Importance of the Mitral Subvalvular Apparatus for Left Ventricular Functional Anatomy

By

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Summary: The mitral subvalvular apparatus is so important to attain the integrity of the left ventricular geometric model and systolic pump function of the heart. We conducted a detailed dissection of the anatomic structure of mitral valve complex and left ventricle of 10 adult hearts from fixed human cadavers (eight male and two female) at Department of Anatomy, Faculty of Medicine of Istanbul University and Department of Cardiovascular Surgery, Koşuyolu Heart and Research Hospital. The distribution of chordae tendineae and classification of musculus papillaris were recorded. The distribution of chordae tendineae varied slightly both anterior and posterior groups. Musculus papillaris was not symmetrical in all subjects. Four type of musculus papillaris were distinguished. The insertio angulus of musculus papillaris varied between 20° and 55°. The left ventricular distances (inflow-outflow) and axes (short-long) were determined as the criteria, together with the mitral subvalvular apparatus, to gain the architecture of the left ventricle. We believe that the goal a more precise data collection and developed model will influence our understanding of functional anatomy of left ventricular subvalvular apparatus, and concept of changes in left ventricular configuration after mitral valve surgery.

The mitral valve is an integral part of the left ventricle so its anatomical presence plays an essential role in the left ventricular geometry and mechanics⁷⁾. The mitral valve is not only a plain heart valve for prevention of back flow during left ventricular ejection, but also functional part of a very complex pumping chamber^{12,24)}. The mitral valve leaflets are connected to the left ventricle wall by annulus, chordae tendineae and papillary muscles. Papillary muscles are considered as branches of the intramural myocardial fibers which originate from the atrio-ventricular ring, head towards to apex, rise up again and radiate into the papillary muscles^{3,14)}. All these elements work together to make a functional unit, supporting the ejection of blood during systole.

Material and Methods

Ten human hearts were obtained from fixed

human cadavers (eight male and two female) who had expired due to noncardiac causes. Ten human hearts were dissected to elucidate the clinical anatomy of these purportedly anatomosurgical segments together with the arrangement of left ventricular architecture.

The left atrium was open and then a catheter was inserted through the aortic outflow tract, and saline solution was injected to pressurize the left ventricle and check for any regurgitation or incompetence due to chordal or leaflet abnormalities. The left ventricle was entered transaortic route. The left ventricle wall was opened from anterior wall through left ventricle outflow tract (Fig. 1).

The distribution of chordae tendineae was analyzed by categorizing each chordal structure, noting the following:

- 1) the insertion to the valve structure (anterior or posterior leaflet)
- 2) the location in relation to the leaflet edge (marginal, secondary, basal),

3) the number of each group (anterior marginal, anterior secondary, posterior marginal, posterior secondary, posterior basal).

Musculus papillaris anterolateralis and Musculus papillaris posteromedialis classification and measurements were recorded by each division, noting the following:

1) the relationship between the heads and chordal distribution,

2) the number and the type of each papillary muscle subdivision,

3) the insertio angulus between papillary muscles.

Four types of musculus papillaris were identified^{21,26}. In Type I musculus papillaris was single. In Type II musculus papillaris had two heads, one of which sent chordae exclusively to the posterior leaflet. In Type III musculus papillaris was also divided, one head supporting the commissural area exclusively. Type IV musculus papillaris was rather complex than Type III (Fig. 2).

All diameter measurements were performed by laying 4-0 suture along the dimension to be measured and then the suture was pulled straight and compared to a compass.

Left ventricular measurements were made of the following structural dimensions:

- 1) the inflow distance (mitral valve to apex)
- 2) the outflow distance (apex to aortic valve)
- 3) the short axis (musculus papillaris level)
- 4) the long axis (mitral leaflets level)

Results

The mitral subvalvular structures records were analyzed according the parameters which were de-

scribed above.

The distribution of chordae tendineae varied slightly both anterior and posterior groups (Table 1). The number of anterior marginal chordae tendineae was ranged 3 to 6 (mean: 4.5). The number of anterior secondary chordae tendineae was ranged 3 to 4 (mean: 3.8). The number of posterior marginal chordae tendineae was ranged 4 to 10 (mean: 5.2). The number of posterior secondary chordae tendineae was ranged 3 to 14 (mean: 4.7). The number of posterior basal chordae tendineae was ranged 0 to 7 (mean: 3.3). The distribution of posterior chordae tendineae were determined in large range due to posterior leaflet scallops. Most chordal origins from both papillary muscles split to insert into the valve leaflets at both marginal and secondary positions.

Musculus papillaris were not simetrical in all subjects. Four type of musculus papillaris were distinguished (Table 1).

Type I: This type of musculus papillaris was undivided. Type I was observed 20% (in 2) of anterolateral papillary muscles, and 0% (in 0) of posteromedial papillary muscles.

Type II: This type of musculus papillaris was divided along a sagital plane into two heads. One head supported the posterior leaflet exclusively. The other head was related to the commissural region and to the anterior leaflet. Type II was the most common presentation and observed 60% (in 6) of anterolateral papillary muscles, and 50% (in 5) of posteromedial papillary muscles.

