Morphological And Morphometric Analysis Of Mitral Valve Leaflets In A Sri Lankan Population
Fresh Autopsy Study

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ABSTRACT

A fundamental knowledge of cardiac anatomy forms the cornerstone of clinical cardiology and many publications have appeared dealing with its detailed anatomy in Caucasians and in some other racial groups. We present data of morphology and dimensions of the mitral valve and its relationship with demographic data in a Sri Lankan population. This will be helpful for the anatomists, surgeons and radiologists. Three hundred and twenty (320) fresh adult hearts obtained from natives of Sri Lanka who had died of noncardiovascular causes were studied to determine the basic variations of the morphology and morphometry of mitral valvular apparatus.The findings were compared with previous studies in other racial groups. Mitral annular circumference (MAC) ranged from 58–110 mm with a mean of 93.24 mm ± 7.3SD. The mean size of the MAC was 94.41 mm ±5.9 SD in males and 84.62 mm ± 8 SD in females and the difference was statistically significant ($p<0.001$). Our results of circumference are comparable with those reported from India and are lower than that of Caucasians. A significant positive relationship exists between the mitral annular circumference with age, height an body surface area of the person ($p<0.05$). The contribution of posterior mitral valve leaflet to the annulus was larger (52%) than that of anterior leaflet (34%) and commissural zones (14%). The anterior leaflet is longer in length (20.24 mm ± 2.1SD) than that of the posterior leaflet (13.25 mm ± 2.2SD), and was semicircular (55%) or triangular (4 %). In 5% of the hearts, notches were seen in its free border of anterior leaflet supported by cleft chordae. The posterior leaflet was not consistently triple scalloped, but had one, two, four or five scallops in 110 (34%) hearts. This study highlights the measurements of valve parameters being smaller in Sri Lankans than reported for the Caucasians, with minor morphological variations. Compared with Caucasians, the commissures occupied smaller areas of the annulus, and may facilitate the rapid fusion of valve tissue in rheumatic valvulitis. These would be of significance in echocardiographic analysis and surgical management of valvular disease in Sri Lankans.

Key words: ***Mitral valve, Annular circumference, Fresh autopsy, Leaflet, Sri Lankan***

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I. INTRODUCTION

Excellent knowledge of cardiac anatomy is mandatory to perform surgical procedures and interventions safely and efficiently. Further this information is useful for any advances or custom designing cardiac prosthetic valves and repair of abnormalities in the valves. Currently the norms of measurements utilized for echocardiogram in Sri Lanka, are based on reported studies in Caucasians. There appears to be a geographical variation on the norms of measurements for heart valves [1,2,3,4,5,6,7]. Anatomical norms of measurements for cardiac valve and associated structures have so far not been reported in Sri Lankans. Therefore the present study was undertaken for detailed anatomy of mitral valve. This would be of clinical importance, in assessing the degree and progress of valve stenosis and the valve incompetence in diseased hearts. Further the morphological analysis of the valves will enable us to appreciate/ or confirm the varied anatomy of the components of the valves. The variations in morphology may be significant, in the profile of varying pathological types in heart diseases in Sri Lankans. This knowledge of morphology would assist in the valve replacement with homograft, and also in the application of conservative surgical techniques [8,9].

Anatomy of mitral valve : Mitral valve complex as per text consists of orifice and its associated annulus, the leaflets, the supporting chordae tendineae and papillary muscles. The roots of the valve leaflets are attached to the fibrous skeleton of the atrioventricular opening (annulus). Chordae supports entire free edge of valvular cusps with varying degrees of their ventricular aspect, which prevent the valve from bowing into the atria during ventricular systole. The chordae tendinae are inserted to the papillary muscles, two in number, anterolateral and posteromedial arising from the ventricular wall, hold the valve in situ. The chordae tendinae complex with its papillary muscle is termed 'subvalvular apparatus'. The anatomic regulation of the blood flow across the orifice depends on a complex interaction between these five elements [10].

