

Original Article

Mitral valve beyond classical view – A morphometric evaluation



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ABSTRACT

Introduction: Different interventional procedures like annuloplasty, valvulotomy/valvuloplasty, repair and replacement of the mitral valve of heart for regurgitation or prolapse are increasing day by day. This emphasizes the need for clear understanding of the mitral valve anatomy. The present study is an endeavor to find out the real anatomy of mitral valve in Eastern Indian population.

Material and methods: The present study was conducted on 52 adult formalin fixed heart specimens. Morphometric parameters of mitral valves like number and location of leaflets, annular circumference and diameter, length of annular attachment of each leaflet and their height were observed and analyzed statistically.

Results: Among the samples 40% are having three cusps and 6% are with single cusp. Mean annular diameter and circumference were found to be 2.6 ± 0.495 cm and 9.27 ± 1.017 cm respectively. Mean length of attachment of anterior and posterior cusps along the annulus is nearly same. Mean height of anterior and posterior cusps was noted 1.87 ± 0.399 cm and 1.46 ± 0.418 cm respectively.

Discussion: This study will improve our understanding for structural and functional value of mitral valve complex which will enrich the existing data and help the cardiothoracic surgeons and prosthetic manufacturers during valve operations.

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1. Introduction

In this modern era, cardiovascular diseases are becoming an important cause of morbidity and mortality. Effective functioning of the heart depends on proper synchronized working of several valves like mitral, tricuspid, aortic and pulmonary during systole and diastole. Morphological changes of the structures of valves can affect its mechanical integrity which leads to abnormal valve closure and regurgitation of blood.¹ The mitral valve is of great importance as its structural alteration is very common in different valvular heart disease in comparison to other valves. Management of diseased valve is done by surgical procedures or replacement of it according to the condition. The dynamic advancement of therapeutic and diagnostic cardio-invasive procedures implies a marked rise of interest in the studies of cardiac anatomy. For successful post surgical functioning of valves, the valve complex anatomy should be maintained properly during the interventional procedures. On the other hand, for selection and synthesis of prosthetic valves proper morphometric knowledge of the valve is essential.

The classical image of the mitral valve is bicuspid with anterior and posterior leaflets. Unobstructed forward flow of blood through valve depends on mobility, pliability and structural integrity of valve leaflets.² Valve morphogenesis begins with the transformation of endocardial cushion to myocardial cells through epithelio-mesenchymal transformation (EMT).³ Now it is said that hemodynamics may also play a role that alters gene expression during the valve development.⁴ The anterior/aortic or septal cusp has few or no marginal indentation and is seen to guard 1/3rd of the atrioventricular orifice. The posterior or mural cusp, which usually has 2 or more indentations, occupies the rest of the circumference.⁵ But anatomic and morphologic studies of the mitral valves by researchers show much variations in the valve complex. As the anterior leaflet is in fibrous continuity with the aortic valve thus an accessory cusp when present anteromedially it may lead to appreciable subaortic stenosis or aortic regurgitation or even damage of the conduction tissue which causes arrhythmia in the affected patient.⁶ Accessory cusp will affect the normal apposition of the valve during closure, thus leads to mitral regurgitation.⁶ It also seen in different studies that a broad racial and ethnic disparities exist in the epidemiological records on the incidence and prevalence of cardiovascular diseases.⁷ Dhawan and Bray⁸ in their study have found substantial differences in total vessel diameter among Caucasians and Asians. Existing controversies, its

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clinical significance and lack of studies on Eastern Indian population an extensive study on the anatomic variation of mitral valve in this population of this region is necessary. The objective of this study is to find out the incidence of variation in mitral valve anatomy and to measure the different dimensions of this valve. This baseline data will enrich the previous records and will be helpful for the cardiothoracic surgeons as well as prosthesis manufacturers during replacement of valves in this population.

