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Original Article

Morphology of Chordae Tendinae of Mitral Valve in Adult Indian Cadavers

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***ABSTRACT*:**

Background: Chordae tendineae are the fibrocollagenous strings supporting the cusps of the mitral valve. For the efficient functioning of the left ventricle after valve replacement surgery and to avoid the mitral valve prolapse preservance of chordae tendinae is significant. This necessitates the clear understanding of morphology of chordae tendineae. **Materials and methods:** The present study was done on 98 embalmed human heart specimens. The detailed morphology of chordae tendineae of the mitral valve according to number at its origin and insertion, pattern of branching, thickness and level of attachment to the cusps of mitral valve was studied. **Results:** Higher number of chordae tendinae arises from apex of anteriorpapillary muscle:range 6- 21 andthat from posterior papillary muscle: range 3-22.Range of chordae attached to the aortic cusp and mural cusp of the mitral valve was 28- 91 and 33- 84 respectively. Basal zone chordae was present in mural cusp and the chordae attached to clear zone of aortic cusp was present in two specimens. Fan type branching was most common (97%),bifurcating type in 95%, dichotomous in 85% while anastamosis between two chordae tendinae was present in 52% of the specimen.Almost all the specimens with branched chordae in an individual heart had one, two or three tier branching at its insertion. Chordae muscularis was found in six while matted bundle of chordae tendineae was seen in one specimen. **Conclusions:** The present study helps in description and variation of morphology of chordae tendineae so as to improve mitral valve surgeries.

Key words: Chordae tendineae, chordae, cusps, mitral valve, morphology.

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INTRODUCTION:

The mitral valve complex includes the left atrioventricular orifice and its annulus, leaflets of the mitral valve, chordae tendineae and papillary muscles.[1,2,3] The operating surgeon has to keep in mind the biodynamic considerationsbefore proceeding with a prosthetic valve replacement.[4] Eversion of the free edgesof cuspsinto the cavity of the atrium is prevented by the pull of the marginal chordae, whileballooning of the cusps towards the atrium is prevented by centrally attached chordate.[2] Chordae tendinae are fibrous strings that originate from the apical portion of the left ventricular papillary muscles or directly from the ventricular wall[5] and these inserteither singly or after multiple division into the aortic as well as the mural cusps (Figure1). True chordae are those that insert into the valve; False chordae connect papillary muscles to each other or to the ventricular wall.[3] According to their attachments to the leaflets of valve chordae tendineae are classified as follows- commissural, cleft, marginal, rough zone, deep and basal[3]. The arrangement and classification of the chordae including the anatomy of the entire valve complex have been described by Walmsley (1929) and then more by Lam et al. (1970) in details.

Originally Tandler and laterQuain classified chordae tendinae as 1st order, 2nd order, and 3rd order. 1st order chordae are inserted into the free margin of the leaflet. The second 6-8 mm beyond the free margin on the ventricular surface and the third into the basal surface of the leaflet on its ventricular aspect.[5]

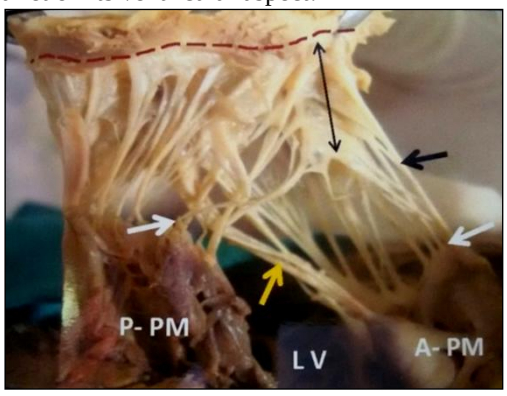

Figure-1: Mitral valve complex showing: A-PM= Anterior papillary muscle, P-PM= Posterior papillary muscle, LV= Left ventricular cavity. Chordae tendinae is seen arising from apex of papillary muscles (white arrow) and inserting into both aortic (black arrow) and mural cusp (yellow arrow). Red dotted line is attached margin of mitral valve. Black double arrow = aortic cusp.