The leaflets are the most important components of the valve. These are mobile and fibroelastic [11]. Leaflet is attached around the entire circumference of the mitral annulus as a funnel like continuous veil. Leaflet's free edge bears several indentations [1, 2, 11, 12, 13, 14, 15, 16] .Majority of the anatomical journals state that two of these indentations are sufficiently deep and regular and are the anterolateral and posteromedial indentations into this funnel. These help to divide the leaflet into antereromedial/anterior and posterolateral/posterior leaflets. The indentations never indent deeply to reach the valve ring, leave some bridging or "commissural tissue" between the leaflets. Therefore the valve tissue is made up of 2 leaflets: anteromedial and posterolateral and 2 commissural areas: anterolateral and posteromedial [1, 11, 14, 15, 16]. The usual pattern is semicircular or triangular anterior leaflet with no indentations and posterior leaflet with three scallops separated by two indentations [1]. This has been accepted by many researchers [2, 4, 14, 15, 16, 17]. However considerable confusion, controversy & difficulties in quantification have arisen because some authors have described occasional or frequent occurrence of accessory leaflets between the 2 major ones.

AIMS AND OBJECTIVES

This study was carried out to determine norms of parameters of the valve orifice and leaflets of the mitral valveof normal hearts in a Sri Lankan adult population and to see whether there is any definable correlation between the mitral annular circumference with the height, weight, age and gender of an individual. And also to evaluate normal variations in valve leaflet morphology. The ethical clearance for this study was obtained from Ethical Review Committee of the Faculty of Medicine, University of Colombo (Ref No EC/05/082).

II. MATERIALS AND METHODS

Three hundred and twenty fresh autopsied adult hearts (n =320) ranging from 18 – 72 years were included in the study. The hearts were from individuals who had died in road traffic accidents, committed suicide or were murdered and the post mortem was carried out within 24 hours of death. Specimens were not harvested if a clinical history of cardiac disease was present and any evidence of heart disease seen in autopsy.

The data obtained from the cadavers were the height in centimeter and weight in kilograms. Body surface area was determined [18].

A circumferential incision was made in the left atrium, parallel to and just above the left atrioventricular groove and entire left atrium was excised. The mitral apparatus was seen through the cut area and the mitral leaflets and commissural areas were identified. A sharp incision was made through the middle of the posterior leaflet between its anterolateral and posteromedial chordopapillary muscles and the incision was extended to the apex of the ventricle to divide the valve and the ventricle. In the opened specimen the presentation of mitral valve complex was as follows; the anterior mitral leaflet was in the middle. The anterolateral half of posterior mitral leaflet with anterolateral group of papillary muscle was to the left. The posteromedial half of posterior mitral leaflet with posteromedial group of papillary muscle was to the right [8].

Mitral Valve circumference was measured at its root / annulus by placing a thread hugging the annulus, starting from the point of cut in posterior leaflet at its root to the other end of the cut and the length of the thread was measured using a transparent ruler (graduated to 0.1 mm) [19]. In the next step of measurements, the entire mitral apparatus was excised free from its attachment to myocardium. The mitral valve apparatus was spread out and pinned to a flat regiform board. The features recorded were shape and number of leaflets; Height of the valve leaflets - measured from the lowest point of the free border of the leaflet along a straight line to its root; Width of the leaflet - Length of insertion of leaflet at the valve root; Spread (length of attachment to annulus) and height of commissural tissue

All data obtained were recorded in a data sheet and tabulated for analysis. Photographs were taken to illustrate the specific findings.

STATISTICAL ANALYSIS

Data analysis was done on a computer package – "Statistical package Minitab for windows (version 14)". Range, Mean and Standard Deviation (SD) for the mean were calculated for each parameter. Correlation between the variables was calculated with the p values. P value less than 0.05 was considered significant. Comparison between the means was analyzed using unpaired t-test.

