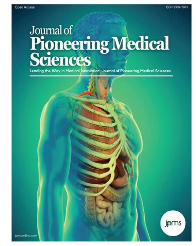

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Age Related Variations in Mitral Valve Annulus-Implications for Mitral Valve Surgery

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Abstract **Introduction:** A valve known as the mitral valve, bicuspid valve, or left atrioventricular valve guards the mitral orifice. It is the entrance connecting the left atrium and left ventricle. Its purpose is to guarantee unidirectional blood flow and prevent regurgitation. **Methods:** This study utilized 100 fresh cadaveric human hearts procured from the Forensic Department of Rajarajeshwari Medical College and Hospital, Bengaluru, Karnataka, India, Measurements were performed using digital Vernier calipers, dissection forceps (pointed, toothed and blunt), scalpel, scissors and string to outline the mitral annulus. The inclusion and exclusion criteria included hearts from individuals aged 20-60 years; those from individuals below 20 years or above 60 years were excluded. **Results:** The cadaveric study on 100 Indian hearts (20–60 years) established normative mitral annulus dimensions using the Anterior–Posterior Length (APL), Inter-Commissural Length (ICL) and Mitral Annular Circumference (MAC) measurements. A significant age-related increase was observed in APL ($p = 0.034$), while ICL ($p = 0.142$) and MAC ($p = 0.678$) showed no significant variation. **Conclusion:** Age-related alterations in the mitral valve annulus, particularly annular dilation, may contribute to functional changes such as regurgitation or stenosis, potentially increasing the complexity of surgical management in older adults.

Key Words Mitral Valve Annulus, Mitral Valve Surgery, Human, Age

INTRODUCTION

A valve known as the mitral valve, bicuspid valve, or left atrioventricular valve guards the mitral orifice. It is the entrance connecting the left atrium and left ventricle. Its purpose is to guarantee unidirectional blood flow and prevent regurgitation. The anterior and posterior leaflets of the mitral valve, as well as an annulus, contribute to this intricate structure. The mitral annulus is where the atrium and ventricle's muscular fibers are joined by two cusps. The orifice's anterior cusps protect one-third of its circumference, while the posterior cusps protect the remaining two-thirds. The papillary muscles' chordae tendineae attach to the mitral valve's two leaflets [1].

The second most prevalent clinically relevant type of valvular abnormality in adults is a disease of the Mitral Valve (MV). Specifically, MV regurgitation is becoming more common as a result of degenerative age processes. Degenerative MV illness is thought to affect 2% to 3% of people in developed countries each year [1,2]. Along with degenerative changes, other factors that contribute to clinically severe MV regurgitation include rheumatic illness, which is more common in less developed nations, cardiac ischemia and infective endocarditis.

In pediatric patients, mitral valve disease can vary greatly, ranging from a simple split in the anterior leaflet of the mitral valve to severe mitral stenosis linked to hypoplastic left heart syndrome or Shone's complex. The accompanying concurrent heart abnormalities, which can significantly impact clinical outcomes, further complicate the healthcare of these children. In addition to being associated with considerable morbidity in both the pediatric and adult populations, Mitral Valve Replacements (MVR) are often not recommended, particularly in developing nations, due to the high post-operative, lifetime therapy costs [3,4,5].

As a result, during the past ten years, children's mitral valve reconstruction has received a lot of attention [6,7]. Reconstructive procedures for the mitral valve are becoming more and more popular. By comparing the morphometric parameters of the mitral valve complex in both the adult and young patient populations, surgeons can establish more accurate surgical guidelines for each age group.

Aim of the Study

The study aims to provide age-related morphometric data for the mitral annulus.

METHODS

This study utilized 100 fresh cadaveric human hearts procured from the Forensic Department of Rajarajeshwari Medical College and Hospital, Bengaluru, Karnataka, India, Measurements were performed using digital Vernier calipers, dissection forceps (pointed, toothed and blunt), scalpel, scissors and string to outline the mitral annulus. Ethical clearance was obtained from the Institutional Ethics Committee of Rajarajeshwari Medical College and Hospital, Bengaluru (RRMCH-IEC/175/2019-20), prior to the conduct of study. The inclusion and exclusion criteria included hearts from individuals aged 20-60 years; those from individuals below 20 years or above 60 years were excluded.

