

Original Research Article

DISPARITY IN MORPHOLOGY OF PAPILLARY MUSCLES OF THE MITRAL VALVE COMPLEX WITH SURGICAL SIGNIFICANCE

Prithvi Chandra Vadlamani ¹, Preeti Shivshankar Awari ^{*2}.

¹ 2nd year MBBS student, Dr. D. Y. Patil Medical College , Hospital and Research centre, Dr. D.Y. Patil Vidyapeeth, Pune, Maharashtra, India.

^{*2} Assistant professor, Department of Anatomy, Dr. .Y. Patil Medical College, Hospital and Research centre, Dr. D.Y. Patil Vidyapeeth, Pune, Maharashtra, India.

ABSTRACT

Background: The mitral valve apparatus, consisting of the mitral valve leaflets and commissures and sub-valvular apparatus- papillary muscles and chordae tendinae; is one of the most complex and intricately designed structures present in the human body and therefore the understanding of anatomical variations of papillary muscles becomes important for surgical interventional procedures, in response to the increasing incidence of valvular heart defects. The aim of the cadaveric analysis was to identify the disparity in the morphometry of the papillary muscles of the mitral valve complex. Therefore this study was taken up with an effort to extend the concepts previously presented as well as to overcome deficiencies in the knowledge of gross architecture and positional nomenclature of the papillary muscles.

Materials and methods: Fifty formalinized cadaveric hearts were the material for study. Papillary muscles of left ventricle were classified according to a system developed by Berdajs et al., (2005), by precisely measuring shapes lengths and widths.

Results: The significant outcome of this study indicates that no two papillary muscles out of the 50 specimens had the same size, shape or position. All the hearts had two distinct groups of muscles – anterolateral and posteromedial. Specific analysis of each group revealed data regarding the muscles. In the antero-lateral group of the specimens, the maximum height and width of the muscles was 37.40mm and 17.06mm respectively and in the postero-lateral group, 33.86 and 26.90mm respectively. Conical shaped muscles were the most commonly found muscles owing to the minimum obstruction posed by them to blood flow.

Implication: Better understanding of morphological variations can help cardiothoracic surgeons to customize surgical procedures according to the papillary muscle pattern of the individual patient.

KEY WORDS: Papillary Muscles, Mitral Valve Complex, Realignment, Papillary Muscle Repositioning, Mitralvalve Homograft Implant.

Corresponding Author: Dr. Preeti Awari, Assistant professor, Department of Anatomy, Dr. .Y. Patil Medical College, Hospital and Research centre, Dr. D.Y. Patil Vidyapeeth, Pune, Maharashtra, India. Mobile no: 9075001993 **E-Mail:** preetyawari@gmail.com; preetiawari18@gmail.com

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INTRODUCTION

The mitral valve apparatus is one of the most complex and intricately designed structures present in the human body, consisting of two main components as mitral valve leaflets with

commissure and sub-valvular apparatus which include papillary muscles and chordae tendinae. Appreciation of the role of left ventricular papillary muscles in closure of the mitral orifice during ventricular systole was a breakthrough

in clinical cardiology of the 1960's. Myocardial structures of the ventricles and papillary muscles have tremendous importance despite their small size [1].

The synchronous contraction of papillary muscles normally prevents mitral leaflet prolapse. Over the years, it has been established that fibrosis, necrosis or hypoxia of the left ventricular papillary muscles can lead to loss of contractility with varying degrees of mitral regurgitation [1].

Shape of the papillary muscles greatly affects the passage of blood flow. Usually described as conical shape of papillary muscles facilitate smooth cardiovascular physiology by posing minimum obstruction to blood flow. The chances of left ventricular outflow tract obstruction are higher in hypertrophy of fan-shaped papillary muscles and muscles with a broad apex. Increase in size and in the number of muscles may contribute to left ventricular outflow tract obstruction especially when it is accompanied with progression of hypertrophic cardiomyopathy.

As the incidence of valvular heart defects is increasing, information regarding the anatomical variations of papillary muscles can help the surgeon to restore the physical integrity of the mitral valve complex through procedures like realignment, repositioning, reconstructions and re-sectioning. Advanced and non-invasive modalities used for the detection and confirmation of anomalies require a thorough anatomical knowledge to interpret radiological images [2,3].

Though muscles are two in number as a rule, there are usually groups of papillary muscles arranged fairly close together. The muscles at their bases are sometimes fused or have bridges of muscular or fibrous continuity before their attachment to the ventricular wall. Extreme fusion could result in parachute malformation, with a potential valvular stenosis [4].

Our current knowledge of mitral papillary muscles suggests that their architectural arrangement, in each individual, is as unique as the pattern on their fingertips [2].

Thus, this cadaveric analysis aims to identify the disparity in the morphometry of the papillary

muscles of the mitral valve complex.

