# Morphological Study of the Tricuspid Valve in Human Embalmed Hearts

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**ABSTRACT**

**Background:** The tricuspid valve, situated between the right atrium and right ventricle, is a vital component of cardiac anatomy whose morphological variability has significant implications for surgical and interventional cardiac procedures. Anatomical knowledge of its three leaflets—anterior, posterior, and septal—is indispensable for effective valve repair, prosthetic valve design, and understanding functional tricuspid regurgitation.

**Aims & Objectives:** To measure and compare the annular circumference, leaflet length, and leaflet height of the anterior, posterior, and septal leaflets of the tricuspid valve in human embalmed cadaveric hearts, and to establish normative morphometric data relevant to clinical and surgical practice.

**Materials and Methods:** A descriptive cross-sectional anatomical study was conducted at Father Muller Medical College, Mangalore, Karnataka, on 50 embalmed human cadaveric hearts. Annular circumference, valve diameter, and the length and height of each leaflet were measured using a thread-and-scale method and measuring tape. Descriptive statistics including mean, standard deviation, and range were calculated for all parameters.

**Results:** The annular circumference ranged from 8.9 to 15.3 cm (mean ± SD: 11.84 ± 1.42 cm) and valve diameter from 2.83 to 4.87 cm (mean: 3.75 ± 0.48 cm). The anterior leaflet was consistently the largest with a mean length of 4.82 ± 0.83 cm and height of 2.04 ± 0.23 cm. The septal leaflet showed intermediate dimensions, while the posterior leaflet was the smallest and most variable.

**Conclusion:** Significant morphometric variability exists in the tricuspid valve across cadaveric specimens. The anterior leaflet was the largest in all measured parameters, while the posterior leaflet demonstrated the greatest variability. These findings provide normative data of practical value for cardiac surgeons, interventional cardiologists, and biomedical engineers involved in prosthetic valve design.

**Keywords:** *Tricuspid valve, Morphometry, Cadaveric study, Leaflet dimensions, Annular circumference*

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## INTRODUCTION

The tricuspid valve is a complex, functionally vital structure of the right heart, situated at the atrioventricular junction between the right atrium and right ventricle. It consists of three leaflets—anterior, posterior, and septal—supported by a fibrous annulus, papillary muscles, and chordae tendineae. The valve plays a fundamental role in maintaining unidirectional blood flow by preventing regurgitation of blood into the right atrium during ventricular systole.1 Disorders of the tricuspid valve represent a common and increasingly recognized clinical problem, with functional tricuspid regurgitation being the most prevalent form, often occurring secondary to left-sided heart disease, pulmonary hypertension, or right ventricular dilatation.2

Surgical management of tricuspid valve disease—whether through repair or replacement—requires precise knowledge of the valve's anatomy. The growing use of transcatheter and minimally invasive interventions further underscores the need for accurate morphometric data to guide device selection, annuloplasty ring sizing, and operative planning.3 While considerable research has examined the mitral valve, the tricuspid valve has been comparatively understudied, despite its equally critical role in circulatory physiology.4 Population-specific variations in valve morphology may affect the applicability of data derived from Western or heterogeneous cohorts to Indian patients.5

Cadaver-based anatomical studies remain a cornerstone of valve morphology research, offering direct physical measurements that complement and validate imaging-based assessments by computed tomography (CT), magnetic resonance imaging (MRI), and echocardiography.6 Morphometric data on leaflet dimensions and annular circumference are essential for designing prosthetic valves that are appropriately sized for the target population and for planning reparative procedures such as annuloplasty and leaflet augmentation.7 The present study aims to systematically measure the annular circumference, leaflet lengths, and leaflet heights of the tricuspid valve in embalmed human cadaveric hearts to contribute normative Indian data for clinical and surgical applications.8

## AIMS AND OBJECTIVES

The present study aimed to evaluate the morphometric characteristics of the tricuspid valve in human embalmed cadaveric hearts, specifically to measure the annular circumference and valve diameter, to determine and compare the length and height of the anterior, posterior, and septal leaflets, to identify the degree of variability in leaflet dimensions across specimens, and to provide normative anatomical data with clinical implications for cardiac surgery, interventional cardiology, and prosthetic valve design.