All hearts underwent standardized dissection. The coronary sinus in the left atrioventricular groove was isolated from the left circumflex artery by careful removal of surrounding epicardial fat, followed by assessment of coronary artery dominance patterns. A left atriotomy was performed via a midline longitudinal incision along the posterior atrial wall, extending from between the pulmonary veins to the mitral annulus, with perpendicular incisions at the lower end to create two atrial flaps and fully expose the mitral valve leaflets and annulus. Three key mitral annulus dimensions were measured post-atriotomy: circumference (traced with string and measured), anterior-posterior length (from A2 leaflet midline to P2 leaflet midline) and inter-commissural length (from anterior to posterior commissure).

Data for anterior-posterior length, inter-commissural length and annulus circumference are expressed as mean ± Standard Error of the Mean (SEM). Age-related differences were analyzed using one-way Analysis of Variance (ANOVA), with statistical significance set at $p \leq 0.05$. Analyses and graph plotting were conducted using SigmaPlot version 14.5 (Systat Software Inc., San Jose, USA).

RESULTS

The study presents cadaveric measurements of the mitral valve orifice (annulus) from 100 autopsied hearts, focusing on age-related variations in key dimensions. These findings offer insights into normal anatomical growth patterns, with implications for cardiac surgery, prosthetic valve sizing and understanding age-dependent changes in valve function.

The cohort included 100 hearts from individuals aged 20-60 years, from 57 males (57%) and 43 females (43%). Participants were stratified into three age groups: 20-30 years (n = 27), 31-50 years (n = 51, the largest group) and 51-60 years (n = 22). This stratification allows analysis of progressive changes across young adulthood to middle age.

APL measures the front-to-back diameter of the mitral orifice, a critical dimension for valve closure and prosthetic annuloplasty ring selection. Mean values increased steadily with age: 16.574 mm (20-30 years), 17.042 mm (31-50 years) and 17.201 mm (51-60 years), as shown in Table 1 and Figure 1. This ~4% rise from youngest to oldest group suggests gradual annular remodelling or dilation with aging, consistent with known age-related cardiac changes like mild fibrosis or chamber enlargement.

ICL represents the distance between the anterior and posterior commissures (leaflet attachment points), reflecting the valve's transverse span and influencing leaflet coaptation. Means progressed as follows: 37.094 mm (20-30 years), 38.263 mm (31-50 years) and 38.575 mm (51-60 years), as per Table 2 and Figure 2. The ~4% age-related increase aligns with annular expansion, potentially affecting systolic function or predisposing to regurgitation in pathological states.

Table 1: Antero-Posterior Length (APL) of the Mitral Orifice

Age (years)	Mean length (mm)	SE	Statistics
20-30	16.574	0.160	F = 3.498 P = 0.034
31-50	17.042	0.137	
51-60	17.201	0.161	