This study was done with an effort to extend the concepts previously presented as well as to overcome deficiencies in the knowledge of gross architecture and positional nomenclature of the papillary muscles.

Aims and Objectives: The overall aim of our study was to characterize and analyze the morphology of the papillary muscles of left ventricle to identify disparity amongst them.

MATERIALS AND METHODS

Materials: Dissection kit, Vernier Callipers, 50 formalin-preserved cadaveric hearts

Methodology:

1. Study design - A cadaveric observational study
2. Study population- Western Indian cadavers
3. Time duration of study- Two months
4. Sample size - 50 formalin fixed hearts from 50 cadavers.
5. Inclusion criteria- A total of 50 formalin-preserved hearts of human cadavers were used in this study
6. Exclusion criteria- Hearts with necrosed, fibrosed valves and papillary muscles were excluded from the study.
7. Procedure details- The hearts were first washed and the cavity of the left ventricle was opened by taking a longitudinal incision along the left border, which extended from the left auricle to the apex of the heart. Blood clots were removed and the chamber was washed with water to clearly visualise the papillary muscles [8].

Groups of the papillary muscles were identified:
1) Antero-lateral 2) Postero-medial groups.

The respective groups were classified according to the system devised by Berdajs et al., (2005), where the following three main groups of morphological variants of papillary muscle were defined [5]:

Group I: The first group includes muscles with one head and one insertion. The head of the papillary muscle was undivided and gave rise to all the chordae tendinae, which fanned out to corresponding parts of the leaflets.

Group II: this group includes a papillary muscle

with two heads either with separate or with common base. The dorsal head gave rise to the chordae tendinae supporting the posterior leaflet and the ventral head was related to the anterior leaflet of the mitral valve. This group was subdivided into two variants as follows:

Group II/A: Both heads had a common base.

Group II/B: Each head of papillary muscle having separate base. Total two in number

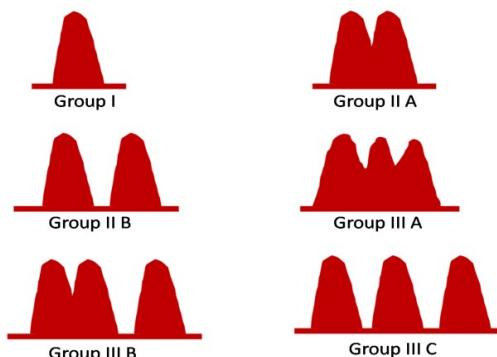
Group III: Muscles with three or more heads were included in this group. The head related to the commissural zone was found between the ventral and dorsal heads. The dorsal head supported the posterior leaflet and the ventral head supported the anterior leaflet of the mitral valve.

Group III/A : All three heads had a common base.

Group III/B : The origin of the papillary muscle was divided into two parts. One head with its separate base was totally divided from the other part of the papillary muscle and other two or more heads with common base

Group III/C : Each head of papillary muscle having its separate base. Total three or more in number

Fig. 1: Morphological classification of papillary muscles of left ventricle of heart.



Shapes of the muscles in each group were observed and noted.

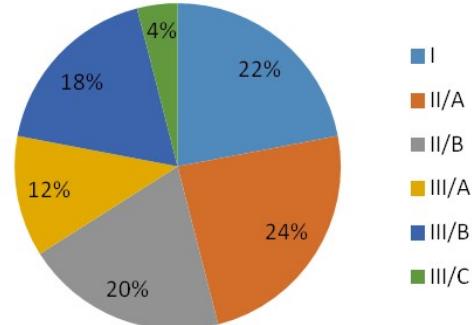
For measurement of height and width of these muscles, Vernier Caliper was used, which gave us precision upto two decimal places .The same methodology was used by Kavitha et al. (2018).^[9] The tallest papillary muscle in each group was measured and the width around the centre of each bundle taken.

OBSERVATIONS AND RESULTS

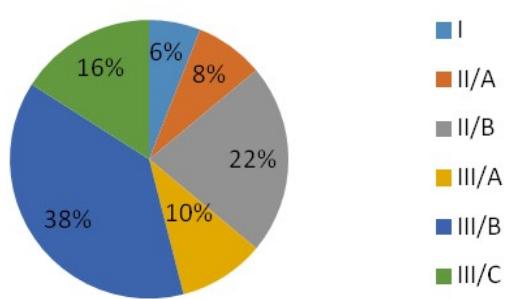
Following the general measurement procedures of Berdajs et al., (2005) [5], the shapes recorded

and height and width of each papillary muscle were measured and noted.

Pie chart 1: shows the percentage of various types of papillary muscles seen in anteroleteral group of mitral valve complex. In anterolateral group two groups were more common group I was seen in 22% specimens and group II/A was seen in 24% of specimens.



