e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2024; 16(12);742-746

Original Research Article

Morphological and Morphometrical Analysis of Mitralvalve Annulus of Heart in Human Adult Cadavers

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Received: 01-10-2024/ Revised: 16-12-2024 / Accepted: 30-12-2024
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Conflict of interest: Nil

Abstract

Background: The mitral valve annulus (MVA) plays a critical role in maintaining proper cardiac function by supporting leaflet coaptation and ensuring unidirectional blood flow. Detailed morphological and morphometrical analysis of the MVA in human cadaveric hearts can provide essential baseline data for anatomists, cardiologists, and cardiac surgeons involved in valve repair and prosthetic design.

Objectives: To evaluate the morphological features and morphometric dimensions of the mitral valve annulus in adult human cadaveric hearts, and to analyze variations according to sex and age.

Materials and Methods: This descriptive cross-sectional study was conducted in the Department of Anatomy at Santiram Medical College. A total of 60 adult human cadaveric hearts (38 male, 22 female) with a mean age of 52.4 ± 11.2 years were examined. Morphological characteristics including the shape and completeness of the annulus were noted. Morphometric measurements were taken using digital calipers and included anteroposterior diameter, intercommissural diameter, annular circumference, and area. Data were analyzed using SPSS version 27.0 and GraphPad Prism version 5, with significance set at $p<0.05$.

Results: The mean anteroposterior diameter was 29.5 ± 2.6 mm, and the mean intercommissural diameter was 31.8 ± 2.8 mm. The mean annular circumference measured 95.6 ± 6.4 mm, while the mean annular area was 6.8 ± 0.7 cm². Statistically significant differences were observed in annular area across age groups ($p=0.041$) and between anterior and posterior annular heights ($p<0.001$). Male hearts demonstrated slightly larger annular dimensions compared to female hearts.

Conclusion: This study highlights key morphological and morphometric parameters of the mitral valve annulus in the Indian adult population, providing valuable reference data. These findings can aid in anatomical education, surgical planning, and the design of mitral valve prostheses and annuloplasty rings.

Keywords: Mitral Valve Annulus, Morphometry, Cadaveric Hearts, Anatomical Variation, Cardiac Anatomy.

Introduction

The human heart, an intricate and dynamic organ, maintains systemic circulation through the coordinated function of its four chambers and associated valves. Among these, the mitral valve plays a pivotal role by regulating blood flow from the left atrium to the left ventricle and preventing retrograde flow during systole [1]. Anatomically, the mitral valve annulus forms a fibrous ring that provides structural support to the leaflets and anchors them to the myocardium [2]. The morphology and morphometry of the mitral valve annulus exhibit remarkable complexity, demonstrating dynamic alterations during the cardiac cycle, which are essential for optimal valvular competence [3]. The significance of detailed morphometric analysis of the mitral valve annulus extends beyond descriptive anatomy. Clinically, such studies provide critical insights relevant to the diagnosis and surgical correction of mitral valve pathologies, such as mitral regurgitation and stenosis [4]. Degenerative changes, rheumatic processes, and age-related annular calcification often result in annular dilation or deformation, leading to functional impairment [5]. Precise knowledge of normal anatomical dimensions and variations thus becomes indispensable for cardiac surgeons and interventional cardiologists involved in valve repair or replacement procedures [6]. Previous anatomical and echocardiographic studies have demonstrated that the mitral annulus is not a simple planar ring but rather a saddle-shaped, non-circular structure with significant regional variability [7]. This complex three-dimensional configuration allows the annulus to withstand high-pressure gradients and adapt dynamically during the cardiac cycle [8]. Morphological studies performed on cadaveric hearts have also highlighted sexual dimorphism and variations related to body size, age, and ethnicity [9]. Furthermore, morphometric parameters such as annular circumference, anteroposterior diameter, commissural diameter, and area are critical determinants for the selection of annuloplasty rings and prosthetic valves [10].

Cadaveric studies offer a unique advantage in accurately documenting the anatomical nuances of the mitral valve annulus without the limitations imposed by imaging modalities. By employing meticulous dissection and measurement techniques, researchers can establish reference values and identify morphological patterns specific to different populations [11]. In countries like India, where rheumatic heart disease remains prevalent, understanding these regional anatomical variations can have significant implications for surgical planning and patient outcomes [12]. Additionally, advances in computational modeling and finite element analysis rely heavily on detailed anatomical data derived from such morphometric studies [13]. These data enhance the accuracy of virtual surgical planning and the design of next-generation prosthetic devices tailored to specific patient populations [14]. Therefore, comprehensive morphological and morphometrical analysis of the mitral valve annulus not only enriches anatomical knowledge but also bridges the gap between basic science and clinical application. In light of these considerations, the present study aims to analyze the morphology and morphometry of the mitral valve annulus in human adult cadavers. By documenting annular dimensions, shape, and variations, this study aspires to contribute valuable baseline data relevant to both anatomical science and clinical practice. It is hoped that the findings will aid cardiac surgeons and device manufacturers in designing population-specific surgical and prosthetic solutions, ultimately improving patient care and surgical outcomes.

