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Original Research Article

Anatomical variations of papillary muscles in human cadaveric hearts of Chhattisgarh, India

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ABSTRACT

Background: In both ventricles of the heart papillary muscles play important role for proper cardiac valvular function of heart. The present study was done to analyse the papillary muscles of heart with respect to the variations in their number, length, shape, position and pattern in both ventricles.

Materials and Methods: Forty well preserved cadaveric human hearts were used for the study. The variations in the papillary muscles of both right and left ventricles were categorized, documented and photographed.

Results: In the right ventricle, authors observed 31.42% anterior, 34.3% posterior and 34.3% septal papillary muscles, and in the left ventricle, 41.7% anterior and 58.3% posterior papillary muscles. Classical papillary muscles were observed in 64.3% heart specimens in right ventricle and 55% in left ventricle. Authors found conical, pyramidal and broad apexed papillary muscles in 44.3%, 51.4% and 4.3% heart specimens respectively in right ventricle, whereas in left ventricle the corresponding values were 33.3%, 30% and 36.7%. Separate bases and fused apex pattern was observed in 24.3%, single base and divided apex in 55.7% heart specimens in right ventricle and in left ventricle in 45% and 43.3% heart specimens respectively. The length of anterior, posterior and septal papillary muscle in right ventricle was 1.27±0.45, 1.36±0.52, 0.92±0.54 cm respectively whereas in left ventricle, the mean length of anterior and posterior papillary muscles was 2.13±0.44 and 1.76±0.46 cm. In right ventricle mean thickness was 1.17±0.31cm whereas in left ventricle it was 2.16±0.32 cm.

Conclusion: The papillary muscles has complex and variable anatomy. Knowledge of this variation to the cardiac surgeons during reparative surgical procedures conducted for mitral/ tricuspid valve replacement is of utmost importance to prevent untoward event.

1. Introduction

The function of the ventricular papillary muscles is to prevent overextension by drawing atrioventricular valve annulus toward the apex.[1] In the right ventricle which has three papillary muscles, anterior papillary muscle is largest while the septal papillary muscle is relatively small. In the left ventricle, the two papillary muscles supporting the cusps of the mitral valve may be bifid and they also vary in length as well as breadth. It is well known that the closure of the atrioventricular valve during systole is regulated by the papillary muscle and their chordae. The right branch of the atrioventricular bundle passes through the moderator band or the septo-marginal trabecula which extends from the ventricular septum to the base of anterior papillary muscle and also prevents over distension of right ventricle. The large trabeculae including the moderator band are major hindrance for the repair of apical ventricular septal defects.[2] The anatomic variations of the tricuspid valve also occur in association with various syndromes and congenital anomalies. Chordo papillary variations have been found to be relevant in

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papillary muscle dysfunction, mitral valve prolapses, mitral valve replacement etc.[3] So the variability in number, length and the shape of the papillary muscles become clinically relevant.[4] The rupture and dysfunction of papillary muscles and chordae are mainly responsible for causing mitral valve prolapse. We know that embryologically the heart muscles develop from the trabecular myocardial ridge by process of gradual delamination of ventricular wall. So, incomplete delamination of trabecular ridge leads to morphological variations of papillary muscles.[5]

2. Materials and Methods

The study was conducted using forty well preserved adult cadaveric human hearts obtained from the department of Anatomy. The age (40-60 years approx.) and the cause of death of the cadavers was not known. The ventricles were opened by giving incisions along the anterior wall to expose the interior perfectly. The blood clots were removed and the chambers washed clearly with water in order to accurately visualise the papillary muscles. The variation in number, position, length, pattern and shape of the papillary muscles along with thickness of both ventricles were noted. The digital Vernier calliper (Mitutoyo) with 0.02 mm precision was used to measure the length of the papillary muscle (from tip to the basal attachment). With careful observation, the number of additional heads in papillary muscle was documented. The shape at the tip was classified as conical, broad-based and pyramidal. In both left and right ventricles, the variation of the papillary muscles were observed and divided into separate base & fused apex, single base and divided apex, small projections of papillary muscles, long papillary muscles, perforated papillary muscles and base attached to a large bridge (Figures 1, 2, 3 and 4). The values of the length of papillary muscles and thickness of both ventricles of cadaveric heart specimens were presented as Mean± SD and p value was calculated using student t-test (Table 2 and Table 3). Different variables of the papillary muscles were compared between two ventricles and p value was calculated by performing chi-square test (Table 1). P-value < 0.05 was considered as statistically significant. Statistical software SPSS 21 version was used for statistical analysis. Since the bodies were donated to the institution for teaching and research purpose, there was no ethical issue in reporting the present findings.