2. Materials and methods

For this study, fifty two formalin fixed human adult cadaveric hearts procured from the department of Anatomy. Sex could not be ascertained as we included some previously collected departmental specimen also for our study material. Any specimens with grossly identifiable anomaly which might affect its topography or having calcified mitral valves were excluded from the study. After cleaning the specimen, we dissected and removed the left atrium to expose the mitral valve and measured the diameter and circumference of it. Then an incision was given along the left border of ventricle to open the mitral valve complex properly. We have cross checked the length of circumference after opening the valve. Variations of the leaflets were noticed and photographs were taken. The fibrous annular ring and attachment of the valve cusps along its anterior and posterior margin were examined and noted. Maximum height of individual cusp was recorded. By using digital vernier caliper (MITUTUYO, with measurement resolution 0.01 mm) and malleable millimeter ruler all the following parameters were measured:

1. Annular diameter.
2. Circumference of the annular ring of mitral valve (fibrous margin to which cusps are attached).
3. Basal/annular attachment of all cusps – measurement of attached margin of the cusps along the annular fibrous ring.
4. Maximum height of the anterior and posterior cusp – measurement of distance from tip of cusp to its annular attachment.

Statistical analysis was done using Statistica Software, Good-man fit test was done to see the distribution of data and the results were tabulated. *P* value < 0.05 considered as significant.

3. Results

All the parameters are showing normal distribution by Goodman-fit test. Mean annular diameter and circumference is 2.60 ± 0.495 cm and 9.27 ± 1.017 cm respectively. In present study 28 specimens (54%) show classical bicuspid mitral valve. Rests 24 (46%) are varying in number of cusp. These are two types, 21 (40%) presents 3 cusps while 3 (6%) are with single cusp. The specimens where mitral valve appears as a single curtain along the total annular circumference with no complete indentation (which reaches up to the fibrous annular ring) for differentiation of anterior and posterior cusps are considered as monocuspid valve (Fig. 1). In tricuspid valve specimens (3 cusps), the accessory cusp is attached more to the posterior margin (23%) of the annulus rather than to its anterior margin (17%). The three leaflets according to their basal position are either named as anteromedial, anterolateral, and posterior (Fig. 2) or posteromedial, posterolateral and anterior (Fig. 3). Mean annular attachment for anterior cusp is 4.33 ± 0.716 cm and for posterior is 4.77 ± 0.827 cm. Mean ratio of basal attachment of anterior and posterior cusp (including accessory cusp) with the annular circumference is 0.47 ± 0.070 cm and 0.51 ± 0.068 cm respectively. It indicates that occupancy of anterior and posterior cusp is more or

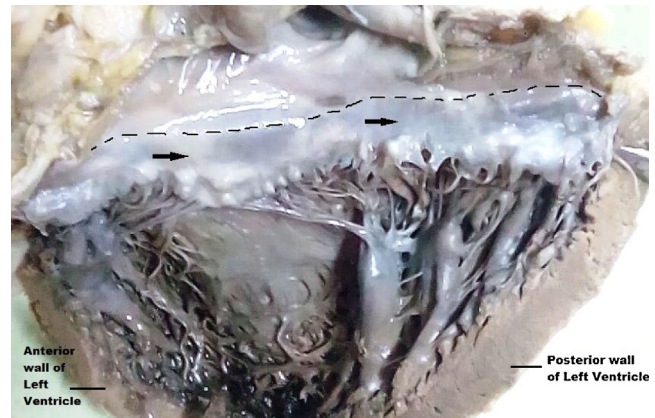


Fig. 1. Monocuspid mitral valve, arrow indicate no complete indentation in leaflet.

