Morphometric Study of Mitral Valve in South Odisha - A Cadaveric Study

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ABSTRACT

BACKGROUND
The heart is a pair of valved muscular pumps combined in a single organ. For the proper functioning of the heart, all valves should be intact. Mitral valve (MV) prolapse and regurgitation is the main cause of MV replacement. The dimensions of mitral valve and the cusps vary from person to person. We wanted to measure the average size of the valve components with respect to the annulus in the cadavers of South Odisha region, which would help in the selection of prosthetic valve in cardiac surgery.

METHODS
This comparative study was carried out on 58 adult cadaveric human hearts. Left atrium was opened along the left border of heart so as to expose the mitral orifice. Parameters of different components of the valve were measured by using appropriate instruments.

RESULTS
The mean annular circumference of the mitral valve was found to be 8.84 ± 1.24 cm; The annular attachment and height of anterior cusp were 2.94 ± .81 cm and 2.55 ± 0.27 cm respectively. The annular attachment and height of posterior cusp were 4.52 ± 0.78 cm and 1.2 ± 0.17 respectively. The annular area was found to be 5.22 ± 1.13 cm^2. The combined cusp area was found to be 9.38 ± 2.32 $cm.^2$

CONCLUSIONS
The size of mitral valve parameters in the South Odisha region were found to be less compared to other studies. This study might help cardio-thoracic surgeons as well as the prosthetic valve manufacturing companies for the rough estimation of the mitral valve size.

KEY WORDS
Mitral Valve, Anterior Cusp, Posterior Cusp, Annular Circumference, Annular Valve Area and Combined Cusp Area

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BACKGROUND

The heart is a valvular muscular pump present in the middle mediastinum. For the proper functioning of the heart, all the valves should be intact[1]. Mitral valve prevents the backflow of blood into the left atrium. The mitral valve complex consists of mitral orifice and its associated annulus, the cusps, the supporting chordae tendineae, and papillary muscles. Mechanical support is provided by fibro elastic cardiac skeleton.

The mitral valve is described as consisting of a continuous veil attached around the entire circumference of the mitral orifice. Its free edge bears several indentations; two are sufficiently deep and regular to be named as anterolateral and posteromedial commissures.[1]

The anterior / aortic cusp is seen to guard one third of the circumference, having semi-circular or triangular in shape with few or no marginal indentation. The posterior / mural leaflet is regarded as the valvular tissue posterior to the anterolateral and posteromedial commissures. The extent of the commissural area is defined by noting the spread of insertion of the fan-like commissural chordal branches.[2]

Thus, defined the posterior leaflet has a wider attachment to the annulus, guarding two thirds of the circumference,[1,2] it also rules out existence of extra cusps as observed by some workers. The indentations divide the posterior cusp into three scallops, the middle being the largest[1,] Raghunatha metal[2] observed in 92 % hearts the posterior cusp was tri-scalloped, and the middle scallop was largest in 84 % of hearts.

Various heart diseases affect the valves causing stenosis, regurgitation or prolapse of leaflets resulting in valve insufficiency. Such cardiac diseases require repair of the valve; and when damage of the valve is more due to disease pathology, valve replacement surgery will be attempted with the artificial valve.[3]

Conservative mitral valve repair surgery with preservation of annulo-papillary muscle continuity by retaining the subvalvular apparatus whenever possible is gaining popularity as it provides excellent long-term results with increased survival rates as compared with the replacement of the valve especially in mitral regurgitation cases. As operation for the correction of mitral incompetence and grossly stenosed valve becomes more common, a better understanding of the detailed anatomy of the mitral valve and its functional correlation is the need of the hour.

For the mitral valve surgery to be successful attention has to be given to the exact dimension of each valvular component, otherwise there will be further structural deformity of the repaired valve or valve prosthesis-patient mismatch in case of replacement.

The mitral valve parameters, now a days are measured using modern imaging techniques. There is a gradual increase in annular size during diastole to maximum in late diastole after p-wave and the minimal size reached in systole.[4] Hence, details of the morphometry of mitral valve can be studied manually. The quantitative data obtained by imaging method is also comparable to the direct anatomical or surgical measurements.[5]

Many publications dealing with the detailed anatomy are found in literature, but most of these works were done outside Odia population.

So, we wanted to measure the different parameters of the mitral valve cusps and annulus, which would be helpful to the cardiothoracic surgeons to determine the type and size of the prosthetic mitral valve which would be appropriate for the population of South Odisha suffering from mitral valve disease.

