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Original Research Article

MORPHOLOGICAL AND MORPHOMETRIC STUDY OF THE MITRAL AND TRICUSPID VALVE ANNULI: AN ANATOMICAL STUDY ON 50 HUMAN CADAVERIC HEARTS

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ABSTRACT

Background: The atrioventricular valve annuli are key supporting structures that maintain valvular competence and contribute to the dynamic function of the mitral and tricuspid valves. Their morphology and morphometry are clinically relevant for echocardiographic interpretation, surgical repair, annuloplasty, and transcatheter interventions. **Aim:** To describe the gross morphology and morphometric features of the mitral and tricuspid valve annuli in 50 human cadaveric hearts and to assess variation with age and sex. **Materials and Methods:** Fifty human cadaveric hearts (29 male, 21 female) were obtained from the Departments of Anatomy and Forensic Medicine, Gauhati Medical College and Hospital, Guwahati, Assam, India. Specimens were fixed in 10% buffered formalin and examined by standard dissection. Morphometric parameters of the mitral annulus, including total circumference, average diameter, leaflet attachment circumferences, and leaflet heights, were measured using a Vernier caliper and flexible measuring tape. Specimens were grouped into three age categories: 20–39 years, 40–59 years, and 60–80 years. Descriptive and comparative statistics were applied. **Results:** The mean total circumference of the mitral annulus was 8.12 ± 1.46 cm and the mean average annular diameter was 2.12 ± 0.58 cm. The anterior leaflet attachment circumference measured 2.91 ± 0.49 cm, while the posterior leaflet attachment circumference measured 4.36 ± 0.80 cm. Male hearts demonstrated larger annular dimensions than female hearts, and annular dimensions increased with age. The tricuspid annulus was qualitatively larger and more compliant than the mitral annulus. **Conclusion:** The atrioventricular valve annuli are dynamic anatomical structures that show significant variation with age and sex. The present morphometric data may be useful for anatomists, cardiologists, and surgeons involved in valvular disease evaluation and intervention.

INTRODUCTION

The heart is the central pump of the circulatory system and depends on coordinated chamber contraction and valve function to maintain effective blood flow. The atrioventricular valves, namely the mitral valve on the left and the tricuspid valve on the right, are critical in preventing retrograde flow during ventricular systole.[1,2]

The mitral valve separates the left atrium from the left ventricle, while the tricuspid valve separates the right atrium from the right ventricle. Each valve is supported by an annulus, which forms the structural base for leaflet attachment and contributes to valve competence.[3]These annuli are not rigid rings; rather, they are dynamic structures that change shape during the cardiac cycle to facilitate proper leaflet coaptation.[4]

The mitral valve typically has two leaflets, anterior and posterior, whereas the tricuspid valve generally has three leaflets: anterior, posterior, and septal.[5] The mitral annulus is characteristically saddle-shaped and non-planar, while the tricuspid annulus is larger and more distensible.[6]

Annular dilatation is a major mechanism in functional mitral and tricuspid regurgitation and is commonly seen in cardiomyopathy, ischemic heart disease, and heart failure.[7,8]Because of this, accurate knowledge of annular morphology is important in valve repair surgery and prosthetic ring selection.[9,10]It is also increasingly relevant in transcatheter valve interventions.[11]

Although imaging studies have provided valuable information, cadaveric studies remain important because they permit direct anatomical measurement without influence from loading conditions or imaging artefacts.[12]In addition, several studies have shown that cardiac dimensions differ across populations, sexes, and age groups.[13-16]Data from Indian populations, especially from the northeastern region, remain limited.

Therefore, the present study was undertaken to evaluate the morphology and morphometry of the mitral and tricuspid valve annuli in 50 human cadaveric hearts and to analyse age- and sex-related differences.

MATERIALS AND METHODS

Study Design

This was a descriptive cadaveric anatomical study conducted in the Department of Anatomy, Gauhati Medical College and Hospital, Guwahati, Assam, India.

Specimens

A total of 50 human cadaveric hearts were studied. Of these, 29 were from male and 21 from female individuals. The specimens were obtained from the Department of Anatomy and the Department of Forensic Medicine after completion of all legal and institutional formalities.

Age Grouping

The specimens were divided into three age groups: Group A (20–39 years), Group B (40–59 years), and Group C (60–80 years).

Inclusion Criteria

Hearts from individuals who died of non-cardiac causes or accidents, specimens without gross valvular deformity, morphologically intact hearts suitable for measurement.

Exclusion Criteria

Hearts with congenital cardiac anomalies; hearts with obvious acquired valvular disease; specimens with damage or postmortem distortion preventing accurate measurement.

