RESEARCH ARTICLE

MORPHOMETRY OF CHORDAE TENDINEAE OF MITRAL VALVES AND ANNULOPAPILLARY DISTANCE FOR MITRAL ALLOGRAFTS

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ABSTRACT

Background: Mitral valve is the complex variable structure with 2 cusps and 2 papillary muscles which are connected by collagenous structure chordae tendineae supporting the entire free edge of the valvular cusps.

Aims & Objective: To study the morphological and morphometric analysis of chordae tendineae and to compare the morphometric measurements among cadaveric and autopsied heart specimens of south Indians and the effect of formalin in causing shrinkage of chordae tendineae. The annulopapillary distances were measured for mitral allografts.

Material and Methods: The prospective study was done on 45 cadaveric and 15 autopsied heart specimens. The left atrium and left ventricle were cut open and the measurements of the Mitral valve chordae tendineae were taken using Vernier calliper and recorded. The chordae tendineae was measured from tip of papillary muscles to the edges of the cusp. The annulopapillary distance was measured from tip of papillary muscles in 2 o', 4 o', 8 o', 10 o' clock positions to that of mitral annulus. The data's were analyzed using student's t test to compare between the cadaveric and autopsied heart specimens.

Results: Aortic cusp chordae tendineae of both specimens were approximately same 1.6 to 1.8cm, whereas in mural and commissural cusp mild difference of 2-3mm was observed 1.5 to 1.7 cm. The annulopapillary distance was equal in both the specimens 2cm. Two heart specimens showed complete absence of commissural chordae and 6 hearts showed absence of basal chordae.

Conclusion: Many studies were done on morphometry of mitral valve but the present study on morphometry of chordae tendineae of mitral valve did not show any significant changes among cadaveric and autopsied heart specimens. The data will be of great use to cardiac surgeons for surgical reconstruction of mitral valves and annulopapillary distance for mitral allografts.

Key-Words: Chordae Tendineae; Mitral Valve; Annulopapillary Distance; Cadaveric Heart; Autopsied Heart

Introduction

Human Mitral valve is the complex, dynamic, and highly variable structure. Mitral valve has an orifice with its supporting annulus, leaflets, a variety of tendinous chordae and papillary muscles. True chordae are divided into intercusp chordae, rough zone chordae and basal chordae. Chordae branches from a single stem soon after their origin from apical one third of papillary muscle or proceed as a single chordae that divide into several branches near their attachment. Fifty percent of the false chordae are irregularly distributed and are connected to each other or to ventricular wall including the septum.[1]

Chordae Tendineae is endothelial covered collagenous threads.[2] The commissural and cleft Chordae are fan shaped, and are attached to the indentations and margins of adjacent leaflets. The rough zone Chordae were attached close to the free margin of the cusp. Basal Chordae extend from the ventricular wall to the basal component of a cusp. Normal mitral valve function depends upon the anatomic and mechanical integrity of the Chordae tendineae.[3] Tandler J suggested most commonly used classifications of chordae tendineae into three orders[4], (i) 1st Order: Chordae tendineae inserted into the leaflet's edge; (ii) 2nd Order: Chordae Tendineae inserted into the 6 to 8 mm beyond the free margins; and (iii) 3rd Order: Chordae Tendineae inserted into the basal portion of the ventricular aspect of the posterior leaflet.

Several pathologies may result in anatomical and functional abnormalities of the papillary muscles such as ischemia, fibrosis and rupture.[5] The chordae that are abnormally long or short, ectopically inserted or ruptured (calcified) result in mitral regurgitation due to the mitral apparatus impairment.[6-8] Chordae supports the entire free

edge of the valvular cusps, together with varying degrees of the ventricular aspects. Some evidence suggests that those valves with unsupported areas of free edge become prone to prolapsed in later life.[1]

Preservation of the annulopapillary muscle continuity in mitral valve replacement is important. In normal hearts, the annulopapillary muscle distances of the mitral apparatus are similar in 2 o', 4 o', 8 o' and 10 o' clock positions. The importance of annulopapillary muscle continuity has been widely recognized for left ventricular function during prosthetic valve replacement in mitral regurgitation.[9] The present study was done for the morphological and morphometric analysis of chordae tendineae and to compare the morphometric measurements among cadaveric and autopsied heart specimens of south Indians and to find out the effect of formalin in causing shrinkage of chordae tendineae. The annulopapillary distances were measured for mitral allografts.