III. OBSERVATIONS / RESULTS

DEMOGRAPHIC DATA

Demographic data; such as gender, body weight, height and body surface area of 319 cadaver hearts is shown in Table 1. A specimen, which showed outlier, was excluded from the morphometric analysis. There were 267 males and 52 females, ages ranging from 18–78 years with a mean age of 43.83 years ± 15 SD. Height for the entire group ranged from 122 to 188 cm (mean 163.04 cm ± 8.7 SD) and weight ranged from 38 – 97 kg with a mean weight of 60.23 kg ± 9 SD. The average body surface area was 1.72 m^2 ± 0.1 (range 1.21 – 2.16 m^2)

Table 1 : Distribution of demographic data

Gender	Age – Years	Height – cm	Weight – kg	Body surface area-m^2
	Mean±SD (Range)	Mean ± SD (Range)	Mean ± SD (Range)	Mean ± SD (Range)
Male (267)	44.3± 15.1 (18 – 78)	164.78± 7.6 (121–188)	61.20± 9.1 (38 – 97)	1.75 ± 0.1 (1.2 – 2.16)
Female (52)	41.46 ±14.5 (20 – 69)	154.11± 8.8 (128–180)	55.25 ± 6.6 (44 – 69)	1.58 ± 0.1 (1.36–1.92)
Overall (319)	43.83 ± 15 (18 – 78)	163.04± 8.7 (121–188)	60.23 ± 9 (38 – 97)	1.72 ± 0.1 (1.21–2.16)

MITRAL ANNULAR CIRCUMFERENCE (MAC)

MAC ranged from 58 – 110 mm with a mean of 93.24 mm ± 7.3 SD. In males the MAC ranged from 64 – 110 mm with a mean 94.41 mm ± 5.9 SD. In females the annulus ranged from 58 – 106 mm with a mean 84.62 mm ± 8.0 SD (Fig 1)

Comparison of the mean MAC of male & female hearts

The mean mitral annular circumference in men and women compared by "**unpaired t-test**" (the hypothesis applied there is no difference between the mean mitral annular circumference of male & female) showed, that there was a statistically significant difference between the mean mitral annular circumference of males and females ($p < 0.001$) In addition, the distribution of mitral annular circumference in both sexes is shown in Fig 2 by Box Plot. The box plot indicates the mean and median value of mitral annular circumference in males is higher than that of females

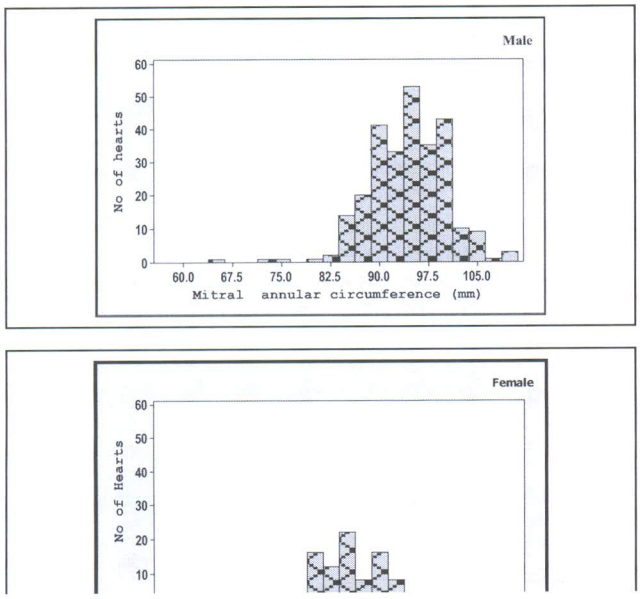

Fig 1 : Distribution of the mitral annular circumference in the two sexes

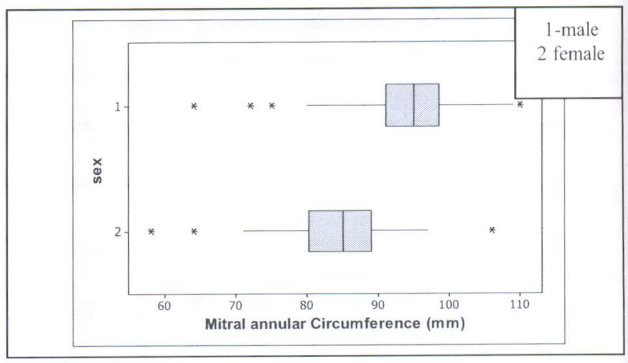

Fig 2 : Box plot of mitral annular circumference versus sex
The grey boxes indicate the distribution of middle 50 % of the total data and the horizontal lines on either side of the box indicate the rest of the data evenly. Stars (*) indicate the outliers. The vertical line within the box is the median. This shows a symmetrical distribution of data.

