Original Article

Morphometric analysis of tricuspid valve: An Indian perspective

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Abstract

Background: The morphometry of tricuspid valve complex is of clinical importance for cardiovascular surgeons and there is scarcity of such data in Indian literature. The study was conducted to record normal tricuspid valve measurements which would serve as baseline data for the Indian population. **Material and Methods:** The study was carried out on 100 formalin fixed hearts without any pathology from patients who had died of non-vascular causes and whose age ranged from 8 to 85 yrs. The hearts were grouped into three cohorts corresponding to age, 54 hearts aged between 8 to 40 yrs, 42 hearts aged between 41 to 64 yrs and 4 hearts aged 65 yrs and above. Dissection was performed according to standard autopsy techniques. The measurements were recorded using a flexible millimeter ruler and surgical suture material. The dimensions measured were the attachment lengths of anterior, posterior and septal leaflets. The circumference of the valve along with the frontal and sagittal dimensions was measured. Area of the valve expressed as a triangle and as an ellipse was calculated. **Results:** The measurements obtained were assessed using SPSS software. Statistically significant increase in tricuspid valve measurements were observed with advancing age both in men and women. In younger hearts the tricuspid valve resembled a triangle and with advancing age the tricuspid valve became more elliptical in shape. **Conclusion:** We hope this study will serve as baseline data for the tricuspid valve measurements in the Indian population and it will be of clinical use for patients with various tricuspid valve abnormalities.

Key words: Morphometric analysis, tricuspid valve, cardiac valve

INTRODUCTION

Cardiovascular specialists have entered an era of renewed interest and enthusiasm regarding the diagnosis and treatment of valvular heart disease.[1-4] However, interest in and knowledge of the tricuspid valve has always lagged behind that of the mitral valve.[1,5,6] The normal data of the tricuspid valve complex is of great clinical importance but published works on the normal dimensions are surprisingly scant.[5,7] Although many Indian studies of mitral valve are available, very few studies providing tricuspid valve data in the Indian population are available in literature. An added problem with the tricuspid valve is its structural complexity, which makes it really difficult to assess the complete valve on two-dimensional echocardiography.[5,8-10] Hence knowledge of tricuspid valve is important. Autopsy data of normal tricuspid valve can help in defining the normal dimensions of the tricuspid valves, which can be used as the baseline data by cardiac surgeons.[1,5,11,12]

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In this study, we tried to define the normal tricuspid valve complex data by measuring various leaflet measurements, annular circumference and the area of the valve in the Indian population.

Normal tricuspid valve complex

The tricuspid valve is a multi-component complex structure and consists of three leaflets (anterior, posterior and septal), the chordae tendineae, two discrete papillary muscles, the fibrous tricuspid annulus, right atrial and right ventricular myocardium.[1,13,14] It is the most apically placed valve and has the largest orifice.[13,14] 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 toward the right ventricle.[1,8,14-16] Due to this non-planar complex structure of tricuspid valve, it is not possible to visualize all the cusps simultaneously in one cross-sectional view by standard transthoracic two-dimensional echocardiography.[1,13,14-16]

MATERIALS AND METHODS

The study was carried out on 100 formalin-fixed hearts from patients who had died of non-vascular causes and were autopsied. No gross abnormality of the tricuspid valves was noted. There were 66 males and 34 females whose ages ranged from 8 to 85 years. The hearts were grouped into three cohorts corresponding to age: 54 hearts aged between 8 and 40 years (32 males, 22 females - Group I), 42 hearts aged between 41 and 64 years (32 males and 10 females - Group II) and 4 hearts aged 65 years and above (2 males and 2 females - Group III). Number of samples in group III was less than desired as the autopsies were conducted only on medicolegal cases of road traffic accidents and suicide cases consisting predominantly young to middle-aged adults. Dissection was performed according to standard autopsy techniques. Using scissors, the initial cut was made from the inferior vena cava to the right atrial appendage and the tricuspid valve was exposed.[17] The measurements were recorded using a flexible millimeter ruler and surgical suture material. The following measurements of the tricuspid valve were recorded: attachment length of anterior leaflet (1), posterior leaflet (2), septal leaflet (3), frontal dimension (4), sagittal dimension (5) and the atrial circumference of the tricuspid valve attachment (6). The frontal dimension was measured from the commissure between the anterior and septal leaflet of the tricuspid valve along the axis of the right atrioventricular orifice to the sharp margin of the right ventricle. The sagittal dimension was measured perpendicular to the frontal dimension at the midpoint of its length.[5]

A triangle was constructed using the attachment lengths of the three leaflets of the tricuspid valve (1–3) [Figure 1] and an ellipse using dimensions 4 and 5 to determine the shape of the tricuspid valve [Figure 2]. The areas of these geometric figures were calculated according to the formulae, for the triangle: ½ × base × height and for the ellipse: 3.14 × a × b [Figure 3]. The results obtained were analyzed in SPSS software for Windows version 16 using Independent *t* test to determine the statistical significance of age and sex differences in various measurements of the tricuspid valve.