3. Results

The results are explained in Tables 1, 2 and 3. In our study we observed 44.3% conical apex, 4.3% broad apex and 51.4% pyramidal apex in right ventricles whereas 33.3% conical apex, 36.7% broad apex, 30.0% pyramidal apex in left ventricles. We also found the classical papillary muscles in 64.3%, 2 groups in 10%, 3 groups in 2.9%, 4 groups in 1.4% and multi-apical in 21.4% heart specimens in right ventricle whereas the classical papillary muscles were found in 55%, two groups in 28.3%, three groups in 3.3% and multi-apical in 13.3% heart specimens in left ventricle (Table 1, Figure 2). In current study, the thickness of the right ventricle varies from 0.40 to 1.70 cm with a mean thickness of 1.17 ± 0.31 cm whereas in left ventricle it varies from 1.50 to 2.70 cm with a mean value of 2.16 ± 0.32 cm. (Table 2).

4. Discussion

The anatomic variations of the papillary muscles found in cadaveric human hearts are the topic of academic interest. Mamatha et al. conducted study on 15 heart specimens and observed double anterior papillary muscle in 3 heart specimens in right ventricles and in 2 heart specimen in left ventricle while the double posterior papillary muscle in right and left ventricle were observed in eight and six specimens respectively.[4] In current study, we observed double anterior and posterior papillary muscle in 16 heart specimens in right ventricle and in 22 heart specimens in left ventricle (Figure 1). Aktas et al have described the single papillary muscles as conical, mammillated, sloped, arched, flat topped, wavy, grooved, stepped and saucerized.[6] Victor et al have classified the papillary muscles based on their shape as conical, mammillated, wavy, flat topped, stepped, arched, sloped, grooved and saucerized.[7] Study of 52 adult cadaveric hearts conducted by Anubha et al showed various shapes of the individual muscle belly which were classified as truncated, conical, bifurcated, trifurcated and flat topped. Superolateral muscles (identical to anterolateral muscle) were mainly of truncated type (66.23%) while the inferoseptal (identical to posteromedial) muscles were mainly of conical type (45.76%). Flattop papillary muscles were found mostly in superolateral group while the bifurcated and trifurcated papillary muscles were mainly found in inferoseptal group.[8] Gunnal et al have classified 4 types of shapes of the papillary muscles which were broad apex (50.48%)> conical (45.51%)> pyramidal (26.73%) > fan shaped (12.93% in left ventricle.[9] Bose et al found broad apexed (51.67%) > Conical (45%) > Pyramidal apex (3.3%). In the present study, we observed pyramidal apex (51.4%)> conical apex (44.3%)> broad apex (4.3%) in right ventricles whereas, broad apex (36.7%)> conical apex (33.3%)> pyramidal apex (30.0%) in left ventricles. The p-value was also significant (Figure 3 and Table 1).

In present study, we found classical papillary muscles (64.3%)> multiapical (21.4%)> two groups (10%)> three groups (2.9%)> four groups (1.4%) in right ventricle of heart specimens (Table 1, Figure 2) whereas the classical papillary muscles (55%)> two groups (28.3%)> multiapical (13.3%) > three groups (3.3%) in left ventricle of heart specimens (Table 1, Figure 2). Bose et al[10] conducted study on 60 formalin preserved hearts and found two groups in 53.33%> classical papillary muscles (23.33%)>