Correlation between Mitral annular circumference and Demographic data

Table 2 summarizes the correlation between the mitral annular circumference and other variable- age, height, weight and body surface area. A significant positive relationship exists between the MAC and age, height and body surface area of the person (p values < 0.05).

The most significant positive correlation was between the MAC and Age ($r = 0.43$, $p < 0.001$) (i.e the mitral annular circumference increases progressively with age).

Regression equation

Regression analysis was made to characterize the variables that significantly influenced the mitral annular circumference and which would be helpful in predicting the MAC by measurable data. A regression equation was fitted with a p value < 0.05. Using this regression model below, only 42% of mitral valve circumference could be predicted. Therefore 58% , other variables has to be considered.

MAC = 69.9 + 0.141 height + 0.202 age - 7.70 sex

Here sex is a dummy variable. It takes the value one (1) if the gender is male, and zero (0) if female.

Table 2 : Correlation coefficient and p values of mitral annular circumference versus demographic data of the person.

	Correlation coefficient (r)	P value
MAC with age	0.427	**$p < 0.001$**
MAC with height	0.308	**$p < 0.001$**
MAC with weight	0.110	$p = 0.05$
MAC with body surface area	0.26	**$p < 0.001$**

Morphology of anterior mitral leaflet

The anterior leaflet of the mitral valve was semicircular in 55 % of hearts (Fig 3a) and triangular in 40 % of hearts (Fig 3b)

Smaller indentations or notches were seen in the free border of the anterior leaflet in 5 % of hearts (Fig 4a). The notches were confined to the rough zone of the anterior leaflet, varying in depth and width. In 1.6 %, anterior leaflet was notched, with regular triple scalloped appearance (Fig 4b).

Morphology of posterior mitral leaflet

The posterior leaflet was quadrangular with sloping sides. The free margin of the posterior leaflet exhibited 1 to 5 scallops (Fig 5a, 5b, 6a, 6b & 7) Scallops were designated as; P1, P2, P3, P4, P5. Variations in the scallops of the posterior leaflet is shown in Table 3. It shows, mitral valve with three scallops in the posterior mitral leaflet and was the commonest variable (65.6 %).

Morphology of commissural zone

The two major leaflets were joined to each other at either extremity by a cuff of valve tissue the commissural tissue. These commissural tissues were identifiable by the characteristic fan shaped arrangement of commissural chordate (Fig 7).

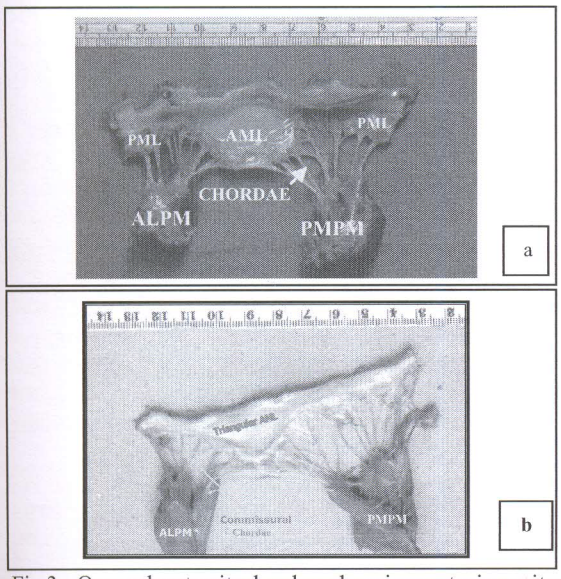

Fig 3 : Opened out mitral valve showing anterior mitral Leaflet in the middle

a. Semicircular anterior mitral leaflet
b. Triangular anterior mitral leaflet

AML-anterior mitral leaflet, PML-posterior mitral leaflet, ALPM-anterolateral papillary muscle, PMPM-posteromedial papillary muscle

