	0.8
POSTERIOR CUSP	Height	1.31	1.42	1.2	1.3	0.6	2	1.30
	Basal Length	3.51	3.78	3.24	3.51	2.0	5.5	0.97
SEPTAL CUSP	Height	1.14	1.33	0.94	1.3	0.7	2	0.69
	Basal Length	2.02	2.38	1.65	2.6	1.2	3.4	1.31
Anterior Cusp	Basal length : Circumference (Ratio)	0.46	0.44	0.47	0.45	0.38	0.59	0.05
Posterior Cusp		0.34	0.32	0.37	0.31	0.22	0.52	0.09
Septal Cusp		0.25	0.27	0.23	0.26	0.09	0.37	0.06

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Table 2: Frequency of leaflets in Tricuspid valves in different studies.

No of cusps	Present study	Kocak et al [7]	Skweark et al [8]	Mishra et al [9]	Chauhan et al [10]
One	3.85%				
Two	21.15%	20%	---	5.83%	1%
Three	46.15%	70%	9.3%	51.66%	89%
Four	15.38%	10%	36.15%	31.66%	10%
Five	7.69%		33.3%	8.33%	
≥ Six	5.77%		17.4%	4.99%	

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Table 3 **:** Comparison of present and previous studies regarding annular morphometry.

Authors	Methods	Country & Year	Annular measurements (cm)	
			Circumference	Diameter
Present study	Cadaveric	**India** 2020	10.32	2.94
Premkumur et al [13]	Cadaver	**India** 2017	8	2.6
Rohilla et al [15]	Cadaver	**India** 2015	09.50	------
Kalyani et al [14]	Cadaver	**India** 2012	10.7	2
Kocak et al [7]	Cadaver	Turkey 2014	12.4	
Skwarek et al [16]	Cadaver	Poland 2008	12	3.1
Antoniali et al [17]	Cadaver	Brazil 2007	10.50	------
Motabagani et al [18]	Cadaver	Soudi Arab 2006	12.39	------
Westaby et al [19]	Cadaver	Birmingham 1984	11.95	3.8
Silver et al [2]	Cadaver	Canada 1971	11.4	
Anwar et al [4]	3D Echo	Nether Land 2007	------	4.0

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Table 4 : Comparison of morphometric data of present study and some previous studies

Authors	Method of Study	Coun-try & Year	Cusps Measurements (cm)					
			Anterior		Posterior		Septal	
			Basal length	Height	Basal length	Height	Basal length	Height
Present study	cadaveric	India 2020	4.68	1.97	3.51	1.31	2.02	1.14
Mishra et al [9]	cadaveric	India 2016	5.00	2.86	1.70	1.50	3.20	2.57
Rohilla et al [15]	cadaveric	India 2015	2.73	-----	2.21	------	2.88	------
Antoniali et al [17]	cadaveric	Brazil 2007	------	------	------	------	3.06	------
Motabagani et al [18]	cadaveric	Soudi Arab 2006	3.72	2.24	2.63	2.22	3.13	1.55
Skwarek et al [8]	cadaveric	Poland 2004	3.02	2.39	2.41	2.14	3.22	1.83

Different studies were done previously to measure different parameters of tricuspid valve[7- 9, 13-21]. Tricuspid annular diameter measurements are of critical importance in selection of patients for surgical decision as well as for the type of surgical technique (valve plication /valve replacement).The tricuspid annulus shows a non – planar structure with an elliptical saddle-shaped pattern having two high points (oriented superiorly towards the right atrium) and two low points oriented inferiorly towards the right ventricle.[4] Although 2D transthoracic echocardiography is helpful to assess valve function and regurgitation severity, it has limitations in describing details of morphology of tricuspid annulus diameter as seen in direct surgical field.