Preparation and Dissection

The thoracic cavity was opened by standard dissection technique. The pericardium was incised and the heart was removed carefully, preserving the great vessels. The specimens were washed and fixed in 10% buffered formalin for at least 72 hours before examination. For mitral valve measurement, the left atrium was opened by an inverted U-shaped incision through the posterior wall. The mitral annulus was exposed and the following parameters were recorded: total annular circumference, average annular diameter, anterior leaflet attachment circumference, posterior leaflet attachment circumference, height of anterior leaflet, and height of posterior leaflet. Measurements were taken with a Vernier caliper and flexible measuring tape. Each measurement was recorded twice, and the average value was used. The tricuspid valve was assessed qualitatively for annular size, shape, and leaflet configuration, but detailed morphometric analysis was not undertaken.

Statistical Analysis

Data were entered into Microsoft Excel and analysed using SPSS version 20.0. Mean, standard deviation, and standard error of mean were calculated. Sex-based comparisons were made using Student's t-test, and age-group differences were analysed using one-way ANOVA. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Specimen Distribution

Table 1: Specimen Distribution

Age Group	Age Range (years)	Male (n)	Female (n)
Group A	20–39	6	10
Group B	40–59	17	7
Group C	60–80	6	4
Total		**29**	**21**

The study included 50 hearts: 29 male and 21 female. Most male specimens were in Group B (40–59 years), whereas the female distribution was relatively more balanced across age groups. [Table 1]

Table 2: Overall Morphometric Measurements

Parameter	Mean (cm)	S.D.	S.E.M.
Total annular circumference	8.12	1.46	0.21
Average annular diameter	2.12	0.58	0.08
Anterior leaflet attachment circumference	2.91	0.49	0.07
Posterior leaflet attachment circumference	4.36	0.80	0.11
Height of anterior leaflet	2.20	0.54	0.08
Height of posterior leaflet	1.73	0.67	0.09

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The mean total annular circumference was 8.12 ± 1.46 cm and the mean average annular diameter was 2.12 ± 0.58 cm. The anterior leaflet attachment circumference measured 2.91 ± 0.49 cm, while the posterior leaflet attachment circumference measured 4.36 ± 0.80 cm. The height of the anterior leaflet was 2.20 ± 0.54 cm and the height of the posterior leaflet was 1.73 ± 0.67 cm. The posterior leaflet attachment was consistently longer than the anterior leaflet attachment. The posterior component represented approximately 60% of the total annular circumference. [Table 2]

Table 3: Sex-wise Differences

Parameter	Male Mean (cm)	Female Mean (cm)	p-value
Total annular circumference	8.44	7.69	<0.05
Average annular diameter	2.24	1.95	<0.05
Anterior leaflet circumference	3.04	2.74	<0.05
Posterior leaflet circumference	4.55	4.10	<0.05
Height of anterior leaflet	2.31	2.06	<0.05
Height of posterior leaflet	1.82	1.60	<0.05

Male hearts showed larger values for total annular circumference, average diameter, leaflet attachment circumferences, and leaflet heights than female hearts, with statistically significant differences. [Table 3]

Table 4: Age-wise Differences

Parameter	Group A	Group B	Group C	p-value
Total annular circumference (cm)	7.84	8.24	8.38	<0.05
Average annular diameter (cm)	2.02	2.14	2.22	<0.05
Anterior leaflet circumference (cm)	2.79	2.95	3.01	NS
Posterior leaflet circumference (cm)	4.19	4.41	4.52	<0.05
Height of anterior leaflet (cm)	2.10	2.23	2.28	NS
Height of posterior leaflet (cm)	1.61	1.77	1.82	NS

A progressive increase in total annular circumference and average diameter was observed across the three age groups. Posterior leaflet attachment circumference also increased with age, while the age-related changes in leaflet heights were less pronounced.[Table 4]

DISCUSSION

The present cadaveric study demonstrates that the mitral and tricuspid valve annuli exhibit measurable variation in relation to age and sex. The mean mitral annular circumference of 8.12 cm in this study is comparable to values reported in earlier Indian cadaveric studies and broadly consistent with morphometric observations from other populations.[13-16]Although direct comparison across studies is limited by differences in methodology, fixation status, sample composition, and whether the annulus was measured in a static or dynamic state, the present findings support the concept that annular size is population dependent and should not be assumed to be uniform across ethnic groups.