There is a marked variation between the arrangements of the chordae amongst individual hearts. Variations including abnormal site of attachments, branching, matting or fusion of chordae, presence of false tendons as well as muscularization of chordae tendineae have been found in the present study. Various studies suggest that the unsupported areas of the free edge of the valves become prone to prolapse later.[3] Preservation of chordae tendinae is important for left ventricular function after mitral valve surgical procedures. If there is any laxity in reattachment of the chordae leads to mitral valve prolapse[6].

Highlighting the role of chordae in proper functioning of the mitral apparatus, a detailed gross morphology of chordae tendineae of the mitral valve becomes very important and their variations can be applied to improve various surgical repair techniques which justify the need to undertake the present study.

MATERIALS AND METHODS:

The research specimens consisted of 98human hearts of both sexes, aged approximately 65years, without any grossly visible pathologic lesions that were available in the department of anatomy, Sri Aurobindo Medical College and P.G. institute, Indore (M.P.). All hearts were fixed in 10% formalin.

Before dissection, they were thoroughly washed. Sternocostal surface of left ventricle was incised near the apex for 1cm, close to the anterior interventricular sulcus and after probing it with finger, the incision was extended without disturbing the mitral components to expose the cavity. The incision extended such that the aorta was slit open and its valve remain intact and the ventricular surface of anterior leaflet of the mitral valve is visualized in its whole extent. The cavity was washed with the jet of running water to remove blood clots. Then, the left atrium was completely removed so that the annular attachment of the mitral leaflets can be visualized from superior aspect. In order to visualize the posterior leaflet, the valve is precisely dissected along its annulus from the diaphragmatic surface of the ventricular wall.

A detailed morphological analysis of chordae under various parameters such as number, the pattern of branching, and level of insertion of chordae to both the leaflets was observed carefully using metallic hooks and hand lens. Observations were evaluated statistically (using SSPS).

RESULTS:

Chordae tendinae arises from apical segment of anterior, posterior and accessory papillary muscles in 89 (90.8%), 83 (84.6%) and 60 (61.2%) of the specimens respectively.Number of chordae tendineae arising from both the papillary muscles and attachment to the cusps was enumerated. It was found that higher number of chordae to arise from anteromedial papillary muscle. Chordae tendinae that arise from the apex of anterior papillary muscle was in range 6- 21 (mean= 12.45, S.D= 3.16 and median= 12). Number of chordae tendineae that arise from posterior papillary muscle was in range 3-22 (mean= 9.67, S.D= 3.85 and median= 10).From accessory papillary muscles other than the major muscles, range of chordae tendinae was 0-14 (mean=3.67, S.D= 4.02 and median= 3). Here, minimum was zero because in most of the specimens accessory muscles were absent.Range of chordae tendineae attached to the aortic cusp was between 28- 91, while the median was 50. Minimum to maximum number of chordae attached to the mural cusp was 33- 84 and median number was 56.

According to its level of attachment to the cusp there was marginal, rough zone, basal, commissural and cleft chordae (Figure3, 4). The number of marginal chordae attached to mural cusp (median= 31) was little more than that of the aortic cusp (median= 29) and range of marginal chordae attached to aortic cusp and mural cusp was between 14- 49 and 21- 49 respectively. The range of rough zone chordae for aortic cusp is 9-48 and that for mural cusp is 6-44. Basal zone chordae was present in mural cusp with range: 4- 17and median: 11 but in one specimen aortic cusp had a chordae inserted close to the attached margin of the cusp (Figure 6). Chordae tendinae attached to the clear zone of anterior cusp was present in two specimens (Figure 5, 6).

Various pattern of branchingsuch as chordae branching from a single stem (fan type), dichotomous, bifurcating and anastamosing pattern was observed (Figure2, 3). More than one type of branching pattern was present in most of the specimen. Fan type pattern was most common (97%). Chordae tendinae arising from papillary muscles can be branched or single can be either thick or thin. Range of thick chordae wasbetween 4-18 and medianis 9, while range of thin Chordae was between 5-31 and median number is 16. Basal zone chordae tendinae also had a typical triangular flaring or widening at its insertion to the cusp (Figure4). It was found in almost all the specimens that the branched chordae in an individual heart had one, two or three tier branching at its insertion (Figure3). One tier was usually present when branching was bifurcating type (Figure2) and two or three tiers were present when chordae tendinae was dichotomous or fan type (Figure3).