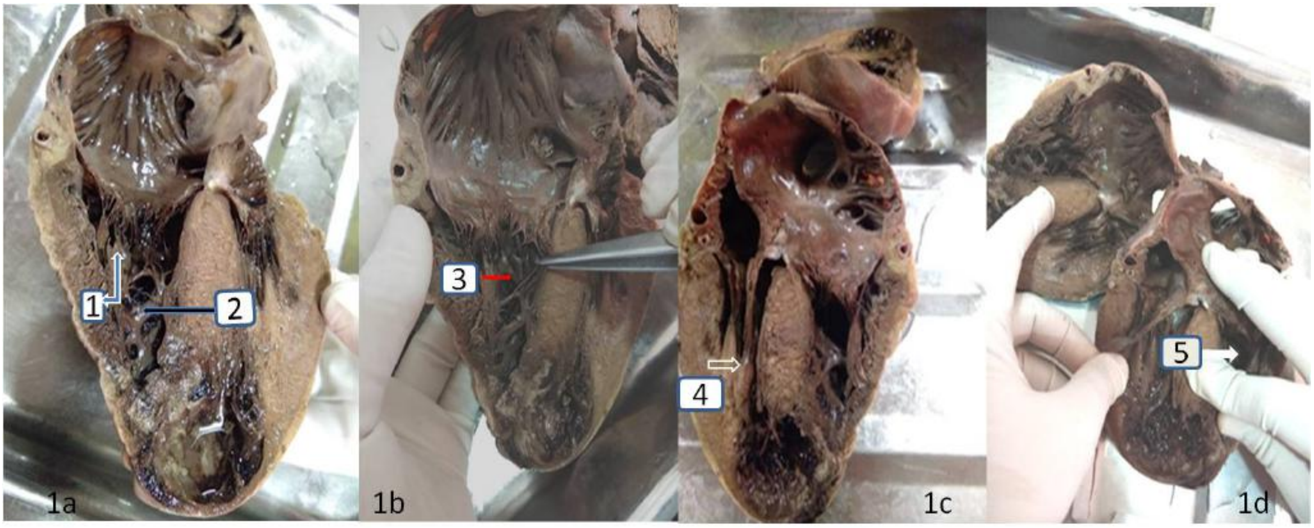

Fig. 1: Showing position of papillary muscles in right and left ventricle; **1a:** 1= Double anterior papillary muscle of right ventricle, 2= Moderator band of right ventricle attached to anterior papillary muscle, **1b:** 3= Double posterior papillary muscle of right ventricle, **1c:** 4= Double anterior papillary muscle of left ventricle, **1d:** 5= Double posterior papillary muscle of left ventricle