Type III: This type of musculus papillaris was divided in a coronal plane into multiple heads. A single head related to the commissural zone. The remaining heads supported the chordae to the anterior and posterior leaflets. The different heads

Table 1. Chordal distribution and papillary muscle classification

NO	A Mar Ch	A Sec Ch	P Mar Ch	P Sec Ch	P Ba Ch	PM Angle	AL PM	PM PM
1	4	4	5	4	3	30°	I	II
2	4	3	5	4	2	25°	II	II
3	3	3	5	3	2	20°	II	II
4	4	4	5	4	1	30°	III	III
5	4	4	10	14	6	25°	II	III
6	5	4	4	4	7	40°	I	IV
7	6	4	6	5	0	55°	II	II
8	5	4	4	3	4	20°	IV	IV
9	5	4	4	3	4	25°	II	III
10	5	4	4	3	4	35°	II	II
AVERAGE	4,5	3,8	5,2	4,7	3,3	31°		
MIN	3	3	4	3	0	20°		
MAX	6	4	10	14	7	55°		
MEDIAN	5	4	5	4	4	28°	II	II

A: Anterior, Mar Ch: Marginal Chordae Tendineae, P: Posterior, Sec Ch: Secondary Chordae Tendineae, PM: Papillary Muscles, Ba Ch: Basal Chordae Tendineae.

Table 2. Left ventricular dimensions

NO	INFLOW (mm)	OUTFLOW (mm)	SHORT AXIS (mm)	LONG AXIS (mm)
1	67,00	76,00	22,00	32,00
2	72,00	87,00	28,00	32,00
3	62,00	67,00	23,00	26,00
4	63,00	80,00	31,00	45,00
5	78,00	82,00	38,00	42,00
6	78,00	91,00	48,00	52,00
7	70,00	79,00	41,00	48,00
8	81,00	81,00	42,00	47,00
9	71,00	80,00	38,00	41,00
10	72,00	81,00	31,00	40,00
AVERAGE	71,14	80,38	34,13	40,50
MIN	62,00	67,00	22,00	26,00
MAX	81,00	91,00	48,00	52,00
MEDIAN	71,00	80,50	34,50	43,50

originated from the same level on the ventricular wall. Type III was observed 10% (in 1) of anterolateral papillary muscles, and 30% (in 3) of posteromedial papillary muscles.

Type IV: This type of musculus papillaris was complex and characterized by division along coronal plane and by staged origin of the different heads. Type IV was observed 10% (in 1) of anterolateral papillary muscles, and 20% (in 2) of posteromedial papillary muscles.

The insertio angulus of musculus papillaris varied in a large range between 20° and 55°. The mean was 30.63° and the median was 27.50°.

The left ventricular geometry depended on certain dimensions (Table 2). The mean inflow distances (mitral valve to apex) of left ventricle was found 71.4 mm (ranged 62 to 81 mm). The outflow distance (apex to aortic valve) of left ventricle was found 80.4 mm (ranged 67 to 91 mm).

The mean short axis (papillary muscles level) of left ventricle was measured 34.1 mm (ranged 22 to 48 mm) and the mean long axis of left ventricle was measured 40.5 mm (ranged 26 to 52 mm).

The left ventricular distances (inflow-outflow) and axes (short-long) were determined as the criteria, together with the mitral subvalvular apparatus, of architecture of the left ventricle.

Discussion

If advances in cardiac surgery are to continue into the twenty-first century, it will be necessary to concentrate on details of matters especially anatomy of the heart^{13,15,18}. Cadaveric studies are the basis for surgical anatomy and new surgical methods before they are applied in patients¹. Our data provides insight into mitral valve structure and

function.

First publications on the surgical anatomy of the mitral apparatus were by Brock and Rusted in 1952^{2,23}. More knowledge about the morphology of mitral subvalvular apparatus was published by authors throughout the 60's^{5,8}. In the early 70's, Lam and Ranagathan introduced the mitral valve nomenclature that has been accepted widely in cardiac surgery^{17,22}.

Left ventricular function improves if the continuity between the papillary muscles and leaflets is preserved in mitral valve operations^{4,16,25}. Authors have noted a significant reduction of the ejection fraction in patients with mitral regurgitation after mitral valve replacement (MVR) without preservation of the subvalvular apparatus^{19,27}. Cardiac function after MVR for chronic mitral regurgitation has been reported to be impaired owing to postoperative elevation of left ventricular afterload and postoperative management of severe cases using conventional MVR is sometimes troublesome⁶.

During conventional mitral valve replacement, leaflets, chordae tendineae and part of musculus papillaris are resected. If the subvalvular apparatus is excised, the left ventricle will be no longer stabilized in the major axis, and its size and shape are altered. The polygon of the forces in the left ventricle has broken up by loss of the anchoring point of the mitral valve apparatus. The left ventricular geometry and architecture are changed by resection procedure^{9,10}. The mitral annulus is a dynamic structure that undergoes alterations in size and shape throughout the cardiac cycle, contracting during systole. Numerous reports have shown this systolic orifice reduction to be due mainly to posterior annular contraction, whereas the anterior perimeter was unchanged during left ventricular

ejection¹¹⁾. The systolic motion of the mitral annulus is very important for normal mitral valvular function and closely linked to overall left ventricular systolic function. The upward displacement of the anterior mitral annulus away from the left ventricular apex at end-systole may possibly minimize resistance to left ventricle outflow during ejection²⁰⁾.

We believe that the goal a more precise data collection and developed model will influence our understanding of left ventricular subvalvular apparatus, and concept of changes in left ventricular geometry after mitral valve surgery. The aim of this study was to obtain further understanding and knowledge about not only mitral valve functional anatomy, but also mitral valve pathology.

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Explanation of Figures

Plate I

Fig. 1. The mitral subvalvular apparatus through left ventriculectomy.

Plate II

Plate II

Fig. 2. The papillary muscles classification.