METHODS

The comparative study was conducted from January 2019 to December 2020 on fifty-eight adult hearts (without any obvious pathology) procured from the collection of embalmed cadavers available in the Department of Anatomy, M.K.C.G. Medical College & Hospital, Berhampur. Since the heart specimens were already removed from the cadavers before the commencement of the study, the sex could not be ascertained. The heart after removing the clots were washed thoroughly under tap water. The two atria were removed from ventricles by dissecting along the line of atrio- ventricular groove. The position of the four valvular orifices and the fibrous skeleton (the right and left fibrous trigones) were identified at the base of the ventricles.

The mitral valve complex was exposed by opening the left ventricular cavity by excising the right ventricle and then giving an incision along the postero-medial commissure and the inter ventricular septum. No papillary muscles were attached to the left side of the ventricular septum.

Parameters of the Study

- The annular circumference was measured at the base of leaflets, by using a surgical silk thread.
- Annular radius was derived by using geometrical formula $2\pi r$ (assuming the annulus to be roughly circular).[1] The area of the mitral orifice (πr^2) was computed manually.
- The width of each leaflet at its annular attachment was measured using the surgical silk thread.
- The height of each leaflet was measured from base to free edge in the central axis, in case of posterior leaflet, the height of middle scallop was used for measurement, since it is the largest scallop. It was measured by a pair of dividers.
- The area of each leaflet was derived by using the formula ½ × base × height, assuming the leaflets to be roughly triangular.
- The commissural depth and width were measured by using a pair of dividers. The extent of the commissure was defined by noting the spread of insertion of the fan like commissural chordalbranches.[2]

Statistical Analysis

Parameters were analysed statistically by using SPSS software. Students 't' test was used for calculations.

RESULTS

Many researchers have measured the parameters of cadaveric hearts. Our observations are compared with those of other workers in Table 1 and 2.

Parameter		Maximum Value	Minimum Value	Mean	SD	P
Annulus circumference (cm)		12.2	8.6	9.84	1.24	
Cusp attachment to annulus (cm)	Anterior	4.9	1.3	2.94	0.81	0.001*
	Posterior	6.8	2.1	4.52	0.78	
Cusp height (cm)	Anterior	3.4	1.9	2.55	0.27	0.001*
	Posterior	1.8	.8	1.2	0.17	
Cusp surface area (cm^2)	Anterior	3.89	2.12	3.45	0.38	0.2
	Posterior	4.42	2.35	3.76	0.44	
Width of commissures (cm)	Antero-lateral	1.3	0.3	0.53	0.18	0.05
	Postero-medial	1.2	0.3	0.63	0.15	
Depth of commissures (cm)	Antero-lateral	1.3	0.4	0.86	0.25	0.04
	Postero-medial	0.9	0.2	0.73	0.16	
Annular area in cm^2		7.79	3.07	5.22	1.13	0.001*
Combined cusp area in cm^2		12.24	6.65	9.38	2.32	

Table 1. Statistical Measurements of the Parameters (N = 58)

*significant

The mean annular circumference of the mitral valve was found to be 9.84 ± 1.24 cm; the annular attachment and height of anterior cusp were 2.94 ±0.81 cm and 2.55±0.27 cm respectively. The annular attachment and height of posterior cusp were 4.52 ±0.78 cm and 1.2 ±0.17 respectively. Width and depth of antero-lateral commissure were 0.53 ± 0.18 and 0.86 ± 0.25 respectively; for posteromedial commissure these values were 0.63 ± 0.15 and 0.73 ± 0.16 respectively. The annular area was found to be 5.22 ± 1.13 cm^2. The combined cusp area was found to be 9.38 ± 2.32 cm^2.

DISCUSSION

The mean annular circumference was found 8.84 (± 1.24) cm. 76 % of our observations lie between 9.2 to 10.1 cm. The findings of other workers range between 7.5 to 12.5 cm. According to Grey[1] it is 9.0 in males and 7.5 in females. The measurements found by imaging technique also falls in this range. The annular attachment of anterior cusp was found to be 2.94 ± .81 cm. The values of other researchers vary between 2.5 - 4.8 mm. The annular attachment of the posterior cusp was 4.52 ± .78 cm. The findings of other researchers showed a wide range from 3.1 - 8.7 cm.[8,10-14]

However, Raghunathan[2] and Khanna S.K[11] have calculated the attachment of individual scallops, still combinedly, the measurement appears to be greater than 4.4 cm. Our findings are corroborative with the lower range of other studies. The anterior cusp bears no scallops in all the hearts studied. This is similar to the observation made by Raghunathan et al.[2]

The height of anterior cusp was 2.55 ± .27 cm and the findings of previous workers is in the range of 1.6 - 3.0 cm. The height at middle scallop was determined to be 1.2 ± .17 cm. Others have determined it to be between 0.8 - 2.5 mm.[2,6-15,18,20,22.]