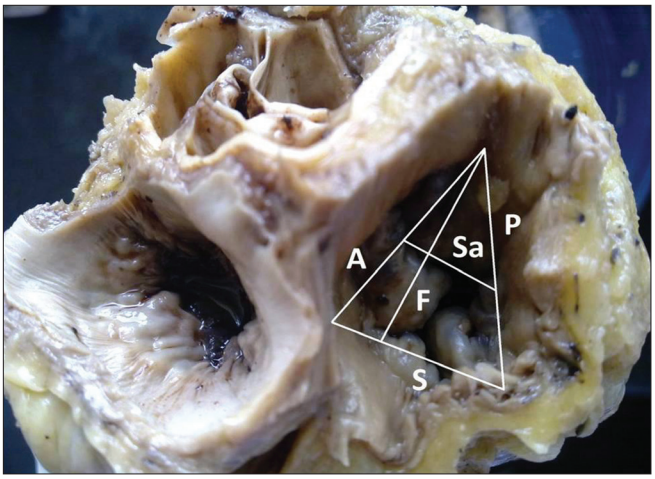

Figure 1: Tricuspid valve in a young individual which is triangular and showing attachment lengths of the leaflets and the frontal and sagittal dimensions

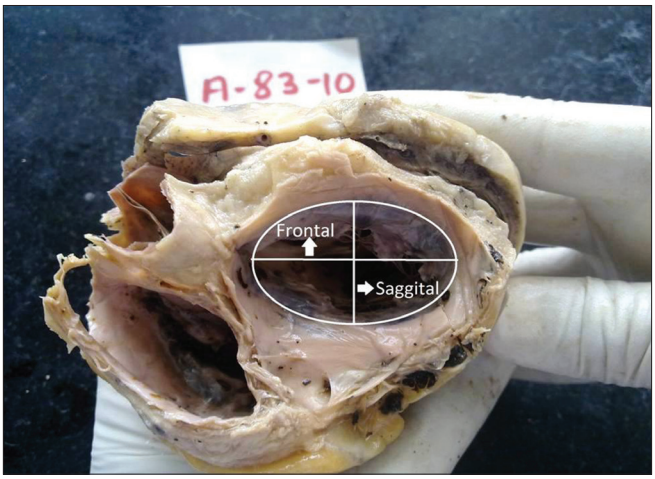

Figure 2: Tricuspid valve in an old individual which is ellipsoid and showing the frontal and sagittal dimensions

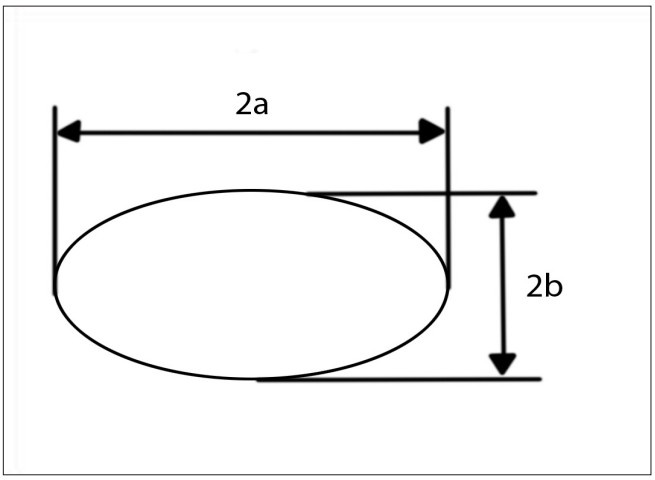

Figure 3: Calculation of area of the ellipse – 3.14 × a × b

RESULTS

The attachment length of the anterior leaflet ranged in men

from 36.40 + 3.02 mm to 47.5 + 3.53 mm and in women from 36.4 + 3.08 mm to 42.5 + 3.53 mm from group I to group III [Tables 1 and 2]. Statistical differences were observed between groups I and II both in men and in women but not between groups II and III, probably due to the less number of cases in group III (only 2 hearts). The attachment length of posterior leaflet increased from 22.81 + 3.74 mm to 25.81 + 5 mm in men and 21.5 + 4.31 mm to 24.2 + 2.89 mm in women between groups I and II, which was statistically significant; however, in men it paradoxically reduced to 23.5 + 2.12 mm in group III, which might be due to less representation in group III. The attachment of septal leaflet increased from 30.12 + 3.41 mm to 36.5 + 4.94 mm in men and from 28 + 3.32 mm to 32.5 + 3.53 mm in women between groups I and III and the increase was statistically significant.