** Hereafter the same abbreviations are used to label the pictures

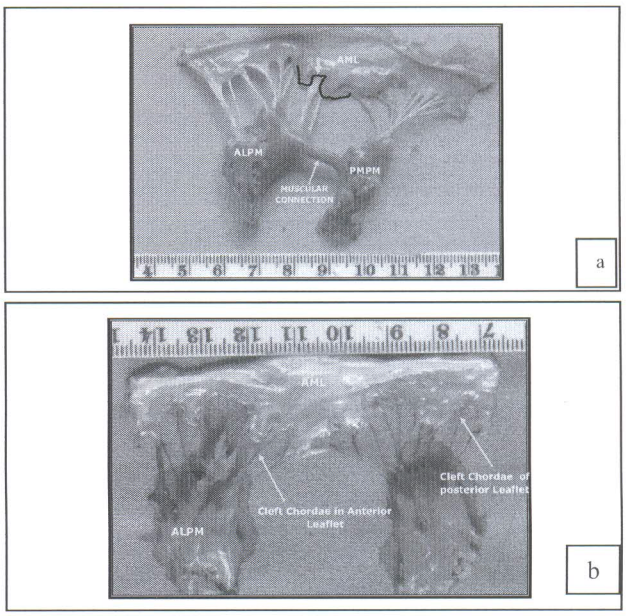

Fig 4: Indentations in the anterior mitral leaflet (AML)

a) Single indentation
dashed line outline the indentation, arrow indicate the indentation supported by a chordae
b) 2 regular indentation giving triple scalloped appearance

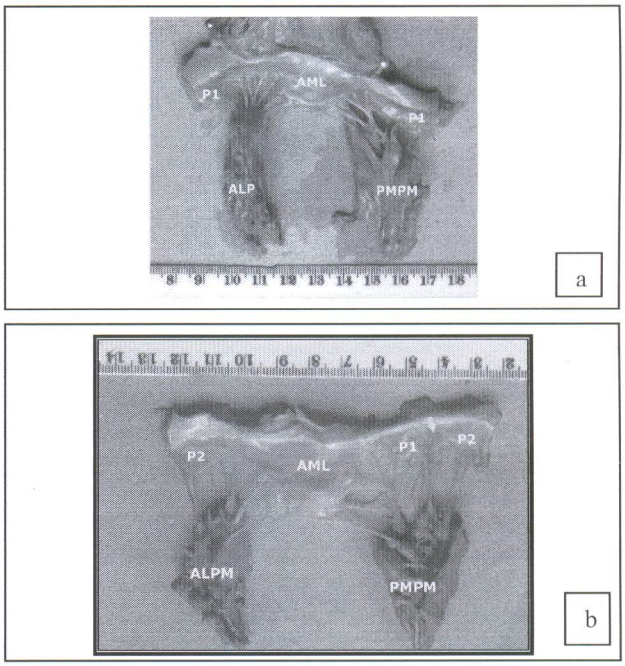

Fig 5 : Posterior mitral leaflet with

a. Single scallope
(2 halves of the posterior leaflet (P1) on either side)
b. Two scallps
P1, P2 are the two scallops of the posterior leaflet, separated by a cleft (arrow).

in 56.03 % of hearts. These two cusps may be the traditional anterior and posterior mitral leaflets. Even though there is a controversy about the morphology of the mitral valve, the papillary muscles and the commissural choardae helped in our study to distinguish the anterior and posterior mitral leaflets and commissural areas clearly.

Table 6 :Comparison of number of scallops in posterior mitral leaflet reported versus current series

Author	Number of Scallops				
	Three Scallops	Single scallop	Two Scallops	Four Scallops	Five Scallops
Present study	**210 65.6%**	**31 9.7%**	**40 12.5%**	**31 9.7%**	**08 2.5%**
Bezerra et al, [16]	91 91 %	1 1 %	7 7 %	1 1 %	
Khanna et al, [2]	16 80 %				4 20 %
Renganathan et al, [1]	46 92 %		2 4 %		2 4 %
Senthilkumar & Anand [7]	6	18	9	12	15

It is stated that with the presence of more scallops in posterior leaflet, in annuloplasty one can easily sacrifice one scallop without much interference to the valve function and further this provides a bigger opening in comparison to a valve without any scallop [2]. The slits between the scallops of posterior leaflet function as secondary (additional) zones of apposition between the adjacent parts of the longer posterior leaflet [24].