The width of the antero-lateral commissure and postero-lateral commissure were 0.53 ± 0.18 cm and 0.63 ± 0.15 cm respectively.

Authors	Type of Study	Annular Circumference (cm)	Annular Attachments of Cusps (cm)		Height of Cusps (cm)		Width of Commissures (cm)		Depth of Commissures (cm)	
			Ant	Post	Ant.	Post.	Ant-lat	Post-med	Ant-lat	Post-med
R.C Brock, (1952)[6]	NA	10.05	- -	- -	1.5 - 1.8	1 - 1.2	- -	- -	- -	- -
Rusted I.E, (1952)[7]	Autopsy	9.9 - M 8.5 - F	- -	- -	2.3 - M 2.1 - F	1.3 - M 1.2F	- -	- -	0.8 - M 0.7 - F	0.8 - M 0.7 - F
Cheichi (1956)[8]	Cadaveric	10.2	3.7 - M 3.3 - F	3.3 - M 3.0 - F	2.1 - M 2.2 - F	1.4 - M 1.2 - F	1.7 - M 1.3F	1.3 - M 1.2 - F	0.8 - M 0.7 - F	0.7 - M 0.6 - F
E.W.T. Morris (1960)[9]	NA	- -	- -	- -	2.7	1.3	- -	- -	- -	- -
L A Du Plessis (1964)[10]	Fresh	10.2	3.5	6.7	2.7	1.3	- -	- -	- -	- -
Raghunathan, lam (1970)[2]	Autopsy	- -	3.6 - M 2.9 - F	1.6 - 2.3 - 1.5 - M 1.4 - 1.8 - 1.1 - F	2.4 - M 2.2 - F	1.4 - M 1.2 - F	1.2 - M 0.9 - F	1.8 - M 1.5 - F	.8 - M .7 - F	0.8 - M 0.8 - F
Khanna S.K (1975)[11]	Cadaveric	9.32 ± 1.1	3.2 ± .48	1.41 - 1.93 - 1.36	2.34 ± .29	1.38 ± 0.29	0.77	0.87	0.72	0.83
Carpentier (1976)[12]	Cadaveric	11.6	3.2	5.5	2.3	1.4	- -	- -	- -	- -
J.A. Ormiston (1981)[4]	Living (echo study)	8.0 - Systole 9.3 - Diastole	- -	- -	- -	- -	- -	- -	- -	- -
Tetsura Sakai (1999)[13]	Cadaveric	9.33 ± 1.1	3.2	4.7	2.34	1.38	- -	- -	- -	- -
Patil D (2009)[14]	Cadaveric	9.70 cm	3.7	5.67	2.3	1.38	- -	- -	- -	- -
Gunal et al. (2012)[15]	Cadaveric	9.12	- -	- -	1.96	1.5	- -	- -	- -	- -
Gupta C (2013)[16]	Cadaveric	9.1	- -	- -	- -	- -	- -	- -	- -	- -
Deopujari (2013)[17]	Cadaveric	8.27 ± 1.25	3.82 ± 0.76	5.26 ± 0.78	- -	- -	- -	- -	- -	- -
Mishra P.P (2014)[18]	Cadaveric	8.7 ± 1.68	3.4 ± .87	5.19 ± 1.16	2.11 ± 0.84	1.52 ± 0.42	- -	- -	- -	- -
Charanya N. (2017)[19]	Cadaveric	8.86 ± 0.16	- -	- -	- -	- -	- -	- -	- -	- -
Ilankathir S. (2017)[20]	Cadaveric	8.29	3.23	4.82	2.42	1.28	- -	- -	- -	- -
Suzannne E.W. (2018)[21]	Imaging	11.71 ± 1.17 Early systole	- -	- -	- -	- -	- -	- -	- -	- -
Sriambika K. (2018)[22]	Cadaveric	8.8 ± 1	- -	- -	1.9 ± 0.26	1 ± 0.16	- -	- -	- -	- -
Geetanjali B.S. (2019)[23]	Cadaveric	8.19 ± 1.01 - M 7.76 ± 0.99 - F	- -	- -	- -	- -	- -	- -	- -	- -
Present study	Cadaveric	8.84 ± 1.24	2.94 ± 0.81	4.52 ± 0.78	2.55 ± 0.27	1.2 ± 0.17	0.83 ± 0.18	0.63 ± 0.15	0.86 ± 0.25	0.73 ± 0.16