## MATERIALS AND METHODS

### Study Design and Setting

A descriptive cross-sectional anatomical study was conducted in the Department of Anatomy, Father Muller Medical College, Mangalore, Karnataka, India. The study was conducted on embalmed adult human cadaveric hearts over an approved academic period following clearance from the Institutional Ethics Committee.

### Sample Size

A total of 50 embalmed human cadaveric hearts were included in the study. The sample size was determined based on available cadaveric specimens and in concordance with prior similar studies in the literature.

### Inclusion Criteria

All embalmed adult human cadaveric hearts with intact tricuspid valve anatomy were included. Hearts in which all three leaflets (anterior, posterior, and septal) were clearly identifiable and accessible for measurement were considered suitable. Only hearts with well-preserved annular and leaflet structures following routine embalming procedures were selected.

### Exclusion Criteria

Hearts with evidence of gross pathology affecting the tricuspid valve, such as calcification, vegetations, rheumatic changes, or congenital malformations, were excluded. Specimens with dissection injuries or embalming artefacts that rendered reliable measurement of leaflet dimensions impossible were also excluded. Hearts with ambiguous or incomplete three-leaflet morphology were not included.

### Dissection and Measurement Methodology

Each cadaveric heart was carefully dissected to expose the right atrioventricular (tricuspid) valve. The right atrium was opened with a standard incision to provide complete visualization of the valve apparatus. Measurements were performed using a non-elastic thread applied along the structure of interest and subsequently measured against a standard ruler, supplemented by a flexible measuring tape for annular circumference. Parameters recorded included: annular circumference (cm); valve diameter (cm); and for each leaflet (anterior, posterior, septal) — the length measured along the free edge from commissure to commissure, and the height measured perpendicularly from the annular attachment to the free edge at its widest point.

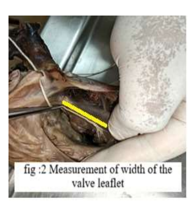

fig :2 Measurement of width of the valve leaflet

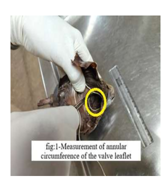

fig:1-Measurement of annular circumference of the valve leaflet

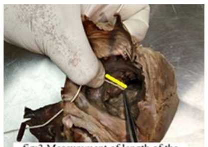

fig:3 Measurement of length of the valve leaflet

**Statistical Analysis**

Data were entered and analysed using Microsoft Excel and SPSS version 22.0. Descriptive statistics—including mean, standard deviation (SD), and range—were calculated for all measured parameters. Comparative analysis of leaflet dimensions was performed across the three leaflets to identify statistically or clinically relevant differences.

## RESULTS

A total of 50 embalmed human cadaveric hearts were studied. All three leaflets of the tricuspid valve were identified in each specimen. The following tables present a systematic account of each measured parameter with descriptive statistics and interpretation.

***Table 1: Annular Circumference and Valve Diameter of the Tricuspid Valve (n = 50)***

| Parameter | Range (cm) | Mean ± SD (cm) |
|---|---|---|
| Annular Circumference | 8.9 – 15.3 | 11.84 ± 1.42 |
| Valve Diameter | 2.83 – 4.87 | 3.75 ± 0.48 |

The tricuspid annular circumference ranged from 8.9 cm to 15.3 cm, yielding a mean of 11.84 ± 1.42 cm. The valve diameter, derived from the annular circumference, ranged from 2.83 cm to 4.87 cm (mean: 3.75 ± 0.48 cm). The relatively wide range of both parameters reflects moderate biological variability in the study population, which is consistent with expected differences in cardiac size across individuals. The annular circumference data is of direct surgical relevance as it guides annuloplasty ring sizing; specimens with larger circumferences may be at greater risk for progressive annular dilatation and functional tricuspid regurgitation.