It is also stated in the literature that additional clefts would be a contributory cause for mitral valve prolapse syndrome (MVPS) [7] and may increase the chances of mitral regurgitation (MR) with the disturbances in edge – edge cusp closure [23].

In our study series, the commissural or bridging tissue was present in almost all the hearts. The report says that closure of the mitral orifice with considerable degree of mutual contact of atrial surface of the leaflets is not possible without the presence of additional valvular tissue at the junctional zone and because of that commissurotomy should never reach the mitral ring [13]

Our findings of percentage of contribution of leaflets and commissural tissue to the circumference were compared with previous studies in table 7. The present study and study on Africans [4] shows similar contribution of the leaflets to the circumference (anterior mirtral leaflet – 34 %, Posterior mitral leaflet 50 – 52 %). The commissural areas occupy only 14 – 17 %. But, a study on Caucasians [1] shows commissural areas occupies 25 % of the circumference and anterior mitral leaflet 30 % and posterior mitral leaflet 45 %. The reduction in the area occupied by the commissures at the annulus results in the two major leaflets being in closer proximity to one another. This would encourage more rapid fusions at the commissures after minimal rheumatic valvulitis [4].

The present study showed that the average height of the anterior leaflet (2.02cm) is greater than that of the posterior leaflet (1.3 cm). These measurements accord with the literature with decimal variations. This concludes that the basal measurements (width) of the anterior leaflets are distinctly shorter than the posterior leaflet; whereas the height of the anterior leaflet is significantly greater than the posterior leaflet (anterior leaflet is greater in length and shorter in breadth). This is in accord with finding in literature [1, 4, 15, 17].

V. CONCLUSION

This study attempts to bring into focus certain details of morphology and morphometry of mitral valve leaflets and annulus which have not been reported for Sri Lankan adults. The mean mitral annular circumference is significantly smaller in our population than in the reported values of Caucasians. The obtained values are of considerable significance for application in Echocardiographic analysis and surgical management and would be of assistance in the manufacture of indigenous valves. The morphological analysis shows that considerable number of posterior mitral leaflet had more or fewer than three scallops and indentations in anterior mitral leaflet were found, supported by cleft chordae.

Table 7 : Contribution of leaflets and commissural area to the valve circumference s in the present study and reported in the literature

	Present study	Adebo et al, [4]	Ranganathan et al, [1]	
Leaflet	**Overall**	**Overall**	**Male**	**Female**
Anterior	**3.2 (34 %)**	3.4 (34 %)	3.6 (30%)	2.9 (30 %)
Posterior	**4.81 (52%)**	5.0 (50 %)	5.4 (45%)	4.3 (45 %)
Middle scallop	**2.27**	1.9	2.3	1.8
Anterolateralscallop	**1.27**	1.6	1.6	1.4
Posteromedialscallop	**1.27**	1.5	1.5	1.1
Commissure	**1.3 (14 %)**	1.7 (17 %)	3.0 (25%)	2.4 (25 %)
Anterolateral	**0.7**	0.8	1.2	0.9
Posteromedial	**0.6**	0.9	1.8	1.5