Both single as well as branched chordae were present at the commissures.It was found that in some specimenscommissural chordae arise from ventricular septal wall (Figure7) or from a separate muscle head (Figure8). Anterolateral and posteromedial commissural chordae arises from separate muscle head in 7% and 18.4% of the specimen respectively.Amongst branched chordae at commissures, the dichotomous type of chordae tendinae was found in 10% while rest of 90% was fan type.

Muscular or fleshy chordae (chordae muscularis) was observed in sixspecimens (Figure 9). In three specimens, muscular chordae arises from the posteriomedial papillary muscles, in two specimens it arises from anterolateral papillary muscles, while in one it arise from both the papillary muscles. It was inserted in either aortic or mural cusp. Range of length was between 1 to 1.4 cm. In most of the specimens false tendons were also observed

connecting the two papillary muscles between the papillary muscles and the ventricular septum and between papillary muscle and the ventricular wall. In one Specimen, it was observed that the chordae fused and matted with one another forming a thick and wide mass soon after its origin from the papillary muscle and inserted into the mural cusp (Figure10).

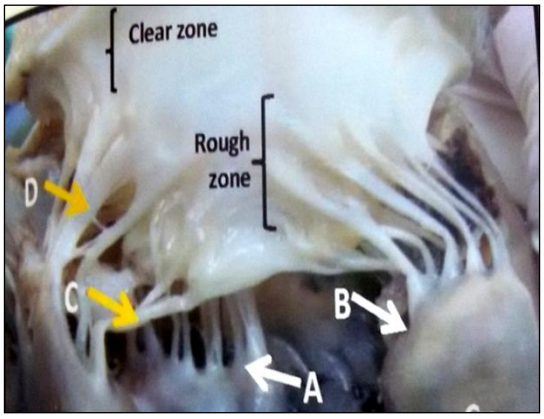

Figure-2. Showing rough and clear zone of ventricular surface of aortic cusp. A and B= Origin of chordae from papillary muscles. C= Bifurcating chordae inserting into margin, D= Anastamosing pattern inserting into rough zone.

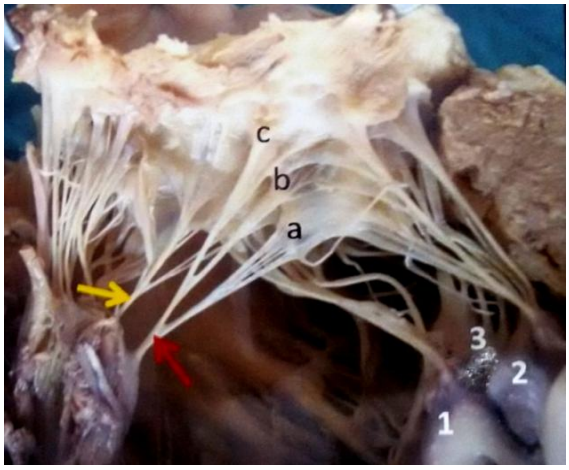

Figure-3. Showing commisural chordae fan type (yellow arrow), dichotomous branching and typical rough zone (red arrow) chordae inserting at 3 levels (a= margin, b= rough zone, c= junction of rough and clear zone. 1,2,3= multiple apex of papillary muscle

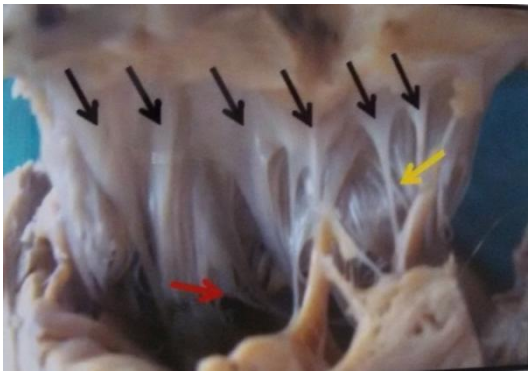

Figure-4. Ventricular surface of mural cusp showing basal zone chordae (black arrow), rough zone chordae (yellow arrow) and marginal chordae (red arrow)