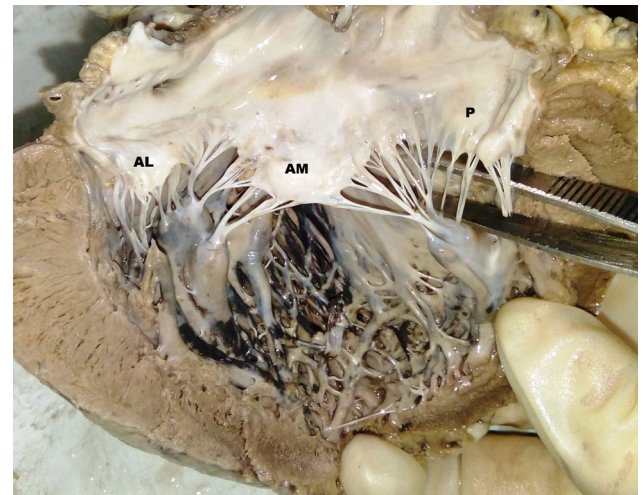


Fig. 2. Double anterior cusp in mitral valve, AL – anterolateral, AM – anteromedial, P – posterolateral cusps.

less same along the annulus fibrous ring. Mean height of anterior cusp is 1.87 ± 0.399 cm and posterior cusp is 1.46 ± 0.418 cm. Morphometry of annular diameter and circumference, basal attachment of cusps along anterior and posterior margins and its ratio with total circumference of annulus, height of anterior and posterior cusps are depicted in Table 1. Different parameters related to height of each cusp (including accessory) attached to the anterior and posterior

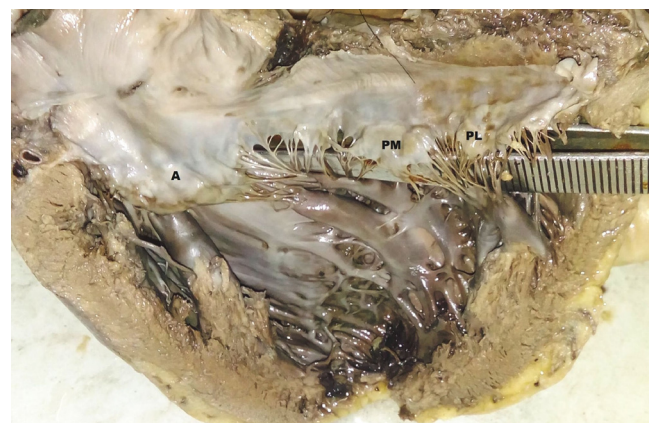


Fig. 3. Double posterior cusp in mitral valve, A – anterior, PM – posteromedial, PL – posterolateral cusps.

Table 1
Measurement of different parameters (in cm) of mitral valve.

Parameters		Mean	95% CI UL	95% CI LL	Median	Min	Max	SD
Annulus	Diameter	2.60	2.46	2.74	2.50	1.80	3.70	0.495
	Circumference	9.27	8.99	9.56	9.25	7.50	12.00	1.017
Anterior cusp	Height	1.87	1.75	1.98	1.85	1.10	2.90	0.399
	Basal length	4.33	4.13	4.52	4.10	2.80	5.80	0.716
Posterior cusp	Height	1.46	1.34	1.57	1.40	0.70	2.50	0.418
	Basal length	4.77	4.54	5.00	4.70	3.20	6.50	0.827
Cusp basal length: circumference	Anterior	0.47	0.45	0.49	0.47	0.30	0.62	0.070
	Posterior	0.51	0.50	0.53	0.51	0.38	0.70	0.068

Table 2
Comparison of accessory cusps height.

Cusp attach to annulus		Anterior margin of annulus			Posterior margin of annulus		
		Double cusp		Single cusp	Single cusp	Double cusp	
Specimens % (n)		17.31 (9)		82.7 (43)	76.92 (40)	23.08 (12)	
Parameters		Antero – medial	Antero – lateral	Anterior	Posterior	Postero – medial	Postero – lateral
Cusp height (cm)	Mean	1.30	1.43	1.83	1.30	1.53	1.43
	Median	1.4	1.4	1.8	1.30	1.50	1.40
	Min	0.6	1	1.1	0.7	0.9	1.1
	Max	1.7	2	2.8	1.9	2.4	2.0
	SD	0.33	0.36	0.36	0.32	0.40	0.25
	95% CI-LL	1.04	1.15	1.72	1.19	1.27	1.27
	95% CI-UL	1.55	1.71	1.94	1.40	1.79	1.59