VI. REFERENCES

1. Ranganathan N, Lam JHC, Wigle ED & Silver MD. Morphology of the Human Mitral Valve II. The Valve Leaflets. Circulation 1970; XLI (March) : 459 – 67.
2. Khanna SK, Talwar JR, Gopinath N & Chandra J. Morphology of Mitral Valve .Indian heart Journal 1976; 28 (1) : 46 – 51.
3. Patil D, Mehta C, Prajapati P, Morphology of mitral valves in human cadavers. (2009The internet Journal of Cardiology; 7(2) :2043 – 2050
4. Adebo OA. Morphology of the mitral valve apparatus. Anatomical variation in the African. West African Journal of Medicine 1987; 6 (3 & 4) : 165 – 74
5. Sahni D and Indrajit. Size of the valve and thickness of anterior walls of the ventricles of the adult Indian hearts. Indian Heart Journal 1992; 43 (5) : 361 – 5.
6. Adebo OA, Lun KC, Lee CN, Chao TC. Age-Related changes in normal Chinese hearts. *Chinese Medical Journal* 1994; 107 (2) : 88 – 94.
7. Senthilkumar B and Anand A. Morphometric study of mitral valve in human hearts – A comparative Anatomical Study. International Journal of Pharma and Bio Sciences 2013 (Oct); 4 (4) : (B) 105 – 110.
8. Victor S V and Nayak VM. Variations in the Papillary Muscles of the Normal Mitral Valve and their Surgical Relevance. Journal of Cardiac Surgery 1995; 10 (5) : 597 – 607.
9. Acar C, Tolan M, Berrebi A et al. Surgery for acquired heart disease. Homograft replacement of the mitral valve. Graft selection, technique of implantation and results in forty – three patients. The Journal of Thoracic and Cardiovascular Surgery 1996; 3 (2) : 367 – 80.
10. Standring S. Heart and Great vessels. In: Gray's Anatomy, The Anatomical Basis of Clinical Practice, 39th Edition, Elsevier, Churchill Livingstone, Edinburgh, 2005 : 995 – 1027.
11. Silverman ME, Hurst JW . The mitral complex (Review): Interaction of the anatomy, physiology and pathology of the mitral annulus, mitral valve leaflets, chordae tendinae and papillary muscles. American Heart Journal 1968; 76 (3) : 399 – 418.
12. Harken DE, Ellis LB, Dexter L, Farrand RE, Dickson JF. The Responsibility of thePhysician in the Selection of Patients with Mitral Stenosis for Surgical Treatment. Circulation 1952; V : 349 – 62..
13. Chiechi MA, Lees WM & Thompson R. Functional anatomy of the normal mitral valve. Journal of Thoracic Surgery 1956; 32 (3) : 378 – 98.
14. Ho SY. Anatomy of the mitral valve. Heart 2002; 88 : 5 – 10.
15. Datta AK, Mukherjee MM & Ghosh S. Morphology and morphometry of the mitral valve in normal Human hearts. Indian Heart Journal 1984; 36 (6) : 384 – 90
16. Bezerra AJC, DiDio LJA & Prates JC. Variations of the area and shape of the left atrioventricular valve and its cusps and leaflets. Surgical Radiological Anatomy 1994; 16 : 277 – 80.
17. Bezerra AJC, DiDio LJA & Prates JC. Dimensions of the left atrioventricular valve and its components in normal human hearts . Cardioscience 1992; 3 (4) : 241 – 4.
18. McArdle WD, Katch FI, Katch VL. Exercise physiology energy, nutrition and human performance 5th Edition, Lipponcott, Williams and Wilkins, Philadelphia 2001; pp – 191
19. Rusted LE, Scheifley CH and Edwards JE. Studies of the Mitral Valve. I. Anatomic Features of the Normal Mitral Valve and Associated Structures. Circulation 1952; VI (December): 825 – 31.
20. Lam JHC, Ranganathan N, Wigle ED & Silver MD. Morphology of the Human mitral valve I. Chordae Tendineae : A new classification. Circulation 1970; XLI (March) : 449 – 58.
21. Eckner FAO, Brown BW, Overll E, Glagov S. Alteration of the Gross Dimensions of the Heart and its Structures by Formalin Fixation. Virchows Arch Pathol Anat 1969; 346 : 318 – 29.
22. Andrade NMM, Tinois E, Vieira RW et al. Coefficients of proportions of the atrioventricular valves : an anatomical study of valvar segments of normal individuals. Braz Journal of Cardiovascular Surgery 2005; 20 (3) : 255 – 60.
23. Gunnal SA, Farooqui MS, Wabale RN. Study of mitral valve in human cadaveric hearts Heart views 2012 Oct-Dec; 13 (4): 132 - 135
24. Kanani M & Anderson RH. Editorial : The Anatomy of the mitral valve : A Retrospective Analysis of Yesterday's Future. The Journal of Heart Valve Disease 2003; 12 : 543 – 47.