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Original Article

Anatomy Section

Morphological and Morphometric Study of Papillary Muscles in Adult Cadaveric Hearts: A Cross-sectional Study from Central India

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ABSTRACT

Introduction: A normal Atrioventricular (A-V) valve complex of the human heart comprises the A-V ring, cusps, chordae tendineae, and papillary muscles. Papillary muscles are small pillar-like myocardial structures that stabilise the position of the tricuspid and bicuspid valves. A detailed understanding of normal anatomy, as well as its possible variations, can help surgeons in various surgical repairs of valve prolapse and regurgitation involving the papillary muscles.

Aim: To review the morphology of papillary muscles in both ventricles.

Materials and Methods: This descriptive cross-sectional study was carried out on 60 formalin-fixed adult cadaveric heart specimens collected from the Department of Anatomy of Netaji Subhash Chandra Bose Medical College, Jabalpur, Madhya Pradesh, India from January 2023 to December 2023. These human hearts were carefully dissected to open both the right and left ventricles and expose the anterior, posterior, and septal papillary muscles. Different morphological features of the papillary muscles present in both ventricles were documented and photographed. The details collected were entered into an Excel sheet and analysed.

Results: In the present study, there were approximately 33 male adult human hearts and 27 female adult human hearts. The anterior and posterior papillary muscles were present in both the ventricles of all the hearts; however, the right septal papillary muscle was present in only 13 specimens (21.66%). The lengths of the right (15.22±4.642 mm) and left (19.61±5.24 mm) anterior papillary muscles were longer than those of the remaining papillary muscles. The breadths of the right (6.243±2.144 mm) and left (9.992±3.972 mm) anterior papillary muscles were wider compared to other papillary muscles. The anterior and posterior muscles predominantly appeared conical (100%), while the septal muscle was chiefly merged with the septal wall (83.3%).

Conclusion: In-depth knowledge of the normal and variable anatomy of the papillary muscles will help cardiac surgeons determine appropriate surgical repair procedures for the valvular complex and helps in dealing with pathological conditions such as valve prolapse or regurgitation.

Keywords: Anterior, Atrioventricular rings, Posterior, Valve, Ventricles

INTRODUCTION

Papillary muscles are small, pillar-like myocardial structures projecting within the cavities of the ventricles and are attached to their walls [1]. It is the conventional functioning of these muscles that upholds the integrity of the mitral and tricuspid valves [2]. There are three papillary muscles, namely the anterior, posterior, and septal muscles, in the right ventricle, and two, namely the anterolateral and posteromedial papillary muscles, in the left ventricle. These papillary muscles attach via chordae tendineae to the A-V valves. During right ventricular contraction, the papillary muscles draw the tricuspid annulus towards the apical surface. This, in turn, causes a shortening of the axis and an increase in the sphericity of the chamber for ejecting blood [3-6].

Due to an affluent lifestyle, heart diseases have become a significant cause of death, and valvular diseases contribute notably to the increasing morbidity and mortality rates. Artificial and cadaveric valves are used in replacement surgeries of cardiac valves. For the fixation of cadaveric heart valves, the operating surgeon should be well-versed in both the dimensions and architecture of the heart's valves [7]. Structural abnormalities of the papillary muscles can result in unexpected complications and the death of the patient. The rupture of a papillary muscle, which occurs 2-7 days after an acute myocardial infarction, is considered one of the most grievous complications, with mortality rates reaching 50% within the first 24 hours and potentially escalating to 90% in the following week without surgical intervention [1]. The tricuspid valve lesions that occur due to mechanical trauma are mainly due to some congenital variations, such as tricuspid atresia, congenital tricuspid valve regurgitation, and Ebstein anomaly [8]. Therefore, the current study conducted in Central India aims to highlight the morphological features of the papillary muscles in both ventricles of the heart, which have not been adequately addressed in previous research [8,9].