margins of annulus are tabulated in Table 2. We have found that mean heights of single cusp is 1.83 ± 0.36 cm for anterior and 1.30 ± 0.32 cm for posterior one. But height decreases when two cusps are present anteriorly (anteromedial – 1.30 ± 0.33 cm, anterolateral – 1.43 ± 0.36 cm) while close to its normal one in case of double posterior cusps (posteromedial – 1.53 ± 0.40 cm, posterolateral – 1.43 ± 0.25 cm).

4. Discussion

Different studies have done previously to measure different parameters of mitral valve by different methods.^{9–18} Cadaveric studies are reported in Brazil, Japan and India (in different states) recently.^{9–16} 2D echocardiography method has done to record the mitral leaflets and their annular attachments during the cardiac cycle.^{17,18} 2D echocardiography is a tomographic technique which

allows visualization of mitral valve leaflet margin only from ventricular aspect but the depth or height cannot be ascertained. By cadaveric measurements this obstacle can be overcome.

In our study range of diameter and circumference of the valve is 1.8–3.7 cm and 7.5–10.9 cm respectively. We find 46% specimens are with variable cusps (40% tricuspid and 6% monocuspid valve). Mean basal length for anterior and posterior cusps is 4.33 ± 0.716 and 4.77 ± 0.827 cm respectively. Mean height of anterior and posterior cusps is 1.87 ± 0.39 cm and 1.46 ± 0.41 cm respectively. Measurements of mitral valve parameters reported by this study are compared with others in Table 3. Valve diameter noted by us is very close to Kapil et al. whereas circumference noted by us corresponds with values reported by Gunal et al., Gupta et al., Sakai et al. and Omislon et al. but differs from others (Table 3).

By convention mitral valve consists of anterior/aortic cusp and posterior/mural cusp. Previous studies showed that variation in

Table 3
Comparison of present study with others.

Author	Year	Country	Method	Annular diameter (cm)	Annular circumference (cm)	Annular basal length (cm)	Height of cusp (cm)
Present study	2015	India (West-Bengal)	Cadaveric	2.60 ± 0.49	9.27 ± 1.01	Ant: 4.33 Pos: 4.77	Ant: 1.87 Pos: 1.46
Gunnel et al. ⁹	2012	India (Maharashtra)	Cadaveric	2.22	9.12		Ant: 1.96 Pos: 1.50
Mishra et al. ¹⁰	2014	India (Maharashtra)	Cadaveric		8.7 ± 1.68		
Kapil et al. ¹¹	2013	India (Karnatak)	Cadaveric	2.56 ± 0.32	8.03 ± 0.82		
Gupta et al. ¹²	2012	India (Manipal)	Cadaveric		9.1 ± 0.44		
Patil et al. ¹³	2009	India (Surat)	Cadaveric		8.24		Ant: 1.92 Pos: 1.10
Okamoto et al. ¹⁴	2007	Japan	Cadaveric		8.8		
Andrade et al. ¹⁵	2005	Brazil	Cadaveric		7.92		
Sakai et al. ¹⁶	1999	Japan	Cadaveric	2.97 ± 0.35	9.32 ± 1.1	Ant: 3.20 ± 0.48 Pos (middle scallop): 1.93 ± 4.1	Ant: 2.34 ± 0.29 Pos (middle scallop): 1.38 ± 0.29
Ormiston et al. ¹⁷	1981	California	Two-dimensional echocardiography		9.3 ± 0.9		
Krishnaiah et al. ¹⁸	2011	India (Hyderabad)	Two dimensional echocardiography	Male: 2.19 Female: 1.96	Male: 7.56 Female: 6.87		

Ant: anterior; Pos: posterior.