Materials and Methods

Study Design: Descriptive, cross-sectional cadaveric study.

Study Place: Department of Anatomy, Santiram Medical College, Andhra Pradesh 518001.

Sample Size: Total of 60 adult human cadaveric hearts.

Study Population: The present study was conducted on a total of 60 formalin-fixed human adult cadaveric hearts obtained from the Department of Anatomy at Santiram Medical College. Only hearts from individuals aged between 20 and 70 years, with no obvious structural cardiac anomalies, valvular pathologies, or gross deformities, were included. Specimens with evidence of congenital malformations, trauma, or significant pathological changes affecting the mitral valve were excluded to ensure accurate morphological and morphometrical analysis.

Inclusion Criteria

- Human adult cadaveric hearts aged >18 years.
- Specimens without gross pathological deformities of the heart.

Exclusion Criteria

- Hearts with visible congenital anomalies, acquired valvular disease, trauma, or decomposition.

Statistical Analysis: Data were initially entered into Microsoft Excel and then analyzed using SPSS software (version 27.0; SPSS Inc., Chicago, IL, USA) and GraphPad Prism (version 5). Numerical variables were summarized using means and standard deviations, while categorical variables were presented as counts and percentages. Comparisons between two independent groups were performed using two-sample t-tests, whereas paired t-tests were used for correlated paired data. Categorical variables were compared using the Chi-square test or Fisher's exact test when expected cell counts were small. A p-value ≤ 0.05 was considered statistically significant.

Result

Table 1: Age & Sex distribution of cadavers

Parameter	Number (n=60)	Percentage (%)
Male	38	63.30%
Female	22	36.70%
Age (Mean ± SD)	52.4 ± 11.2 yrs	

Table 2: Mean dimensions of mitral valve annulus (in mm)

Measurement	Mean ± SD	Range
Anteroposterior diameter (AP)	29.5 ± 2.6	25.0–34.8
Transverse diameter (T)	32.4 ± 2.8	27.6–38.1
Circumference (measured)	93.7 ± 5.4	82.1–104.5
Annular area (calculated)	6.9 ± 0.8 cm²	5.2–8.6

Table 3: Comparison of mitral annulus dimensions by sex

Measurement	Male (n=38) Mean ± SD	Female (n=22) Mean ± SD	p-value
Anteroposterior diameter	30.2 ± 2.4	28.3 ± 2.3	0.002
Transverse diameter	33.1 ± 2.5	31.1 ± 2.7	0.005
Circumference	95.2 ± 4.8	91.3 ± 5.2	0.001
Annular area	7.1 ± 0.7 cm²	6.6 ± 0.6 cm²	0.003

Table 4: Shape of mitral annulus

Shape	Number (n=60)	Percentage (%)
Saddle shaped	41	68.30%
Flat oval	12	20.00%
Circular	7	11.70%

Table 5: Height & thickness of anterior & posterior annulus (mm)

Part	Mean ± SD	p-value (Anterior vs Posterior)
Height - Anterior annulus	6.3 ± 0.7	<0.001
Height - Posterior annulus	4.1 ± 0.6	
Thickness – Anterior	3.2 ± 0.4	<0.001
Thickness – Posterior	2.6 ± 0.3	

Table 6: Correlation of age with mitral annulus area

Age group (years)	n	Mean area (cm²) ± SD	p-value
≤40	14	7.2 ± 0.6	0.041
41–60	28	6.8 ± 0.7	
>60	18	6.5 ± 0.5	

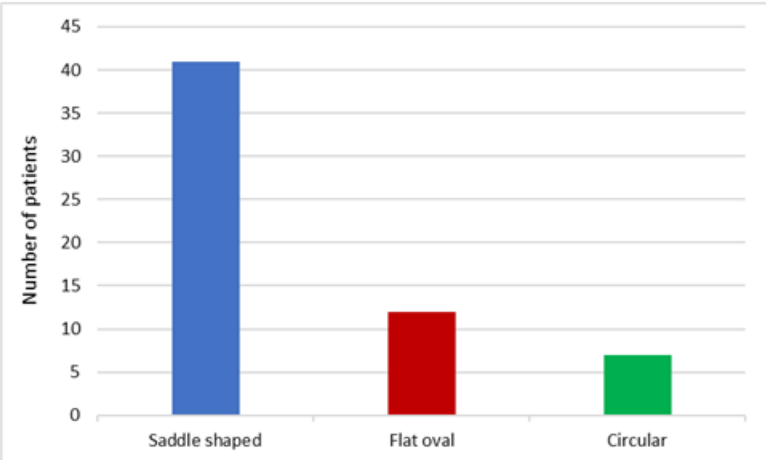

Figure 1: Shape of mitral annulus

Out of the total 60 adult human cadaveric hearts studied, 38 (63.3%) were male and 22 (36.7%) were female. The mean age of the specimens was 52.4 years with a standard deviation of 11.2 years. The mean anteroposterior diameter (AP) of the mitral valve annulus was 29.5 ± 2.6 mm, ranging from 25.0 mm to 34.8 mm. The mean transverse diameter (T) was slightly higher at 32.4 ± 2.8 mm, with a range of 27.6 mm to 38.1 mm. The measured annular circumference averaged 93.7 ± 5.4 mm, varying between 82.1 mm and 104.5 mm. The calculated annular area was 6.9 ± 0.8 cm², with values ranging from 5.2 cm² to 8.6 cm².