MATERIALS AND METHODS

This descriptive cross-sectional study was conducted in the Department of Anatomy at Netaji Subhash Chandra Bose Medical College, Jabalpur, Madhya Pradesh, India from January 2023 to December 2023. The heart specimens were used with consent from relatives. Ethical approval for the study was obtained from the Institutional Ethics Committee of the study institute (No. IEC/2022/4373-98).

Inclusion criteria: A total of 60 adult human hearts, irrespective of age (18-60 years) and sex, that were brought for autopsy in the mortuary—preferably from the vicinity of the study institute—were included, provided that the time of death was known.

Exclusion criteria: Heart specimens with visible deformities upon inspection, enlarged hearts, and those affected by diseases like cardiomyopathy, valvular abnormalities, and coronary artery disease were excluded from the study. Additionally, heart specimens from decomposed bodies, mutilated bodies, and those of individuals who

died from poisoning, drowning, burns, or any cutting or crushing injuries to the heart were also excluded from the study.

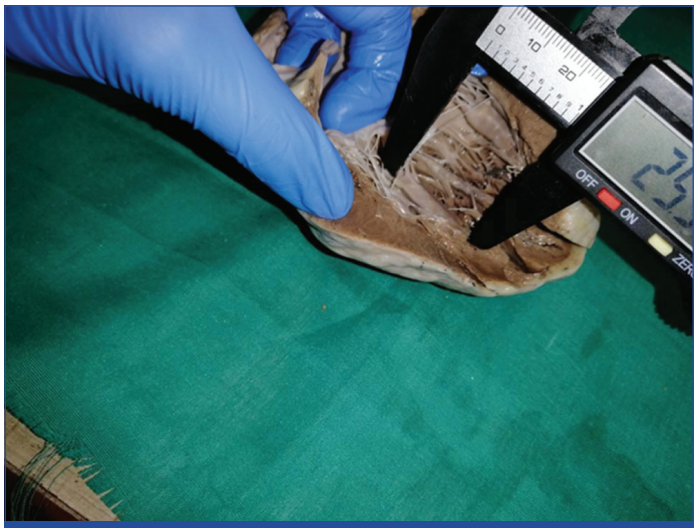
STUDY PROCEDURE

The collected heart specimens were immersed in a preservative solution of 10% formalin. The dissection procedure was carried out following the Cunningham manual [10]. The ventricles were opened by making vertical incisions from the right atrial wall to the apex of the right ventricle. Blood clots were removed, and the chambers were washed properly in order to visualise the papillary muscles accurately.

Detailed description of the dissection procedure: Dissection was performed according to standard techniques. The first incision was made by passing from the right atrium to the apex of the right ventricle through the ventricle's lateral margin. The second cut was made along the anterior surface of the heart, just to the left of the interventricular groove, extending from the apex of the ventricle to the annulus. The tricuspid valve complex was carefully dissected to avoid cutting the papillary muscles and the chordae tendineae attached to them. The right ventricle flap was then reflected inferiorly, and the interior of the heart was meticulously washed to remove blood clots from the ventricles, exposing the papillary muscles and chordae tendineae.

The cavity of the left ventricle was opened by making a longitudinal incision along the left border of the heart, extending from the left auricle to the apex of the heart. On the diaphragmatic surface of the left ventricle, a cut was made along the posterior interventricular sulcus, and a subsequent incision was made parallel to the left A-V groove. The left ventricle flap was then reflected laterally, and the interior of the ventricles was rinsed thoroughly to remove any remaining blood clots, allowing for clear visualisation of the papillary muscles and chordae tendineae.

A digital Vernier calliper (Mitutoyo) with a precision of 0.02 mm was used to measure the length of the papillary muscle (from tip to basal attachment) and the breadth of the papillary muscle (greatest horizontal length) [Table/Fig-1,2]. Variations in the number and shape of the papillary muscles, along with the thickness of both ventricles, were documented and photographed.