***Table 2: Morphometric Dimensions of the Anterior Leaflet (n = 50)***

| Parameter | Minimum (cm) | Maximum (cm) | Mean ± SD (cm) |
|---|---|---|---|
| Length | 3.1 | 6.5 | 4.82 ± 0.83 |
| Height | 1.6 | 2.5 | 2.04 ± 0.23 |

The anterior leaflet was the largest among the three tricuspid leaflets in all 50 specimens. Its length ranged from 3.1 cm to 6.5 cm with a mean of 4.82 ± 0.83 cm, while its height ranged from 1.6 cm to 2.5 cm with a mean of 2.04 ± 0.23 cm. The relatively lower standard deviation in height (0.23 cm) compared to length (0.83 cm) suggests that while the leaflet's horizontal extent varies considerably, its vertical dimension is more consistent across specimens. The anterior leaflet's dominant size is clinically significant as it is the primary contributor to valve coaptation and competence, and forms the preferred target for reconstructive surgical procedures such as leaflet augmentation and bicuspidization.

***Table 3: Morphometric Dimensions of the Posterior Leaflet (n = 50)***

| Parameter | Minimum (cm) | Maximum (cm) | Mean ± SD (cm) |
|---|---|---|---|
| Length | 1.6 | 4.5 | 3.12 ± 0.71 |
| Height | 1.2 | 2.4 | 1.76 ± 0.31 |

The posterior leaflet was the smallest and most morphologically variable among the three leaflets. Its length ranged widely from 1.6 cm to 4.5 cm (mean: 3.12 ± 0.71 cm), and its height from 1.2 cm to 2.4 cm (mean: 1.76 ± 0.31 cm). The high standard deviation in length (0.71 cm) underscores the significant inter-specimen variability of this leaflet. The posterior leaflet is often the least reliable component in valve repair owing to its variability and occasional subdivision into multiple scallops. Its high dimensional variability may partly explain the inconsistency in outcomes following isolated posterior leaflet-based repair techniques, and reinforces the importance of intraoperative assessment rather than reliance on population averages alone.

***Table 4: Morphometric Dimensions of the Septal Leaflet (n = 50)***

| Parameter | Minimum (cm) | Maximum (cm) | Mean ± SD (cm) |
|---|---|---|---|
| Length | 2.6 | 5.6 | 4.02 ± |

| | | | |
|---|---|---|---|
| | | | 0.74 |
| Height | 1.1 | 2.3 | 1.68 ± 0.29 |

The septal leaflet demonstrated intermediate dimensions between the anterior and posterior leaflets. Its length ranged from 2.6 cm to 5.6 cm (mean: 4.02 ± 0.74 cm) and its height from 1.1 cm to 2.3 cm (mean: 1.68 ± 0.29 cm). While the septal leaflet's length variability (SD: 0.74 cm) was comparable to the posterior leaflet, its height variability (SD: 0.29 cm) was lower. The septal leaflet is anatomically unique in that it is directly attached to the membranous interventricular septum and the right fibrous trigone, which restricts its mobility compared to the other two leaflets. This structural constraint is reflected in the relative consistency of its height measurements and must be accounted for when planning surgical approaches involving the septal leaflet.

***0Table 5: Comparative Analysis of Leaflet Length Across All Three Leaflets (n = 50)***

| **Leaflet** | **Range (cm)** | **Mean ± SD (cm)** | **Rank (Largest → Smallest)** |
|---|---|---|---|
| Anterior | 3.1 – 6.5 | 4.82 ± 0.83 | 1st |
| Septal | 2.6 – 5.6 | 4.02 ± 0.74 | 2nd |
| Posterior | 1.6 – 4.5 | 3.12 ± 0.71 | 3rd |

A comparative analysis of leaflet lengths reveals a clear hierarchical order: the anterior leaflet (mean: 4.82 ± 0.83 cm) was the longest, followed by the septal leaflet (mean: 4.02 ± 0.74 cm), and then the posterior leaflet (mean: 3.12 ± 0.71 cm). This ranking was consistent across all 50 specimens. The anterior leaflet's superior length contributes to its dominant role in covering the atrioventricular orifice and ensuring effective coaptation. The difference in mean lengths between the anterior and posterior leaflets (approximately 1.7 cm) is surgically meaningful, as it determines how different repair strategies—such as quadrangular resection of the posterior leaflet or anterior leaflet augmentation—should be tailored to the individual patient's valve anatomy.