Materials and Methods

The study was done on 45 cadaveric and 15 autopsied heart specimens. The study was approved by Institutional ethical committee of VMKV Medical College, Salem. Autopsied hearts were fixed in formalin for 3 days, measurements were taken from all the hearts on the 4th day, whereas in cadaveric hearts the measurements were taken from hearts of fresh cadavers i.e., cadavers which were embalmed for the purpose of dissection and the duration of embalming was less than a year. The left atrium and left ventricle were cut open along the left border of hearts without disturbing the mitral components and the pattern of insertion of chordae tendineae to leaflets was observed carefully using hand lens in all the 60 heart specimens by placing the heart in gauze cradle. Mitral valve chordae tendineae were measured using Vernier calliper and recorded. The chordae tendineae was measured from tip of papillary muscles to the edges of the cusp in cadaveric human hearts (Figure 1) and compared with that of autopsied heart specimen's mitral valves.[9]

Annulopapillary Distance

Annulopapillary distance is measured from tip of anterolateral papillary muscles to the annulus at left fibrous trigone (10 o' clock position) and to the point between anterior and middle scallops of mural leaflets (8 o' clock position) and similarly the tip of posteromedial papillary muscles to the annulus, at right fibrous trigone (2 o' clock position) and to the point between the middle and posterior scallops of mural leaflets (4 o' clock position) (Figure 2). The measurements were taken as per the procedure of Sakai et al.[9]

Figure-1: Papillary Muscle with Chordae Tendineae of Aortic Leaflets

Figure-2: Annulopapillary Distance

Statistical Analysis

The measurements of cadaveric and autopsied heart specimen's chordae tendineae were compared using Student's t test to find out the significance at the confidence level of 95%. The resultant measurements obtained were statistically analyzed to calculate the Mean, Standard deviation, Standard error mean and P value. The statistical calculation was done on free statistical graph pad online calculator.

Results

Aortic cusp chordae tendineae of both specimens were approximately same ranging from 1.6 cm to 1.8cm (Table 1) and the comparison of cadaveric hearts anterior main chordae to that of autopsied

heart were highly significant (P≤ 0.001) and the rest of the measurements of aortic leaflets were insignificant (Table 1). The mural and commissural cusp showed mild difference of 2-3mm was observed in the range of 1.5cm to 1.7 cm and the comparison of cadaveric heart's mural and commissural chordae to that of autopsied heart were highly significant (P≤ 0.001) (Table 2). The annulopapillary distance was equal in both the specimens almost 2 cm in length in all the four positions. The comparison among cadaveric heart specimens to that of autopsied heart was highly significant at 10 o' clock and 8 o' clock position and not significant for other positions (Table 3). Two of the heart specimens showed complete absence of commissural chordae in mitral valve.

Table-1: Measurements of Aortic Leaflets Chordae Tendineae

Hearts	Aortic Leaflets [Mean (SEM) cm]					
	Main Chordae		PM Chordae		PC chordae	
	Ant.	Post.	Ant.	Post.	Ant.	Post.
Cadaver Hearts (n=45)	1.41 (0.04)	1.38 (0.39)	1.61 (0.12)	1.64 (0.18)	1.82 (0.23)	1.73 (0.22)
Autopsied Hearts (n=15)	1.31 (0.04) ***	1.37 (0.35) #	1.60 (0.10) #	1.68 (0.19) #	1.74 (0.21) #	1.77 (0.28) #

PM: Paramedian chordae; PC: Paracommissural chordae; SD: Standard Deviation; * P ≤ 0.05; ** P ≤ 0.01; *** P ≤ 0.001; #: Statistically not significant; n – Number of hearts

Table-2: Measurements of Mural Leaflets and Commissural Leaflets Chordae Tendineae

Hearts	Mural Leaflets Mean (SEM) cm		Commissural Leaflets Mean (SEM) cm	
	Anterior	Posterior	ACL	PCL
Cadaver Hearts (n=45)	1.1 (0.02)	1.7 (0.05)	1.3 (0.14)	1.2 (0.14)
Autopsied Hearts (n=45)	1.3 (0.10) ***	1.9 (0.07)***	1.5 (0.02)***	1.5 (0.19) ***

ACL: Anterior commissural leaflets; PCL: Posterior commissural leaflets; SEM: Standard Error Mean; * P ≤ 0.05; ** P ≤ 0.01; *** P ≤ 0.001; #: Statistically not significant; n – Number of hearts

Table-3: Annulopapillary Distance

Measurement	Annulopapillary Distance [Mean (SEM) cm]			
	10 o'c	8 o'c	2 o'c	4 o'c
Cadaver Hearts (n=45)	1.8 (0.21)	1.9 (0.32)	2.1 (0.39)	2.01 (0.37)
Autopsied Hearts (n=45)	2.15 (0.03)***	2.21 (0.03)***	2.25 (0.01)#	2.01 (0.01)#

c: clock position; SEM: Standard Error Mean; * P ≤ 0.05; ** P ≤ 0.01; *** P ≤ 0.001; #: Statistically not significant; n – Number of hearts

Discussion

Patterns of Insertion of Chordae Tendineae to Leaflets of Mitral Valve

Rough Zone Chordae

The rough zone chordae were divided into three strands and attached to the leaflets. The mode of attachment of chordae is to the free margin, between rough zone and clear zone and to a point in between the above 2 attachments as that of the morphological study done by Kavimani et al 2011.[2]

Figure-3: Basal Chordae Tendineae

Figure-4: Commissural Cusp without Chordae Tendineae

Figure-5: Thicker Main Chordae Tendineae

Basal Chordae

The basal chordae arising from the ventricular wall getting inserted into the leaflet were seen in all the 54 hearts (Figure 3) and completely absent in 6 hearts, Kavimani et al reported 43 hearts with basal chordae and 2 hearts without basal chordae.[2]

Commissural Chordae

Commissural chordae inserted to the margins of commissural cusps in 58 heart specimens and in 2

specimens' absence of commissural chordae (Figure 4). The condition may result in mitral regurgitation and prolapse of mitral valve.[1] One of the heart specimens showed a thicker main chorda tendineae which is of 0.9mm in thickness (Figure 5).