The frontal and sagittal dimensions of the tricuspid valve orifice increased between groups I and II both in men and women with the increase being statistically significant [Tables 1 and 2]. The frontal dimension increased from 27.34 + 3.97 mm to 32.5 + 2.12 mm in men and from 24.72 + 2.69 mm to 31 + 4.24 mm in women between groups I and III. The sagittal dimension increased from 15.5 + 2.91 mm to 20 + 1.2 mm in men and from 15.86 + 2.05 mm to 18 + 2.82 mm in women between groups I and III.

The total circumference of attachment of the tricuspid valve increased from 89.34 + 7 mm to 107.5 + 10.6 mm in men and from 85.95 + 6.75 mm to 104 + 5.65 mm in women from group I to group III and the increase was statistically significant ($P < 0.05$) [Tables 1 and 2]. The triangular area was slightly larger than the ellipsoid area in group I. The ellipsoid area increased in group III with the increase being statistically significant ($P < 0.05$). Most of the increase in measurements between groups I and II were statistically significant. The correlation between groups II and III were not statistically significant probably due to the less number of samples in group III. In younger hearts the tricuspid valve resembled a triangle and with advancing age the tricuspid valve became more elliptical in shape.

Table 1: Morphometry of different dimensions of tricuspid valve in millimeters

Measurement	Sex	Age groups		
		I (8–40 years)	II (41–64 years)	III (64 years and above)
Anterior leaf attachment	M	36.40 ± 3.02	42.31 ± 5.2	47.5 ± 3.53
	F	36.4 ± 3.08	42.5 ± 5.12	42.5 ± 3.53
Posterior leaf attachment	M	22.81 ± 3.74	25.81 ± 5	23.5 ± 2.12
	F	21.5 ± 4.31	24.2 ± 2.89	24 ± 1.41
Septal leaf attachment	M	30.12 ± 3.41	32.15 ± 4.47	36.5 ± 4.94
	F	28 ± 3.32	31.4 ± 3.3	32.5 ± 3.53
Frontal dimension	M	27.34 ± 3.97	31.93 ± 4.52	32.5 ± 2.12
	F	24.72 ± 2.69	29.8 ± 4.15	31 ± 4.24
Sagittal dimension	M	15.5 ± 2.91	17.37 ± 2.8	20 ± 1.2
	F	15.86 ± 2.05	18 ± 1.88	18 ± 2.82
Tricuspid circumference	M	89.34 ± 7	100.96 ± 9.30	107.5 ± 10.6
	F	85.95 ± 6.75	98.1 ± 8.56	104 ± 5.65
Triangular area	Both sexes	31.71 ± 7.58	38.67 ± 9.33	39.82 ± 6.53
Ellipse area	Both sexes	29.13 ± 6.95	43.62 ± 9.45	47.16 ± 4.86

Table 2: *P* values showing comparison between three groups

Measurement	Sex	*P* value between group I and group II	*P* value between group II and group III	*P* value between group I and group III
Anterior leaf attachment	M	0.001	0.177	0.014
	F	0.001	1	0.001
Posterior leaf attachment	M	0.009	0.525	0.801
	F	0.088	0.928	0.44
Septal leaf attachment	M	0.045	0.194	0.017
	F	0.012	0.679	0.081
Frontal dimension	M	0.001	0.864	0.081
	F	0.001	0.718	0.006
Sagittal dimension	M	0.012	0.21	0.039
	F	0.009	1	0.04
Tricuspid Circumference	M	0.001	0.345	0.001
	F	0.001	0.382	0.001
Triangular area	Both sexes	0.007	0.812	0.042
Ellipse area	Both sexes	0.001	0.467	0.002

DISCUSSION

The atrioventricular valves are formed in part from the myocardium, and in part from mesenchymal elements like the endocardial cushions.[5,18] Lambers *et al.* have stated that the tissue from the cushions formed the atrial side, while the myocardium gave rise to the ventricular aspect of the leaflet.[19] Comparison of the tricuspid valve to a triangle or ellipse helps in deciding which cardiac chamber exerts a greater influence with atria being more elliptical and right ventricle being more triangular. [5]