The posterior leaflet attachment circumference was greater than the anterior leaflet attachment circumference, a finding that accords with established mitral valve anatomy.[3,4]This asymmetry reflects the structural design of the valve, in which the anterior leaflet is shorter but taller and contributes to the fibrous continuity between the mitral and aortic valves, whereas the posterior leaflet is longer and more scalloped. The unequal distribution of leaflet attachment length is not merely descriptive; it is central to normal coaptation and load distribution. Imaging-based studies have similarly emphasized

Tricuspid Annulus

The tricuspid annulus was observed to be larger and more compliant than the mitral annulus in all specimens. It showed the usual three-leaflet configuration in most hearts. Detailed quantitative measurements were not performed.

that the mitral annulus is saddle-shaped and non-planar, with regional variation in annular height and curvature that influences leaflet stress and valve competence.[4,6,17]

A significant sex difference was observed, with male hearts demonstrating larger annular measurements than female hearts. This aligns with prior morphometric and echocardiographic studies that report larger left-sided cardiac dimensions in males, even after accounting for body size in some cohorts.[15,16]Possible explanations include differences in overall cardiac size, body habitus, hormonal influences on connective tissue, and sex-related variation in ventricular remodeling patterns. From a clinical perspective, these differences may affect echocardiographic reference values, annuloplasty ring sizing, and transcatheter device selection. The use of a single size threshold for all adults may therefore underestimate or overestimate the required repair strategy in specific patients.

The progressive increase in annular dimensions with age may reflect cumulative tissue remodelling, alteration in collagen-elastin architecture, and age-related changes in ventricular geometry.[1,17,18]Kitzman et al. demonstrated that normal hearts undergo measurable structural changes across the adult lifespan, with an overall increase in chamber and valvular dimensions in older age groups.[1]In the present study, the increase in annular

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circumference and diameter with age is likely multifactorial. Aging is associated with reduced annular recoil, myocardial stiffening, and altered fibrous support, all of which may contribute to annular enlargement. Clinically, annular dilatation is a key mechanism in functional mitral regurgitation, particularly in elderly patients with left ventricular dysfunction or atrial enlargement.[7,8,17]The observed age-related trend therefore has direct relevance to the pathogenesis of regurgitant lesions.

The tricuspid annulus was qualitatively larger and more compliant than the mitral annulus in all specimens. This is in keeping with the known anatomy and biomechanics of the right atrioventricular valve, which is less fibrous and more distensible than the mitral annulus.[19,20] The tricuspid annulus is especially prone to dilatation in the setting of right atrial enlargement, pulmonary hypertension, left-sided valvular disease, and atrial fibrillation. Contemporary literature increasingly recognises functional tricuspid regurgitation as an important and often under-treated clinical entity.[19,20]Although the present study did not include detailed tricuspid measurements, the qualitative observations reinforce the need for future quantitative comparisons between the two annuli in cadaveric and imaging-based research.

Comparative studies using echocardiography and three-dimensional imaging have shown that annular geometry is not static but varies throughout the cardiac cycle.[4,11,16,17] Cadaveric measurements, while valuable for direct anatomical assessment, represent a fixed state and therefore may underestimate the dynamic dimension of the annulus during systole and diastole. Nevertheless, such studies remain indispensable for establishing baseline anatomical data, especially in populations where imaging reference values are scarce. The present work adds to the available Indian anatomical literature and provides data from a northeastern population, which may be useful for regional reference and future comparative studies.

The clinical implications of these findings are substantial. For mitral valve repair, annuloplasty ring selection must account not only for the size of the annulus but also its shape, regional asymmetry, and the relationship between leaflet heights and coaptation zone.[9,10,21,22] Overly rigid or undersized rings may distort annular dynamics and contribute to functional stenosis or recurrent regurgitation, whereas adequately tailored repair can restore more physiological geometry. The same principle applies to transcatheter mitral and tricuspid interventions, where precise sizing and understanding of annular non-planarity are critical to procedural success.[11,23,24]The surgical anatomy of the coronary sinus, fibrous trigones, and adjacent conduction tissue also makes the annular region highly relevant to interventional planning.[12]

This study is broadly consistent with earlier anatomical reports describing the mitral annulus as a non-circular, asymmetric structure and the tricuspid annulus as a larger, more compliant ring-like complex.[3,5,6] Differences in reported values across studies likely reflect sample size, fixation effects, dissection technique, and whether measurements were made on the in situ heart, excised specimen, or by imaging. Despite these limitations, the present data support the general principle that annular morphology varies with age and sex and that population-specific morphometry should be considered in both academic and clinical settings.

Limitations

This study had a modest sample size and was limited to hearts from a single institution. Detailed morphometric analysis of the tricuspid annulus was not performed. In addition, cadaveric measurements may not fully reflect in vivo anatomical conditions. Future multi-centre studies with larger samples, body size correction, and 3D quantitative assessment of both annuli are recommended.

CONCLUSION

The mitral and tricuspid valve annuli are dynamic anatomical structures that show significant variation with age and sex. In this cadaveric study, the mitral annulus demonstrated larger dimensions in males than females and showed progressive enlargement with age. The tricuspid annulus was qualitatively larger and more compliant than the mitral annulus.

These findings have practical relevance for anatomical education, imaging interpretation, valve repair, annuloplasty ring selection, and transcatheter intervention planning. Population-specific morphometric data such as these are essential for improving the precision of clinical and surgical management of valvular heart disease.

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