[Table/Fig-1]: Length measurement of papillary muscles.

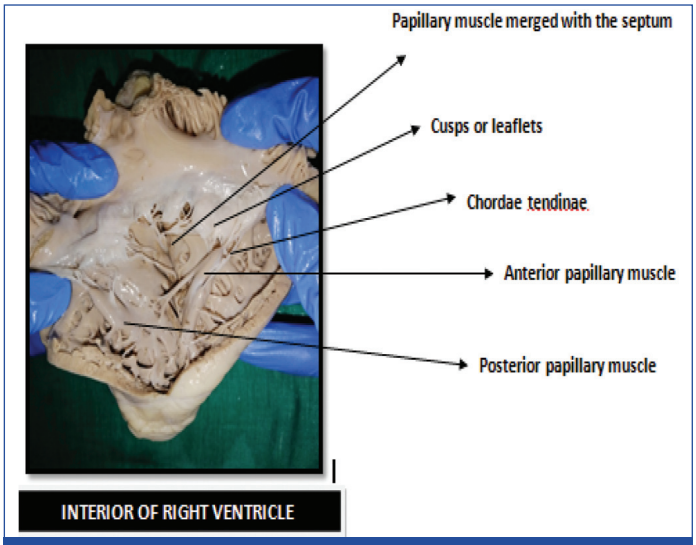
STATISTICAL ANALYSIS

The variables were entered into an Excel sheet and analysed. Normally distributed numerical data were presented as mean and range, while categorical data were presented as percentages.

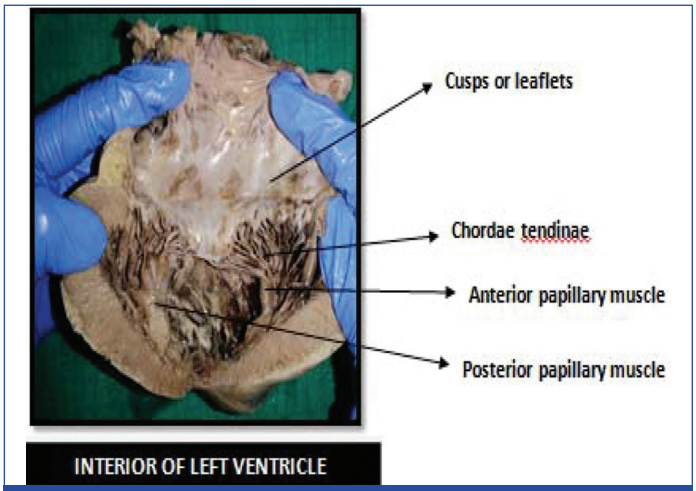
RESULTS

In the present study, conducted in the central part of India, the papillary muscles of the right and left ventricles were found in all 60 heart specimens (100%) examined. The interiors of the right and left ventricles are shown in [Table/Fig-3,4], respectively. However, the right septal papillary muscle was present in only 13 specimens (21.66%). In the right ventricle, all the anterior papillary muscles were predominantly cone-shaped in 53 specimens (88.3%) and had a broad apex in seven specimens (11.66%) [Table/Fig-5-7].

[Table/Fig-2]: Breadth measurement of papillary muscles.

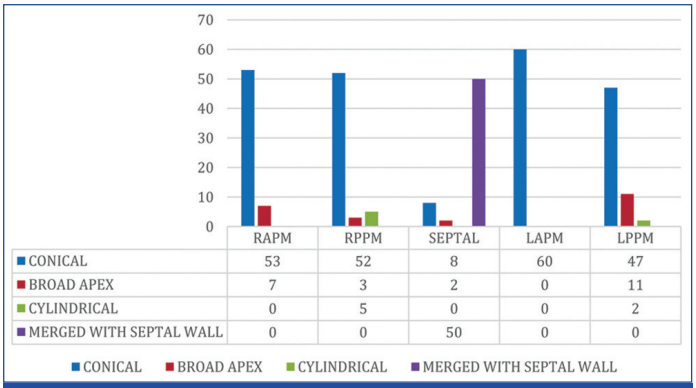


[Table/Fig-3]: Image showing the interior aspect of right ventricle.