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In tricuspid valve, unlike the aortic and mitral valve, it is not possible to visualize all cusps simultaneously in one cross sectional view by standard techniques due to its nonplanar structure. 3D transesophageal image reconstruction and intracardiac echocardiography overcome this problem but at the cost of some procedural risks and an increase in procedural duration.[4] A comparison of the tricuspid valve annulus measured during life using two-dimensional echocardiography with the measurement obtained at autopsy may raise several questions. The method by which the heart is preserved may produce different annular measurements. Apparently, examination of the valve annuli in the fixed state results in a smaller annular size than in the fresh hearts.[11] Smaller measurements obtained by two-dimensional echocardiographic techniques compared with freshly opened hearts may be related to less precise lateral resolution of the ultrasonic method, which tends to underestimate cavitary size.[12] In our study range of annular diameter and circumference of tricuspid valve is 2.1 – 4 cm and 7.3 – 12.7cm respectively. Previous studies by King et al[20], Sairanen and Louhimo [21] and Anwar et al [4] have indicated that tricuspid annular diameter and dimensions of the valve orifice closely correlated with age, body weight, height and body surface area. This partly explains the smaller tricuspid valve and its dimensions in Indians hearts as Indians are shorter and smaller sized when compared to the taller and heftier Western populations.[13,14] Comparing studies of present and previous data of Indians and other countries(Table 3), our study also support this.

Regarding basal length of cusps, the anterior leaflet is the largest, attached chiefly on the posterolateral aspect of the supraventricular crest, whereas the posterior leaflet is notable for the presence of multiple scallops and the septal leaflet is the smallest and arises medially directly from the tricuspid annulus above the interventricular septum.[1] In our study mean basal attachment of anterior leaflet is much more than the values reported by Skwarek et al[8], Motabagani[18] and Rohilla et al[15] respectively. The difference could be due to different morphometric method followed by researchers. Because the small septal wall leaflet is fairly fixed, there is little room for movement if the free wall of right ventricular/tricuspid annulus gets dilated.[1] Dilation of the tricuspid annulus therefore occurs primarily in its anterior/posterior (mural) aspect, which can result in significant functional TR as a result of leaflet malcoaptation.[22] Measurements of basal length and height of tricuspid valve leaflets of our study are compared with others in Table 4. Height of three leaflets is less but basal length is more than others in present study. In our study the ratio of mean basal lengths attachment of anterior leaflet is approx 1.35 times higher than that of posterior leaflet attachment. Septal leaflet attachment is least in our study which is not matched with other studies. Length of annular attachment of the valve leaflets should be kept in mind by cardiothoracic surgeons for proper postoperative functioning of tricuspid valve in case of constructive surgery. We have found larger circumference of annulus (ranged from 10.6-12.7cm) is associated with high percentages of accessory cusps (>3), whereas valve of smaller circumference (7.3-9 cm) is represented with decreased number of cusps (<3). Extra leaflets in greater annular circumference is probably to ensure the mobility of leaflet which otherwise would be compromised because of longer inter commissural length. Athavale et al[23] inferences that an increased annular circumference is expected to show a proportionate increase in number of anterior leaflet (if it is not appropriately compensated by normal valvular components) rather than that of posterior which is also matched with our study. In our study, extra cusps along anterior and posterior/inferior aspect of annulus is 88.89% and 55.5% respectively but no accessory cusps present on septal side.

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Conclusion:

Our analysis represented right atrio-ventricular valve as conventional tri-cuspid in 46.15% only. Rest 53.84% represented as variable, either by increased or decreased cusps number. Accessory cusps are more when circumference of the valve ranged between 10.6 cm-12.7cm. In 28.84% specimens, cusps are more than three whereas in 25% specimen, cusps are less than three in numbers and this could be explained due to small size of Indian hearts. These data will help in better understanding of the anatomy of the tricuspid valve complex and appropriate designing of valvular complex for transplantation. Two rarest form of this study as mono and octa-cuspid valve must add some contribution in this field. We hope the morphometric result regarding normal tricuspid valve presented here would serve as a baseline data for further studies in the Indian population. However it is pertinent to say that the findings of the present study are to be extended in individuals with valvular disease and need to be replicated in large population by other investigators in India. Further, correlation with weight and body surface area and BMI or with advanced techniques as real time three dimensional echocardiography needs to be studied along with other studied parameters. We hope that it will bridge the gap between the surgical and anatomical understanding of morphology of tricuspid valve.

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