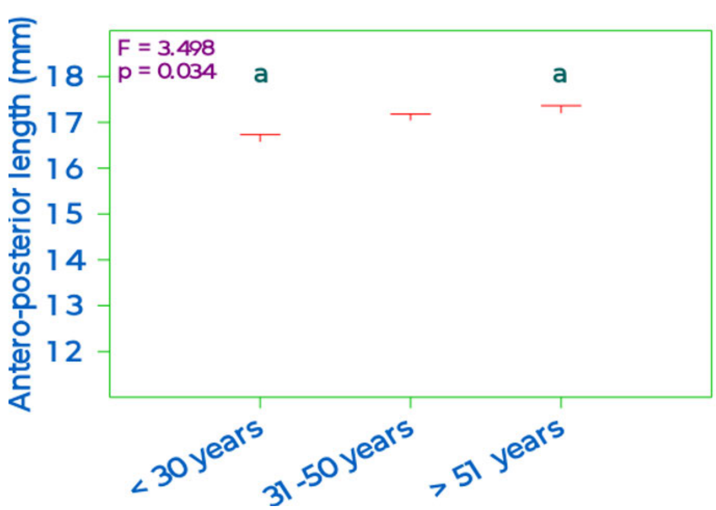

Figure 1: Comparison of Antero-Posterior Length with Age

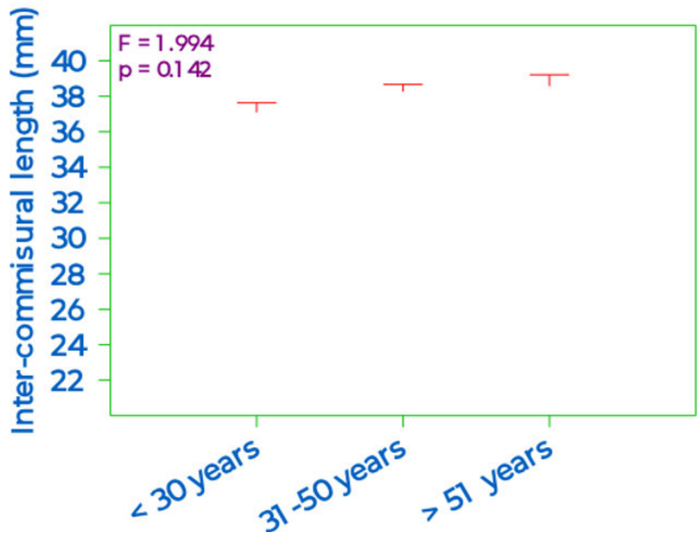

Figure 2: Comparison of Inter-Commissural Length with Age

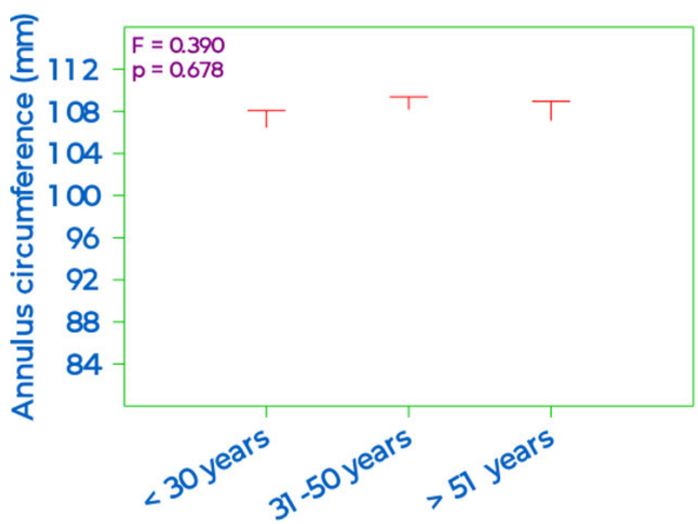

Figure 3: Comparison of Annulus Circumference with Age

Table 2: Inter-Commissural Length (ICL) of the Mitral Orifice

Age (years)	Mean length (mm)	SE	Statistics
20-30	37.094	0.536	F = 1.994 P = 0.142
31-50	38.263	0.402	
51-60	38.575	0.637	

Table 3: Annular Circumference (MAC) of the Mitral Orifice

Age (years)	Mean circumference (mm)	SE	Statistics
20-30	106.462	1.618	F = 0.390 P = 0.678
31-50	108.186	1.189	
51-60	107.118	1.839	

MAC quantifies the full perimeter of the mitral annulus, essential for sizing repairs or replacements. Values were 106.462 mm (20-30 years), 108.186 mm (31-50 years) and 107.118 mm (51-60 years), detailed in Table 3 and Figure 3. Unlike APL and ICL peaks in midlife before slightly declining, possibly due to age-related stiffening or measurement variability; this non-linear pattern warrants further statistical review (e.g., ANOVA for group differences).

Table 4: Comparison of Cardiac Measurements for Age

Parameter	Age (years)	Mean	SE	Statistics
Antero-posterior Length (mm)	20-30	16.574	0.160	F = 3.498 P = 0.034
	31-50	17.042	0.137	
	51-60	17.201	0.161	
Inter-commissural Length (mm)	20-30	37.094	0.536	F = 1.994 P = 0.142
	31-50	38.263	0.402	
	51-60	38.575	0.637	
Annulus Circumference (mm)	20-30	106.462	1.618	F = 0.390 P = 0.678
	31-50	108.186	1.189	
	51-60	107.118	1.839	

The analysis by using ANOVA revealed APL's significance while ICL/MAC trends remained non-significant. Overall, dimensions enlarged modestly (APL/ICL) or stabilized (MAC) with age, larger than typical echocardiographic norms (~90-100 mm MAC) due to post-mortem changes (Table 4)

These dimensions establish normative data for adults up to 60 years, showing modest age progression (APL/ICL) amid overall stability. Surgeons use such metrics to match annuloplasty rings (e.g., avoiding oversizing that risks outflow obstruction). Values are slightly larger than some echocardiographic norms (e.g., ~90-100 mm MAC in living adults), likely due to postmortem changes. Limitations include lack of body size adjustment (e.g., BSA indexing) and unspecified cause of death.