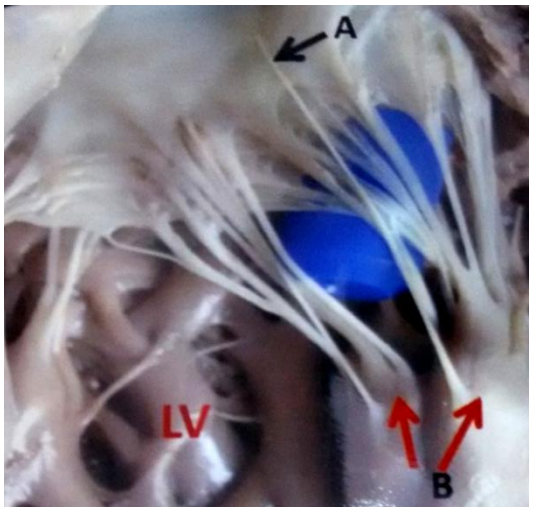

Figure-5. Showing clear zone chordae (A) of aortic cusp, B= origin, LV= Left Ventricle.

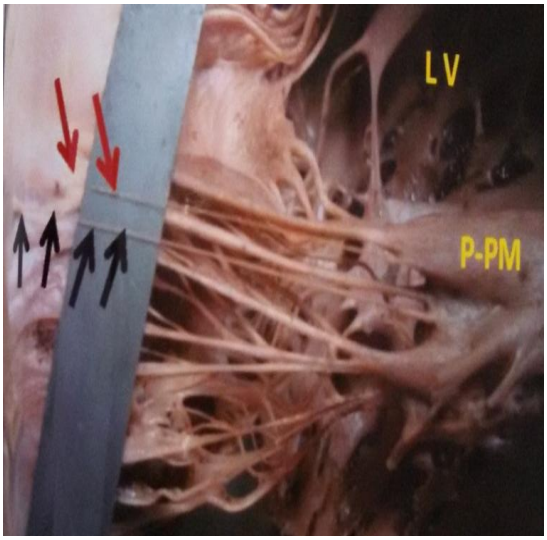

Figure-6. Showing one very thin chordae reaching attached margin (black arrow) and one at the clear zone (red arrow) of aortic cusp. LV= Left Ventricle, P-PM= posterior papillary muscle.

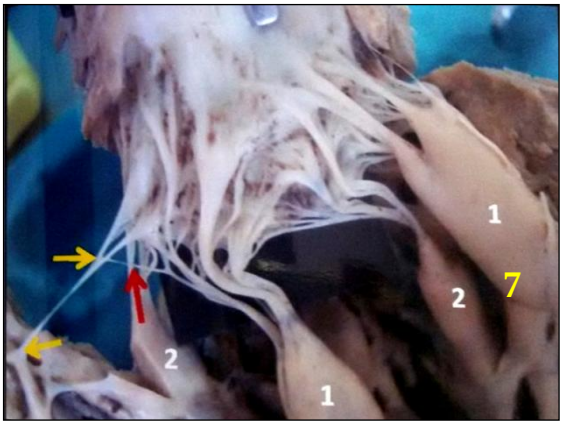

Figure-7. Showing commisural chordae bifurcating and arising from septal wall (yellow arrow) and anastamosing with another (red arrow). 1,2 = two anterior and two posterior papillary muscles.

Figure-8. Showing commisural chordae arising from separate muscle head (yellow arrow).

Figure-9. Showing very thick peculiar chordae muscularis which is bifurcating (red arrow).

Figure-10. Ventricular surface of the mural cusp showing very thick, wide and matted bunch of chordae (black arrows) reaching up to basal zone.