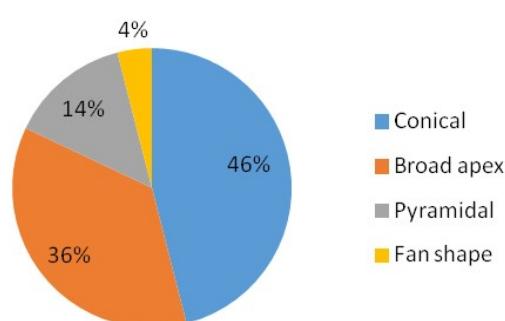
Pie chart 2: shows the percentage of various types of papillary muscles seen in posteromedial group of mitral valve complex. The most common type was III/B seen in 38% of specimens.



The average height and width of the antero-lateral group was 22.85mm and 9.71mm respectively. The average height and width of the postero-lateral group was 22.43mm and 11.87mm respectively. The tallest muscle in the anterolateral group was 37.40mm and in the posteromedial group was 33.86mm.

The thickest anterolateral group measured 17.06mm and the thickest posterolateral group measured 26.90mm.

Pie chart 3: showing percentage of various shapes of anterolateral group of papillary muscle of left ventricle. The most common shape in the AL group was Conical (46%) and the least common was Fan shaped (4%) .



Pie chart 4: Showing percentage of various shapes of posterolateral group of papillary muscle of left ventricle. The conical muscle shape was seen in 58% of hearts. There was no fan shaped muscle seen.

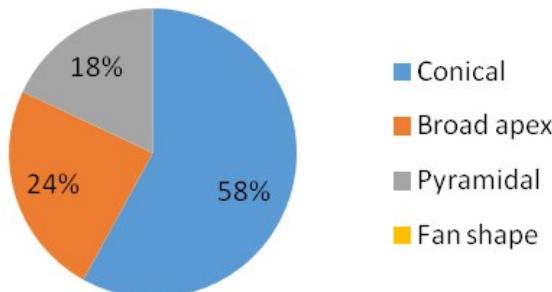


Fig. 2: Group I and IIA group of papillary muscle.

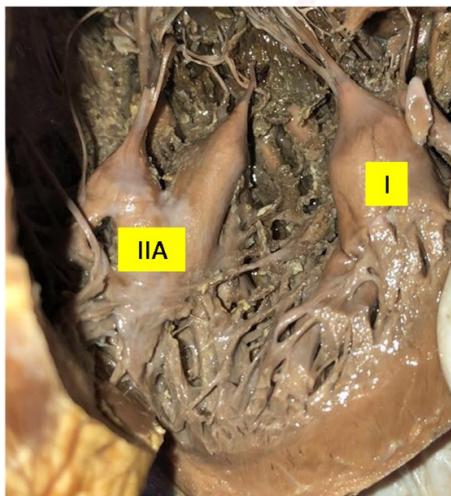


Fig. 3: IIB group in posteromedial papillary muscle.

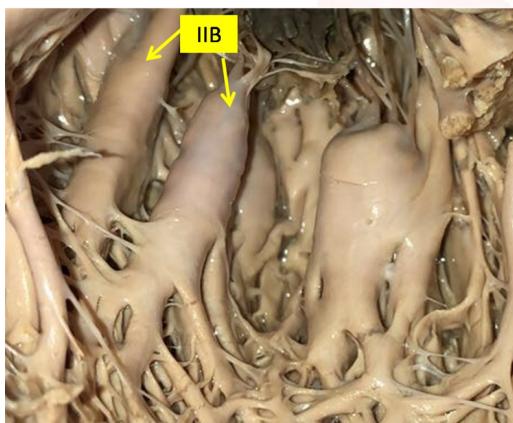


Fig. 4: IIIB group of papillary muscles.



Fig. 5: IIIC group of papillary muscles.



DISCUSSION

The mitral valve complex is subject to a high degree of wear and tear due to the high pressure gradient across it, and in this respect, is different from other valvular complexes. Any pathology of the mitral valvular complex assumes a higher degree of significance owing to its crucial role in cardiovascular physiology. Thus, it becomes the most common choice for research, but there are very few studies focusing on the morphology of the papillary muscle of the mitral valve complex.

Functional morphology of the papillary muscles:

One of the significant results of this study is that no heart had a set of single papillary muscles. They always occurred in groups in every specimen. This can be traced to their embryological development, wherein the papillary muscles develop from the trabecular myocardial ridge by a process of gradual delamination from the ventricular wall. Incomplete delamination of the trabecular ridge in the left ventricle could be the reason for variations in the morphological characteristics of papillary muscles. Myocardial infarction would not affect the functions of the mitral valve so far as there are more papillary muscles in groups. This results in the group being partially affected, and consequently, fewer dysfunctional chordae.