DISCUSSION

This cadaveric study on 100 fresh Indian hearts between 20-60 years, provides essential normative data for mitral annulus dimensions on APL, ICL and MAC. This demonstrates a significant age-related APL enlargement ($p = 0.034$) amid non-significant ICL ($p = 0.142$) and MAC ($p = 0.678$) trends which is crucial for tailoring annuloplasty rings. (e.g., 28-32 mm midlife) This helps to prevent patient-prosthesis mismatch in mitral repair. Studies conducted by Khedekar *et al.* [8] showed Postmortem measurements systematically exceed in vivo norms, such as 3D echocardiographic MAC of 92.6±5.2 mm or CT-derived intercommissural diameters. This is primarily due to absent systolic contraction and tissue relaxation, with autopsy hearts showing ~10-15% larger perimeters than imaged valves. These results were also similar to the study conducted by Krawczyk-Ożóg *et al.* [9] The progressive APL/ICL widening (~4%) mirrors ventricular remodelling and saddle-shape maintenance (annular height:ICL ratio ~20-25%), akin to 3D transthoracic findings in healthy adults where dimensions scale modestly with age up to 50s in the study conducted by Nemes *et al.* [10]

Similarities emerge with recent Indian cadaveric studies. A 2025 study analysis by Rajendran *et al.* [11] a study published from Mumbai among 40 formalin-fixed hearts reported comparable MAC with 92.6±5.2 mm overall. They emphasized sex dimorphism, males being larger and supporting prosthetic sizing for South Asian populations prone to under sizing with Western norms. Another Indian study in 2024 by Kumari *et al.* [12] with mean age 52 years found AP diameter 29.5±2.6 mm, transverse likely higher, akin to ICL. They also noted male predominance in dimensions, reinforcing our midlife peaks for surgical relevance. Iranian study by Mohtaj *et al.* [13] conducted cadaveric study among 88 cadavers, showed similarly age-peaking A2-P1 response (~30-42y) before decline, with larger male annuli, though normalized to BSA they proved age-independent contrasting raw early midlife growth, likely from unindexed Indian body habitus (smaller BSA) amplifying apparent changes.

Contrasts highlight methodological variances by Jayaprakash *et al.* [14] showed results unlike our fresh-heart stability in MAC (peaking 31-50y), a 2024 embalmed Indian series among n = 60 observed annular area decrease post 40y ($p = 0.041$). It attributed to fixation shrinkage (~5-10%) versus our fresh specimens' fidelity. Western autopsy-CT comparisons among n = 51+120) revealed autopsy ICL/perimeter larger ($p<0.0001$) but proportional ratios intact, validating our trends yet underscoring ethnic gaps. The Indian annuli was ~10-20% smaller than Caucasian standards, risking LVOT obstruction with oversized rings. Aging shows calcification-driven stiffening >60y (4.7% annual incidence >75y), explaining 51-60y MAC dip, absent in younger cohorts in the study conducted by Opris *et al.* [15].

Clinically, these metrics optimize repairs in degenerative/rheumatic cases (prevalent in India), favouring rings matching midlife ICL (~38 mm) to cut recurrence <5%; e.g., avoiding >30 mm in young adults. Ethnic tailoring prevents mismatches noted in Indian MVR (higher PPM risk) [16,17].

CONCLUSION

Age-related changes in the mitral valve annulus, such as dilation, contribute to regurgitation or stenosis, complicating surgery in older adults. These variations necessitate tailored annuloplasty ring sizing and repair techniques to optimize outcomes, reduce prosthesis mismatch and minimize risks like LVOT obstruction or recurrence. Future research should emphasize dynamic imaging and ethnic-specific norms to enhance transcatheter and reconstructive feasibility amid rising degenerative prevalence

Limitations

The limitations were, there was no BSA/sex stratification. There was a comorbidity exclusion bias towards "healthy" norms. Future multiethnic CT/MRI validations was required that (e.g., dynamic 4D) could integrate systolic changes, boosting TMVR feasibility amid 2-3% rising prevalence.

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