DISCUSSION:

HasanOzan et al. (2012) observed that 2- 15 chordae tendinae can originate from the apex of papillary muscle and 9- 60 chordaeinserted into the valve[7]. According to Roberts and Cohen (1972) each papillary musclehas an average of 12 chordaeper head[8]. While Kavitha S. et al. (2014)found that the total number of chordae in anterior papillary muscleranged from 7- 16 (mean: 10.42) chordae. The total number of chordae in the posterior papillary muscleranged from 6- 17 (mean: 9.72)[6].In present study the chordae that arise from anterior papillary muscle was 6- 21 (mean: 12.45), from the posterior papillary muscles was 3-22 (mean: 9.67) and from the other accesssory papillary muscles it was 0- 14 (mean: 3.67). Findings in the present study were almost similar to Roberts and Cohen (1972) and HasanOzan et al (2012) and the mean number of chordaefor posterior papillary muscles was found very close to that observed by Kavitha S. et al (2014). In present series it was observed that anterior and posterior cusp had 28-91(median: 50) and 33- 84 (median: 56) chordae attached to it respectively which wasclose to that reported by Victor and Nayak (1995).

Though most of the workers accounted for the total number of chordal attachment to the cusp, but they did not mention the number of chordae attached to various zones of each cusp. In present study it was found that median number of chordae attached to margin and rough zone of anterior cusp was 29 (14- 49) and 22 (9- 48) respectively and that of the posterior cusp was 31 (21- 49) and 22 (6- 44) respectively, while the median number of basal chordae at posterior cusp was 11. Number of marginal chordae was noted a little higher than other chordae. Lam et al. (1970)[5] found basal chordae in 31 of the 50 specimens while in this study it was observed that basal chordae tendineae in 100% of the specimens in the posterior cusp and clear zone chordae tendinae in anterior cusp was found in 2 specimens. No other worker mention for the presence of clear zone chordae tendineae.

Becker & De Wit (1979) described the deficient chordae as chordae with atypical branching pattern that could lead to mitral valve prolapse[9]. In present study various types of branching was seen and fan type pattern (branching from single stem) was most common (97%) bifurcating type was found in 95%, dichotomous in 85% while anastamosis between two chordae tendinae was present in 52% of the specimen. Presence of fan type of chordae tendinae in commissural area was described by Lam et al. (1970)[5] and Interchordal bridges were observed in most of the branching chordae tendinae by Khan A. A. (2012)[10] but other pattern of branching was not specifically eluded by other workers in this field. Kavimani et al. (2011) reported fan like chordae at commissures in 100%[11]. In present series, dichotomous type of chordae was found in 10% of specimens in commissural area while majority was fan like and very fewspecimen also had unbranched chordae tendinae at commissures. Senthilkumar et al. (2013) in their study found absence of commissural chordae in 3.07% [12] while in present study presence of commissural chordae was observed in 100% of the specimens.

SY Ho (2002) observed the occasional presence of muscularisedcordae with diameter 3mm attached to anterior cusp[13]. Lam et al. (1970) found fleshy and muscular chordae in 8 specimens and in all of them chordae inserted into anterior cusp with average length

2cm and thickness 0.3cm[5]. In present study muscular chordae was present in 6 specimens and was found to insert to both anterior as well as posterior cusp with length 1- 1.5cm, thickness was not measured.

In 1 Specimen, it was observed that the chordaetendinae fused and matted with one another forming a very thick and wide mass soon after its origin from the papillary muscle and inserted into the mural cusp. Brock R. C. (1952) mentioned that in the more severe grades of rheumatic valvitis, the chordaetendineae become thickened and matted together; these may form a thick barrier as much as a centimetre or more in both width and constitutes a grave obstacle to the effective surgical relief of mitral stenosis [14].

CONCLUSIONS:

The available literature suggests the clinical significance of preservation of chordae tendineae for the optimal post surgical left ventricular performance of the mitral valve. The present study provides the comprehensive knowledgeof arrangement of chordae tendineae to the cusps and its variations can be applied to prosthetic valve replacement in selection of mitral valve prosthesis as well as other surgical techniques such ascommissurotomy. Also the efficient mechanical closure of mitral valve is possible only when chordae tendineae are properly aligned. Further work on the subject shall include histological aspects to deepen the available knowledge and elaborate future perspective.

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