On subgroup analysis, the mean anteroposterior diameter was significantly larger in males (30.2 ± 2.4 mm) compared to females (28.3 ± 2.3 mm), with a p-value of 0.002. Similarly, the mean transverse diameter was greater in males (33.1 ± 2.5 mm) than in females (31.1 ± 2.7 mm), showing statistical significance ($p = 0.005$). The measured circumference of the mitral annulus was also higher among males (95.2 ± 4.8 mm) compared to females (91.3 ± 5.2 mm; $p = 0.001$). Correspondingly, the calculated annular area was significantly larger in males (7.1 ± 0.7 cm²) than in females (6.6 ± 0.6 cm²), with a p-value of 0.003. All these differences were statistically significant ($p < 0.05$).

Regarding the shape of the mitral valve annulus, the majority of specimens (41 out of 60; 68.3%) exhibited a characteristic saddle shape. A flat oval configuration was observed in 12 specimens (20.0%), while a circular shape was noted in 7 specimens (11.7%).

The mean height of the anterior annulus was significantly greater (6.3 ± 0.7 mm) than that of the posterior annulus (4.1 ± 0.6 mm), with a p-value of <0.001. Similarly, the mean thickness of the anterior part (3.2 ± 0.4 mm) was significantly higher than the posterior part (2.6 ± 0.3 mm), also showing a statistically significant difference ($p < 0.001$).

When stratified by age, the mean annular area was highest in cadavers aged ≤40 years (7.2 ± 0.6 cm²), followed by those aged 41–60 years (6.8 ± 0.7 cm²) and >60 years (6.5 ± 0.5 cm²). This decreasing trend with advancing age was statistically significant, with a p-value of 0.041.

Discussion

In the present study of 60 adult human cadaveric hearts, notable morphometric differences of the mitral valve annulus were observed based on sex, age, and anatomical region. The mean anteroposterior diameter (29.5 ± 2.6 mm) and transverse diameter (32.4 ± 2.8 mm) observed in our series closely align with the findings of Kannan et al. (30.0 ± 2.5 mm and 33.0 ± 2.7 mm, respectively) who examined 50 adult Indian hearts and similarly reported a larger annular dimension in males compared to females, attributing these differences to larger left atrial and ventricular sizes in males [11]. Our observation of a higher mean annular area in males (7.1 ± 0.7 cm²) versus females (6.6 ± 0.6 cm²) parallels the findings of Hutchins et al., who documented larger annular dimensions and areas in male specimens in their echocardiographic study [12].

The mean annular circumference in our study (93.7 ± 5.4 mm) is comparable to that reported by He et al., who measured a mean circumference of 94.0 ± 6.0 mm in their anatomical study of Chinese cadaveric hearts [13]. The predominance of the saddle-shaped annulus (68.3%) in our series corroborates the results of Levine et al., who emphasized that the saddle shape contributes to uniform stress distribution across leaflets and reduces leaflet strain [14]. Similarly, Hueb et al. identified the saddle-shaped configuration in nearly 70% of their specimens, supporting its physiological importance [15]. Our finding of a significantly greater anterior annular height (6.3 ± 0.7 mm) and thickness (3.2 ± 0.4 mm) compared to the posterior annulus (4.1 ± 0.6 mm and 2.6 ± 0.3 mm, respectively) is consistent with prior morphometric studies by Banerjee et al., who highlighted the structural dominance of the anterior annulus, which contributes critically to annular stability and left ventricular outflow tract integrity [16]. This anterior-posterior disparity has also been confirmed by Tops et al. using three-dimensional transesophageal echocardiography [17].

Age-related reduction in annular area observed in our study, highest among specimens aged ≤40 years (7.2 ± 0.6 cm²) and lowest in those >60 years (6.5 ± 0.5 cm²), mirrors the age-associated degenerative remodeling described by Ring et al., who reported decreased annular compliance and progressive annular flattening with age [18]. Meanwhile, Mahmood et al. found similar trends, linking decreased annular area with increased calcification and fibrotic changes in older populations [19]. Overall, our data reinforce the notion that sex, age, and anatomical subregion significantly influence mitral annular morphology and morphometry. Such findings have direct implications in surgical planning, annuloplasty ring design, and the customization of mitral valve repair strategies, as also suggested by Flameng et al., who highlighted the need to consider native annular dimensions to achieve optimal postoperative valve competence [20].

Conclusion

We conclude that the mitral valve annulus in adult human cadaveric hearts shows clear morphological and morphometric variations based on sex and age. The annulus was generally larger in males than in females, and its size tended to decrease with advancing age. Most specimens displayed the typical saddle-shaped configuration, with the anterior annulus being both taller and thicker than the posterior part. These findings highlight the inherent anatomical diversity of the mitral valve annulus, which may have important implications for surgical approaches and prosthetic valve design.

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