The shape of the papillary muscles affects the passage of blood flow. Usually described as conical shaped in standard textbooks, it is confirmed by the current study where, 46% (AL group) and 58% (PM group) of the specimens had conical-shaped papillary muscles. This is in accordance with the fact that conical shaped

papillary muscles pose minimum obstruction to the passage of blood flow, as was studied previously. Other shapes found in the present study included broad-apexed, pyramidal and fan-shapes for the papillary muscles. The chances of left ventricular outflow tract obstruction are higher in hypertrophy of fan shaped papillary muscles, which, as observed in the current study, is uncommon. Their realignment and repositioning is the treatment of choice for symptomatic left ventricular outflow tract obstruction and dysfunction [2].

Implications for corrective procedures: The advancement of open heart surgery paved the way to greater avenues in the knowledge of mitral valves. The structure of the valve and functions of supporting structures were then defined. Ranganthan and Lam (1970) devised a simplified description of the papillary muscle and chordae tendinae and introduced a basic nomenclature which has been used since.^[10] A detailed study of the subvalvular apparatus, carried out here, showed that three main types of papillary muscles exist. The type I papillary muscle is undivided. The apex of the type II papillary muscle is divided into two heads. According to the shape of basal part, this type is further divided into two subtypes. In type III the apical part consists of three or more heads. This type of papillary muscle is divided into three subtypes. With the recent revival of interest in homograft implantation and the introduction of endoscopic procedures in mitral valve surgery, the surgeons' attention has been newly focused on the morphology of the left ventricular subvalvular apparatus.

Accordingly, Victor et al., (1995) presented a classification describing the papillary muscle in figurative language as conical, grooved, wavy, staped and saucerised [6]. Krawczyk-Ożóg et al., (2017) published their work on the anatomy of the mitral valve, measuring the dimensions of papillary muscles and chordae tendinae, classifying the latter as well [3]. They did not classify papillary muscles on grounds of it being highly variable and subjective. Ramsheyi et al. (1996), in their presentation of the left ventricular subvalvular apparatus, defined four groups of morphological variants and included the relationship between the apical portion of

the papillary muscle and the mitral valve leaflets [11]. Their classification was proposed as a guideline for papillary muscle implantation in mitral valve homografting, although the basal parts of the papillary muscles were not defined. In the present study, however, papillary muscles have been classified based on apical as well as basal portions and implantation of the papillary muscle to the left ventricular wall is crucial for the success of this procedure. Mitral valve homograft implantation, could thus be an ideal solution for mitral valve replacement.

The number of papillary muscles forming the group must also be clinically important. Any ischemic event affecting the base of the papillary muscle would render all originating cords dysfunctional, leading to acute mitral regurgitation. Mitral valve complex repair is considered the gold standard of treatment for mitral regurgitation [12]. The physical integrity and physiology of the mitral valve complex is restored with procedures such as chordal shortening, realignment, repositioning, reconstructions and resectioning. Anterior leaflet prolapse caused by elongated chordae can always be addressed with papillary muscle repositioning by bringing down the anterior head and fixing the prolpase. Their dimensions, which would be of immense help to surgeons were thus taken in the current study. Therefore, papillary muscle infarction in a patient with multiple papillary muscle heads damages the sub-valvular apparatus to a lesser extent and would thus cause a smaller hemodynamic effect. Juxtaposing this, however, is the fact that size of the papillary muscle group increases gradually with the number of individual muscles, contributing more to LVOT obstruction, especially when accompanied with the progression of hypertrophic cardiomyopathy [13].

In conclusion, the present study has found considerable variations in the number, shape, dimensions and position of the papillary muscles. The findings neither matched those of other previous studies nor were they similar to the descriptions given in standard textbooks. No two mitral valve complexes have the same architectural arrangement, as each case seems to be unique. There is thus a clear need to conduct future large-scale studies across the

world to derive a better understanding of morphological variations in view of the fact that cardiothoracic surgeons may be able to tailor the surgical procedure according to the papillary muscle pattern of the individual patient.

CONCLUSION

In conclusion, no two papillary muscles out of the 50 specimens had the same size, shape or position. All the hearts had two distinct groups of muscles – anterolateral and posteromedial. Specific analysis of each group revealed data regarding the muscles.

In the antero-lateral group of the specimens, the maximum height and width of the muscles was 37.40mm and 17.06mm respectively and in the posterolateral group, 33.86 and 26.90mm respectively.

Anomalous variations such as interconnected papillary muscles, high end muscles, wrongly inserted chordae in the leaflets and chordae arising from the base of the muscle were observed.

Conical shaped muscles were the most commonly found muscles owing to the minimum obstruction posed by them to blood flow.

Future large scale investigations must be carried out to obtain more clarity on the variations such that surgical procedures can be executed with more precision.

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Conflicts of Interests: None

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