Table 2. Comparison of Annular Circumference, Height and Width of Cusps and Commissures by Different Authors

The measurements collected from others range between 0.6 - 2.4 cm for antero-lateral and 0.7 - 2.6 cm for postero-medial commissures. The value obtained in the present work lies in the lower part of the range given by other researchers.[2,8,11-15]

The depth of the antero-lateral commissure and postero-lateral commissure were 0.86 ± 0.25 cm and 0.73 ± 0.16 cm respectively. The value obtained in the present work lies in the lower part of the range given by other researchers.[2,7,8,11]

Authors	Annular Area (cm^2)	Cusp Surface Area Anterior Cusp	Posterior Cusp	Combined Cusp Area (cm^2)
Quain (1929)[24]	8.55	- -	- -	18.68
J.A. Ormiston[4]	5.2 - 7.1	- -	- -	- -
Cheichi[8]	4.9 - 10.2	4.27 - 4.83	2.70 - 5.32	6.97 - 12.65
Du plessis[10]	- -	4.90	5.00	9.90
Gupta C[16]	7.3	1 - 3	2 - 4	- -
Deopujari[17]	- -	3.51 ± 1.04	2.14 ± 0.61	- -
Mishra P. P[18]	5.1 - 7.5	- -	- -	- -
Sriambika K[22]	6.2 ± 1.46	- -	- -	- -
Geetanjali B. S[23]	5.45 ± 1.34 - M 4.89 ± 1.20 - F	- -	- -	- -
Present study	5.22 ± 1.13	3.45 ± .38	3.76 ± .44	9.38 ± 2.32

Table 3. Comparison of Annular Area and Cusp Area by Different Authors

In present study, the annular area was found to be 5.22 ± 1.13 $cm.^2$ Others have obtained it to be between 426.1 to 793.0 $mm.^2$ Francesco Maffessanti,[25] determined it as 9.1 - 10.8 by imaging technique. Federico Veronesi[26] found that the mitral annulus surface area was 8.0 ± 2.1 cm^2 at end-diastole and decreased to 7.7 ± 2.1 cm^2 in systole, reaching its maximum (10.0 ± 2.2 cm^2) at mitral valve opening. Our findings are much less in comparison to the values obtained by imaging techniques. However, the values obtained by Ormiston[4] agree with our findings.

The anterior cusp area was 3.45 ± .38 cm^2 and the posterior cusp area was 3.76 ± .44 cm^2. The findings of Cheichi et al.[8] is 4.27 - 4.83 cm^2 and 2.70 - 5.32 cm^2 and that of Du Plessis et al.[10] was 4.90 cm^2 and 5.00 cm^2 respectively for the anterior and posterior cusp areas. The areas of the two cusps are comparable despite the variations in their annular attachment and height, with the area of the posterior cusp being marginally high, corroborative with the findings of Du Plessis.[10] The anterior cusp, however seems to cover the majority of the annulus plane surface in systole, even though the two leaflets have almost equal areas.[27]

The combined cusp area was found to be 9.38 ± 2.32 cm^2. The finding of Chiechi[9] was 697 - 1265 mm^2 and of Du Plessis[10] was 990 $mm.^2$ S. L. Mautner[28] found mitral leaflet area 8.7 ± 2.0 cm^2 by imaging method. Our findings agree with the findings of others.

The combined surface areas of both the mitral valve leaflets is almost twice as greater than the area of mitral orifice, permitting a larger area of coaptation.[6,9,11,29] Quain[24] found the annular area: valve area to be 1:1.5 - 1: 2.2. This relation is maintained in our study.

CONCLUSIONS

In the present study, efforts have been made to determine the dimensions of the normal mitral valve and compare them with the findings of other studies from different regions and times.

Irrespective of the type of study (imaging, autopsy and cadaveric), the valve size in our findings fall in the lower part of the range observed by other researchers. The annular area: combined cusp area is well maintained.

We agree with Mishra P.P,[18] that a correction factor needs to be worked out so that imaging parameters and fixed valve measurement match with each other.

There has been a steady advance in the field of surgical intervention for mitral valve disease. Increasing cooperation between the medical professionals and their engineering counterparts has led to development of newer and better prosthetic valves. Hence, a detailed and comprehensive knowledge of the structure of the mitral valve complex with its functional correlation is necessary, thereby justifying its anatomical study.

All the indices and correlations between the measurements are of great value and must be taken into account while making different types of mitral valve prosthesis in bioengineering as a single type cannot solve the purpose.

Data sharing statement provided by the authors is available with the full text of this article at jemds.com.
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