***Table 6: Comparative Analysis of Leaflet Height Across All Three Leaflets (n = 50)***

| **Leaflet** | **Range (cm)** | **Mean ± SD (cm)** | **Rank (Tallest → Shortest)** |
|---|---|---|---|
| Anterior | 1.6 – 2.5 | 2.04 ± 0.23 | 1st |
| Posterior | 1.2 – 2.4 | 1.76 ± 0.31 | 2nd |
| Septal | 1.1 – 2.3 | 1.68 ± 0.29 | 3rd |

In terms of leaflet height, the anterior leaflet was again the tallest (mean: 2.04 ± 0.23 cm), followed by the posterior leaflet (mean: 1.76 ± 0.31 cm), and the septal leaflet (mean: 1.68 ± 0.29 cm). Notably, the ranking of the posterior and septal leaflets differs between length and height comparisons: while the septal leaflet is longer than the posterior leaflet, it is shorter in height. This dissociation is explained by the constrained annular attachment of the septal leaflet along the septum, which restricts its vertical excursion despite its relatively extensive horizontal span. The anterior leaflet's lowest height variability (SD: 0.23 cm) among all three leaflets indicates greater morphological consistency in this dimension, which may be attributed to its structural role as the primary coaptation surface.

***Table 7: Consolidated Summary of All Morphometric Parameters of the Tricuspid Valve (n = 50)***

| **Parameter** | **Anterior Length** | **Anterior Height** | **Posterior Length** | **Posterior Height** | **Septal Length / Height** |
|---|---|---|---|---|---|
| Range (cm) | 3.1–6.5 | 1.6–2.5 | 1.6–4.5 | 1.2–2.4 | 2.6–5.6 / 1.1–2.3 |
| Mean ± SD (cm) | 4.82 ±0.83 | 2.04 ±0.23 | 3.12 ±0.71 | 1.76 ±0.31 | 4.02 ±0.74 / 1.68 ±0.29 |
| Annular Circumference | 8.9–15.3 cm (Mean: 11.84 ± | | | | |

| | |
|---|---|
| | 1.42 cm) |
| Valve Diameter | 2.83–4.87 cm (Mean: 3.75 ± 0.48 cm) |

Table 7 consolidates all measured morphometric parameters into a single reference summary, enabling a holistic view of the tricuspid valve's anatomical profile in the studied population. The anterior leaflet is consistently the largest in all dimensions, while the posterior leaflet shows the greatest length variability. The annular circumference (mean: 11.84 ± 1.42 cm) and valve diameter (mean: 3.75 ± 0.48 cm) reflect the expected range for adult human hearts. Taken together, these measurements establish a normative morphometric dataset for the Indian cadaveric population that can inform prosthetic valve sizing, annuloplasty ring selection, and the planning of transcatheter tricuspid valve interventions. The inter-leaflet differences highlighted in this summary underscore the need for individualized assessment in clinical and surgical settings, rather than reliance on universal morphometric assumptions.

## DISCUSSION

The hierarchical size ordering of the tricuspid leaflets observed in this study — anterior largest, followed by septal and then posterior — is in agreement with the classical cadaveric description by Silver et al.,7 who first systematically documented this arrangement and reported a mean anterior leaflet length of approximately 4.6 cm, a value slightly lower than ours, possibly attributable to differences in population anthropometry or measurement technique. Ranganathan et al.8 similarly described the anterior leaflet as the dominant leaflet in all specimens examined, consistent with our observations. The anterior leaflet's superior dimensions reflect its principal role in atrioventricular coaptation, and this anatomical fact underpins surgical repair strategies such as bicuspidization, in which the anterior leaflet alone is relied upon to maintain valvular competence after exclusion of the posterior leaflet.9

Our mean annular circumference is slightly higher than the 11.4 cm reported by Westaby et al.4 in a Western cadaveric cohort, suggesting mild population-level differences in cardiac dimensions, or that embalming may marginally alter tissue hydration. However, our calculated mean valve diameter closely approximates the mean tricuspid annular diameter of approximately 3.8 cm reported by Alkadhi et al.6 using multi-detector CT in living subjects — a concordance that validates the use of embalmed cadaveric specimens as a reliable morphometric surrogate for in vivo anatomy. This agreement across methodologically distinct studies lends confidence to the clinical applicability of our measurements.