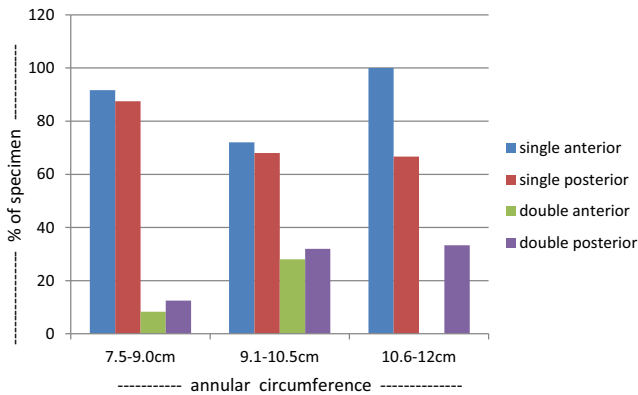


Fig. 4. Bargram shows percentage (%) of single and double anterior and posterior cusps present in different range of annular circumference.

number of cusps are not uncommon. In our study presence of three leaflets is significantly high (40% of cases) whereas the single frill like cusp is in 6% of cases only. The finding differ from the study of Gunal regarding three leaflets where he found 3 cusps in 18.1% cases but more or less same in monocuspid valve (5.17%).⁹ He also noted tetra, penta/hexa cusps which are not seen in our study. In present study we observe that anterior accessory cusp present in 17% of cases whereas posterior accessory cusp in 23% cases. We also noticed that increasing circumference is associated with more incidences of accessory leaflet which is more pronounced on the posterior aspect rather than that of anterior. When the annular circumference ranges 7.5–9 cm, double cusps along the posterior and anterior margins are 12.5% and 8.33% respectively but the incidences of the same are increased to 32% and 28% respectively when the circumferences are within 9.1–10.5 cm range and when circumferences is much more (>10.5 cm), specimens are having 33.33% double posterior cusp only with no splitting of anterior cusp or accessory leaflet (Fig. 4). Deopujari suggested that extra leaflets tend to occur when annular circumference increases which is true even for our study.¹⁹ He also stated that an increased annular circumference is expected to show a proportionate increase in number of anterior leaflet (if it is not appropriately compensated by normal valvular components) rather than that of posterior, which is not matched with our study. So this knowledge is important for the cardiothoracic surgeons and interventional cardiologist as it will be of immense value during designing prototype of mitral prosthetic valve.

Regarding basal attachment anterior leaflet classically occupies a third of the annular circumference where as the posterior leaflet laying the remainder. But in our study the proportion of mean basal lengths of attachment of anterior and posterior leaflet is nearly same (0.47 ± 0.07 cm and 0.51 ± 0.06 cm respectively) which does not match with the studies done by Ho and Fuster et al.^{20,21} Length of annular attachment of the valve leaflets should be kept in mind by cardiothoracic surgeons for proper postoperative functioning of mitral valves in case of constructive surgery.

Heights of the individual leaflets are also very important as conventionally height of anterior leaflet is twice as that of posterior leaflet and thus in case of scarring in Rheumatic heart diseases posterior leaflet undergoes more shrinkage.²² We have observed that the mean height of anterior and posterior leaflets are 1.87 cm and 1.46 cm respectively which again differ from classical view but correspond with the values observed by Gunal.

There might be a difference in measurements of parameters by cadaveric study and echocardiographic study due to formalin fixation and lack of muscle tone in former specimen. This can be minimized by using fresh cadaveric hearts in future study. Further

study also needed to evaluate the difference between parameters of male and female. As this study mainly includes hearts of Eastern Indian origin we expect that these values will be useful for cardiothoracic surgeons and manufacturers of prosthetic valve specific for this population.

5. Conclusion

Annular diameter and circumference of the mitral valve are within the normal limits, but high percentage of accessory cusp, the relation of cusp heights and the basal attachment of anterior and posterior leaflets are not matched with the previous studies which needs special attention for reconstructive surgery of this population.

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Conflict of interest

The authors have none to declare.

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