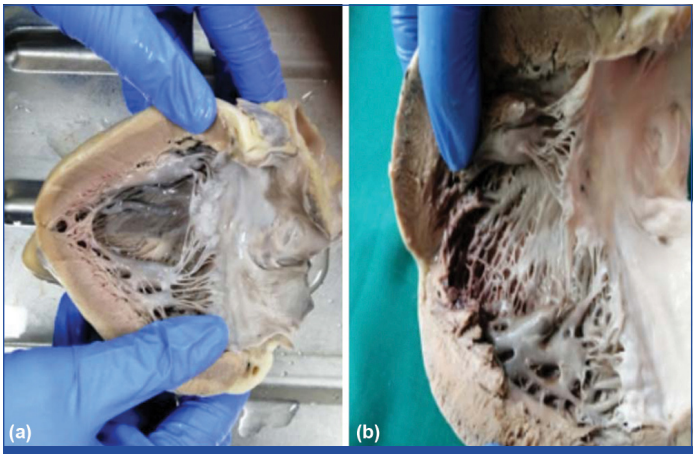


[Table/Fig-4]: Image showing the interior aspect of left ventricle.

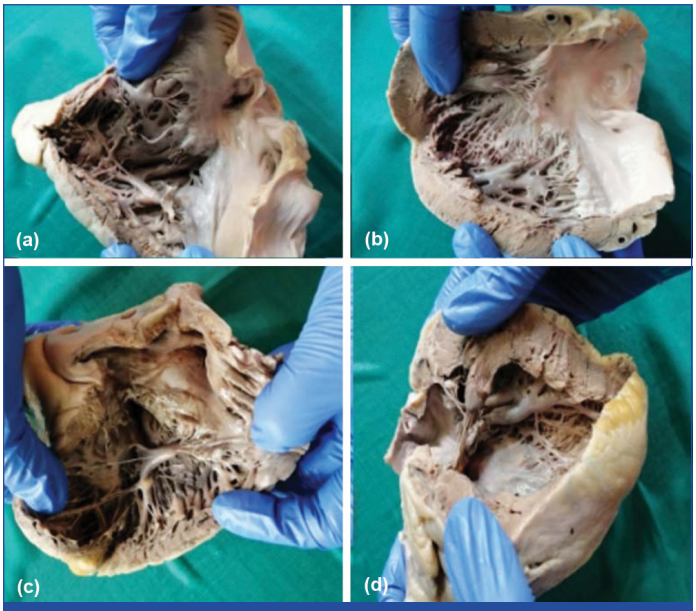
In current study, the length of the right anterior papillary muscle varied from 7.0 to 28.0 mm, with an average of 15.22±4.642 mm, compared to that of the remaining papillary muscles. Additionally, the length of the left anterior papillary muscle ranged from 6.9-30.0 mm, with an average of 19.61±5.24 mm, also compared to that of the remaining papillary muscles [Table/Fig-8]. When comparing



[Table/Fig-5]: Various shapes of papillary muscles in both ventricles.



[Table/Fig-6a,b]: The left ventricle's papillary muscle with a broad apex.



[Table/Fig-7a-d]: Conical papillary muscle of right ventricle.

the lengths of the left and right papillary muscles, the left anterior papillary muscle was found to be longer compared to other papillary muscles.

DISCUSSION

The quantitative and qualitative variations of papillary muscles are clinically significant, as they can precipitate ventricular outflow tract obstruction and severe valvular regurgitation, given that papillary muscles play a major role in ventricular contraction [2]. Cone-shaped papillary muscles pose minimal obstruction to blood flow compared to other shapes of papillary muscles. The findings observed in the present study are consistent with the results of previous studies [Table/Fig-9] [11-13].