The posterior leaflet demonstrated the greatest dimensional variability among all three leaflets, with a length standard deviation considerably wider than that seen for anterior leaflet height. Silver et al.7 similarly noted that the posterior leaflet was the most morphologically inconsistent, frequently presenting as multiple scallops rather than a single continuous structure. This structural heterogeneity is clinically relevant: Dreyfus et al.11 demonstrated that functional tricuspid regurgitation may develop at annular diameters as modest as 40 mm in patients with coexisting left-sided disease, and that the posterior annular segment dilates disproportionately. The variability we observed in posterior leaflet dimensions may partly explain why different patients reach regurgitation thresholds at different degrees of annular dilatation, reinforcing the need for individualized preoperative imaging rather than reliance on population-mean assumptions.

The septal leaflet in our series was longer than the posterior leaflet but shorter in height — a dissociation not always highlighted in prior literature. Ho and Nihoyannopoulos9 attributed the septal leaflet's restricted vertical mobility to its firm attachment along the membranous interventricular septum and the right fibrous trigone, in contrast to the freely mobile anterior and posterior leaflets. This architectural constraint is reflected in the relatively low height standard deviation of the septal leaflet compared to its length variability in our study. Surgically, this is important: the septal leaflet cannot be easily detached and repositioned, and device deployments crossing the tricuspid plane — including pacemaker leads and transcatheter valve systems — must account for the risk of septal leaflet impingement or tethering.

Regarding annuloplasty ring sizing, Filsoufi et al.5 reported that inadequate ring sizing is a key predictor of recurrent tricuspid regurgitation following repair, with undersized rings causing functional stenosis and oversized rings permitting residual regurgitation. The wide annular circumference range observed in the present study — spanning nearly 6.4 cm from minimum to maximum — highlights why a single universal ring size is inadequate for the Indian population, and suggests that a broad range of ring sizes would be required to accommodate the full morphometric spectrum encountered. Victor and Nayak10 similarly emphasized population-specific valve sizing in their Indian cadaveric series on mitral valve morphology. As transcatheter tricuspid valve replacement devices enter clinical practice, the normative morphometric data from the present study provides a foundational reference for device sizing and patient selection in this population.12

## CONCLUSION

This cadaveric morphometric study of the tricuspid valve in 50 embalmed human hearts demonstrates significant anatomical variability in annular circumference and leaflet dimensions. The anterior leaflet was consistently the largest and most dominant leaflet in all specimens, with a mean length of 4.82 cm and height of 2.04 cm, while the posterior leaflet showed the greatest dimensional variability, ranging in length from 1.6 to 4.5 cm. The annular circumference ranged from 8.9 to 15.3 cm, underscoring the need for population-specific normative data. These findings carry practical significance for cardiac surgeons undertaking tricuspid valve repair or replacement, for interventional cardiologists sizing transcatheter devices, and for biomedical engineers designing annuloplasty rings and bioprosthetic valves suited to the Indian population. Future studies should correlate cadaveric measurements with echocardiographic and CT data in living subjects, include demographic variables such as age, sex, and body surface area, and examine functional parameters to enrich the translational applicability of morphometric research.

## LIMITATIONS

The study was conducted exclusively on embalmed cadaveric hearts, which may introduce dimensional changes secondary to the fixation process. The sample did not include demographic variables such as age, sex, height, or body surface area, limiting subgroup analysis. Functional correlation with echocardiography or imaging was not performed, and the study was confined to a single institution, which may limit generalizability.

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