The incidence of organic impairment of the tricuspid valve reported is 10–15% of rheumatic valve diseases.[1] But at necropsy in the Indian subcontinent, the organic tricuspid valve involvement is reported to occur in more than one-third of patients with rheumatic heart disease. [20] Isolated rheumatic tricuspid valve is rare. However, clinically significant tricuspid valve disease in association with mitral or aortic valve disease is reported to be 10–20% of cases.[21] Tricuspid valve regurgitation can also result from severe annular dilatation of the valve without any organic or congenital disease affecting the valve leaflets. [1,22] The functional tricuspid regurgitation detected during assessment of the rheumatic mitral valve was believed to subside after correction of the mitral defect but recent data on follow up of patients undergoing mitral repair suggest otherwise.[1,11] Concomitant surgical repair of tricuspid regurgitation at the time of left-sided rheumatic valve surgery has to be considered as standard of care, as this approach has been shown to result in improved peri-operative outcomes, functional class and survival.[1,11] Post-traumatic damage of the tricuspid valve is more frequent than damage of the mitral valve because the tricuspid valve is located anteriorly to the mitral valve and closer to the chest wall.[23,24] Hence knowledge of the morphology and morphometry of the tricuspid valve helps to differentiate between functional and organic tricuspid pathology.[24] Such data may also be helpful to cardiac surgeons treating patients with tricuspid valve abnormality.

The anterior leaflet is the largest component of the valve.[5,13] It is attached chiefly on the posterolateral aspect of the supraventricular crest, extends along its septal limb to the membranous septum and ends at the anteroseptal commissure.[5] The posterior cusp is notable for the presence of multiple scallops and is wholly mural in attachment and guards the diaphragmatic surface of the atrioventricular junction.[1,13] The septal leaflet is the smallest and its attachment passes from the inferoseptal commissure on the posterior ventricular wall across the membranous septum to the anteroseptal commissure.[1,13] The small septal leaflet is fairly fixed and dilation of the tricuspid annulus therefore occurs primarily in its anterior/posterior aspect, which can result in significant functional tricuspid regurgitation as a result of leaflet malcoaptation. [1] Since the septal leaflet is fixed, tricuspid annular sizing algorithms have been based on the dimension of the base of the septal leaflet.[1] The attachment length of the anterior leaflet increased with age both in men and women and was statistically significant. The attachment length of the posterior leaflet was most variable. The attachment length of the septal leaflet was stable in men and women. These findings are similar to the data reported by M Skwarek *et al.*[5] The anterior leaflet attachment measurements correlated with the values reported by Motabagani.[25] The significant variation in the length of anterior and posterior leaflets in different groups was probably due to development of tricuspid valve in the population studied.

The frontal and sagittal dimensions of the tricuspid valve increased both in men and women with aging which corresponds to data of Skwarek *et al.*[5]

Tricuspid valve regurgitation occurs mainly from annular dilation and right ventricular enlargement.[1,11] The tricuspid valve has the largest orifice among all the cardiac valves and measured an average 114 mm in circumference in males and 108 mm in females.[13] Silver *et al* have reported tricuspid valve circumference to be 114 ± 11 mm in males and 108 ± 13 mm in females. [26] In a study conducted on 96 human hearts by Skwarek M *et al*, the circumference of the tricuspid valve ranged from 107.28 ± 16.76 mm to 120.9 ± 20.95 mm in men and from 104.04 ± 16.76 mm to 110.75 ± 14.38 mm in women.[5] Motabagani in his study of 40 human tricuspid valves has found that the tricuspid valve circumference ranged from 118 to 139 mm in men and 113 to 124 mm in women.[25] In the present study it ranged from 89.34 + 7 mm to 107.5 + 10.6 mm in men and from 85.95 + 6.75 mm to 104 + 5.65 mm in women indicating that the size of the tricuspid valve among Indians is comparatively smaller than the Western data. The reports by King *et al*,[27] Sairanen and Louhimo[28] and Anwar *et al*[15] 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 Indian hearts as Indians are shorter and smaller sized when compared to the taller and heftier Western populations. In this study the tricuspid valve circumference is not correlated with body surface area.

The tricuspid valve area expressed as a triangle and as an ellipse increased with age, which corresponded to data of Skwarek *et al.*[5] In group I, both in men and women, the area of the valve expressed as a triangle was greater than the area expressed as an ellipse. With age, the area expressed as an ellipse was significantly more than the area expressed

as a triangle both in men and women. This indicates the development and evolution of the shape of the valve from a triangular shape to an ellipsoid shape with age. According to Singh and Mohan, the tricuspid valve orifice area significantly correlated to body surface area and they support the practice of indexing valve area by body surface area.[29] In this study none of the parameters were correlated with body surface area or any advanced techniques as real-time three-dimensional echocardiography, which is the limitation of this study.

CONCLUSION

Anatomical measurements, understanding the pathophysiological mechanisms and use of three-dimensional echocardiography in tricuspid valve disease assessment helps the surgeon in treating patients suffering from various tricuspid valve pathologies.[8,14,15] We hope the data regarding normal tricuspid valve presented here would serve as a baseline data for further studies in the Indian population.

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