Measurements of Chordae Tendineae of Mitral Leaflets

The aortic leaflets having 3 chordae main chordae arises from the tip of papillary muscles and attached to middle part of aortic leaflets, paramedial chordae attached to lateral part of aortic leaflets, and paracommissural chordae attached to the periphery of aortic leaflets towards the commissural leaflets Figure 1. The chordae including anterior and posterior were measured by a gentle tension on the leaflets to straighten the chordae tendineae.[9] The aortic leaflet, main chordae were almost in the same range as that of the study carried by Sakai et al in 1999 in Japanese, with a difference of approximately 1 to 2 mm.[9-11] The comparison of cadaveric and autopsied heart specimens did not show any marked difference in the measurements. The mural leaflets, anterior and posterior chordae showed 1.4 cm in the study done by Sakai in Japanese and 1.3 cm by Carpentier, whereas the present study was 1.1 cm and 1.2 cm in cadaveric specimen and 1.3 cm and 1.4 in autopsied heart specimens.[9-11] The commissural chordae of anterior commissural leaflets was 1.7 cm and 1.9 cm in both sets of specimens respectively wherein, the study of Sakai were 1.2cm and 1.3cm and Carpentier were 1.3 cm and 1.5 cm. The present study showed increase in the length of commissural chordae and a slight difference among the cadaveric and autopsied specimens.[9-11] Commissural chordae is guide for identification of commissure in commissurotomy for cardiac surgeon.[12,13] It is necessary to judge the type of repair required and to assess the length and number of chordal substitutes and location of site for reimplantation of ruptured chordae and papillary muscles.[14] In mitral valve prolapse syndrome the left ventricle assumes various configurations which is possibly dependent on the architecture and location of papillary muscles with chordae tendineae subject to pull by the prolapsing leaflet. Chordae tendineae length big or short lead to mitral valve prolapse.[15] The chordae tendineae from anterolateral and posteromedial papillary muscle of both the cusps has no difference in its length all ranges about 1.5 cm approximately.

Annulopapillary Distance

The annulopapillary distance taken at 10 o' clock and 2 o' clock position was 1.8cm and 2.1 cm in cadaveric heart and 2.15 cm and 2.25 cm respectively (Table 3). In 4 o' clock and 8 o' clock position was 2.01cm in both specimens and 1.9 cm and 2.01cm in autopsied hearts respectively. The study done by sakai et al in Japanese showed the annulopapillary distance at 10 o' clock, 2 o' clock, 4 o' clock and 8 o' clock were 2.35cm.[9] The present study annulopapillary distance of south Indians falls almost in the same range of Japanese. If annulopapillary muscle continuity is to be restored with a mitral allograft in mitral valve replacement, preoperative or intraoperative determination of the distance between the tip of papillary muscle and the mitral annulus is crucial in each case because of the anatomical variations of the papillary muscles such as position, number, shortening and development. However our anatomical findings can offer some guidance and the rule by which to determine the length for the procedure.[9]

Table-4: Summary of the Present Study

Parameters	Chordae and Positions	Cadaveric Hearts (cm) (n=45)	Autopsied Hearts (cm) (n=15)
Aortic Leaflets	Main Chordae	1.39	1.34
	Para Median Chordae	1.62	1.64
	Para Commissural Chordae	1.77	1.75
Mural Leaflets	Cleft chordae	1.40	1.60
Commissural Leaflets	Anterior Commissural chordae	1.30	1.50
	Posterior Commissural chordae	1.20	1.50
Annulo Papillary Distance	10 o' clock position	1.80	2.10
	8 o' clock position	1.90	2.21
	2 o' clock position	2.10	2.25
	4 o' clock position	2.01	2.01

Conclusion

The effect of formalin fixation of heart specimens causes mild shrinkage of mitral valvular components. The finding of the present study done in both cadaveric and autopsied hearts did

not show much difference in morphometry of chordae tendineae due to its collagenous nature which was not affected by formalin preservation. The Morphometric data's can be interpolated for mitral valve replacements. The chordae tendineae of both the cusps (aortic and mural) were within the same range and do not show much difference (1.5 cm) (Table 1 & 2). The annulopapillary distance measurements will be of great use to the cardiac surgeons for mitral allografts. During commissurotomy the commissural chordae aids in identifying the commissures whereas the present study showed absence of commissural chordae tendineae (3.07%) and cardiac surgeons cannot rely on it for tracing commissures. The morphometric data was summarized in the table 4. The limitation of the study is done only on south Indian population and in less number of samples. The data's collected from cadaveric hearts and autopsied hearts were almost in the same range and can be used for interpretation of chordae tendineae surgeries in mitral valve. The study has to be further extended with a wide range of population from all over the India with modern technological aids in measuring the chordae tendineae.

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