Sr. No.	Authors and year of the study	Population	Sample size	Shape of papillary muscles
1.	Gunnal SA et al., [11] 2013	Maharashtra, India	116	Broad apex (48%)
2.	Bose P et al., [12] 2015	Uttar Pradesh, India	60	Broad apex (51.67%)
3.	Sinha et al., [13] 2020	Chhattisgarh, India	40	Pyramidal (51.4%)
4.	Present study 2024	Madhya Pradesh, India	60	Conical (88.3%)

[Table/Fig-9]: Documentation and comparison of the shapes of papillary muscles cited from previous studies [11-13].

Gunnal SA et al., conducted a study in 2013, in which they noted that the shape of the papillary muscle affects blood flow in the heart. In their study, it was observed that the majority of papillary muscles were conical in shape (45.51%), while others observed were pyramidal (26.73%), broad-apex (50.48%), and fan-shaped papillary muscles (12.93%) [11]. In the present study, the right anterior papillary muscles were predominantly cone-shaped in 53 specimens (88.3%).

Variations in the papillary muscles may influence the pathophysiological effects of various disorders. Fumimoto KU et al., mentioned in their study that surgical transposition of papillary muscles is performed in cases of mitral regurgitation involving the papillary muscles [14]. This procedure aims to achieve a better grip and improve function, as the papillary muscles are repaired despite differences in attachment, shape, and size [14].

Gerola LR et al., conducted a study on 50 hearts in Brazil and observed that the mean length of the right anterior papillary muscle was 9.0±2 mm [15]. A study conducted in Boston, USA, by Nigri GR et al., in 2001, on 79 hearts revealed that the length of the anterior papillary muscle in the right ventricle was 19.16 mm, the length of the posterior papillary muscle in the right ventricle was 11.53 mm, and the length of the septal papillary muscle was 5.59 mm [16]. In a study conducted on 96 hearts by Harsha BR and Dakshayani KR in South India, the mean length of the right anterior papillary muscle was observed to be 14.9 mm [17].

While comparing the lengths of the left and right papillary muscles in the present study, the left anterior papillary muscle was found to be longer compared to the other papillary muscles. The variations in morphometric values could be due to changes in the selection of geographic regions, racial groups, and variations in the sample sizes chosen.

Limitation(s)

The current study was conducted on only a few hearts in a specific part of Central India. Therefore, further research needs to be conducted on a larger scale to obtain more accurate results.

CONCLUSION(S)

The anatomy of the papillary muscles demonstrates significant diversity in each individual. They play an essential role in the

Variables	Right Anterior Papillary Muscle (RAPM)		Right Posterior Papillary Muscle (RPPM)		Septal papillary muscle		Left Anterior Papillary Muscle (LAPM)		Left Posterior Papillary Muscle (LPPM)	
	Length (mm)	Breadth (mm)	Length (mm)	Breadth (mm)	Length (mm)	Breadth (mm)	Length (mm)	Breadth (mm)	Length (mm)	Breadth (mm)
Mean±SD (mm)	15.22±4.642	6.243±2.144	12.23±5.244	5.87±2.57	2.36±5.58	1.2±3.17	19.61±5.24	9.992±3.972	18.9±5.55	9.152±3.227
Range	7.0-28.0	02.0-13.0	5.0-31.0	2.2-18.7	0 - 24.4	0-17.4	6.9-30.0	3.0-18.0	9.10-32.7	4.0-17.0

[Table/Fig-8]: Table showing the length and breadth of papillary muscles of right and left ventricles.

valvular function of the heart's chambers. In-depth knowledge of these morphological features of the papillary muscles and chordae tendineae is crucial for cardiothoracic surgeons when performing surgeries such as papillotomy and commissurotomy in cases of rheumatic heart disease, as well as papillary muscle realignment, repositioning, leaflet resection in myxomatous lesions, and valve repair or replacement.

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