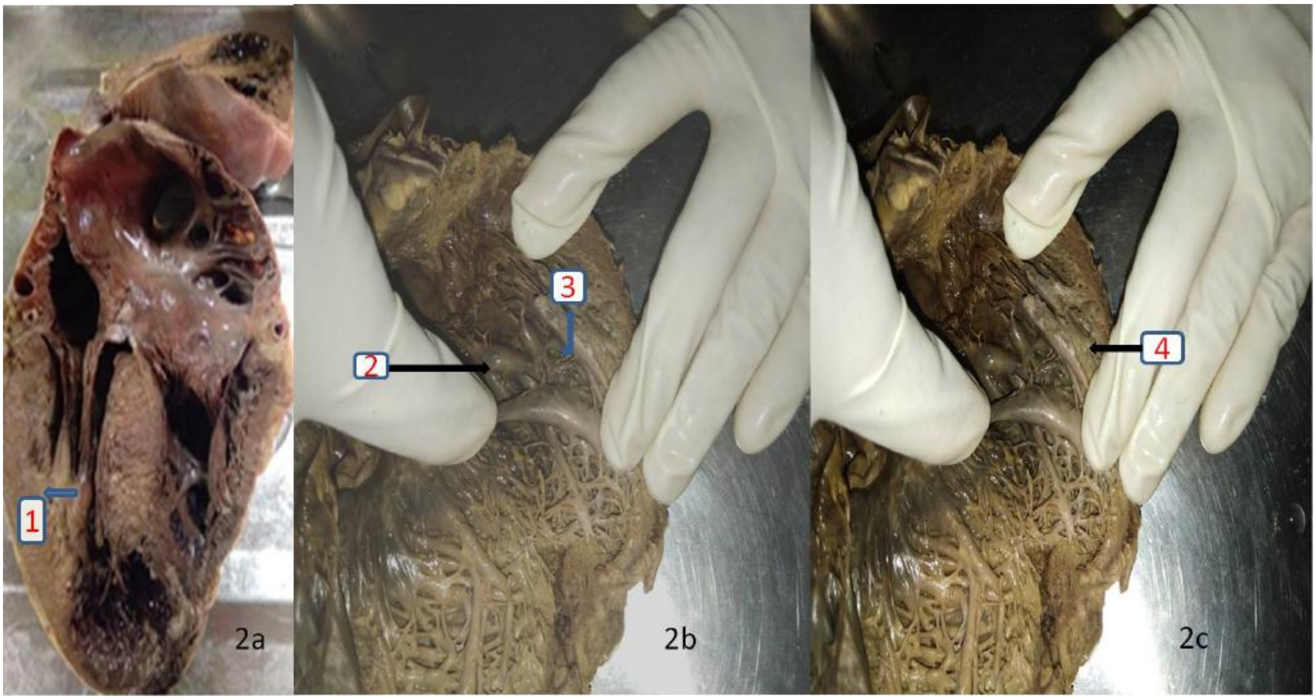

Fig. 2: Showing number of papillary muscles in right and left ventricle; **2a:** 1= Classical, **2b:** 2= 2 groups, 3= 4 groups, **2c:** 4= Multiapical

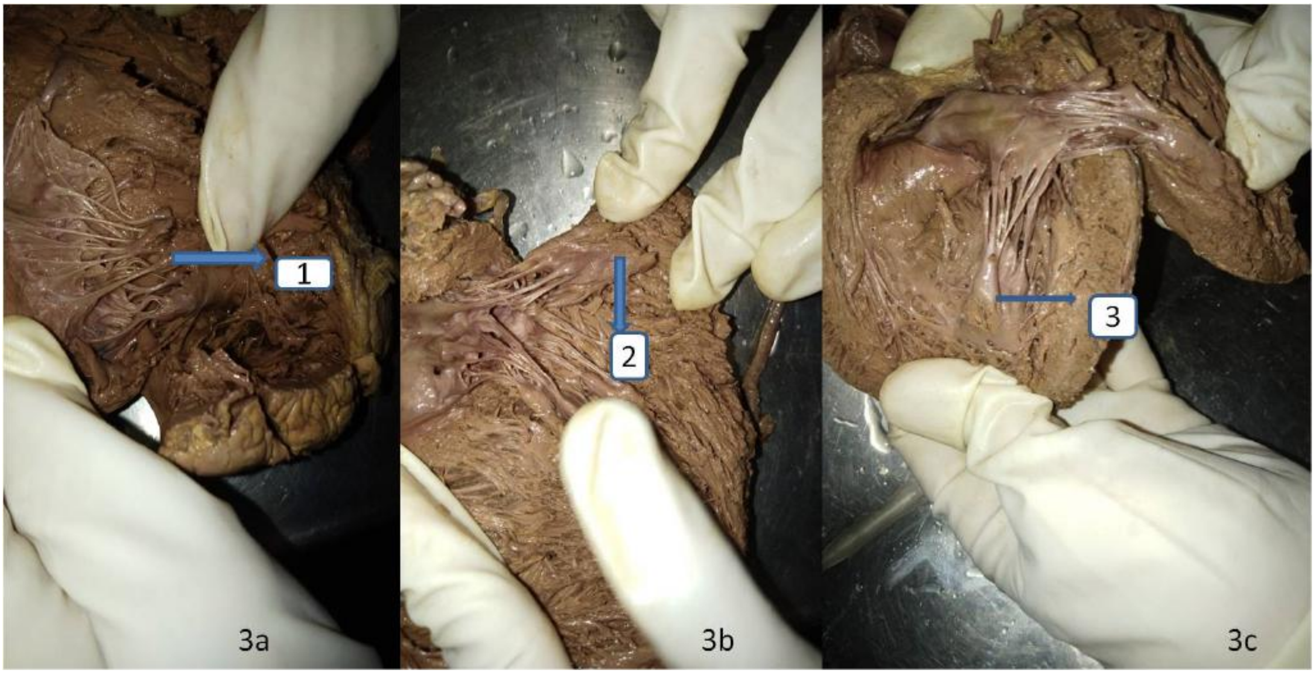

Fig. 3: Showing shape of papillary muscles in right and left ventricle; **3a:** 1= Pyramidal apex, **3b:** 2= Broad apex, **3c:** 3= Conical apex

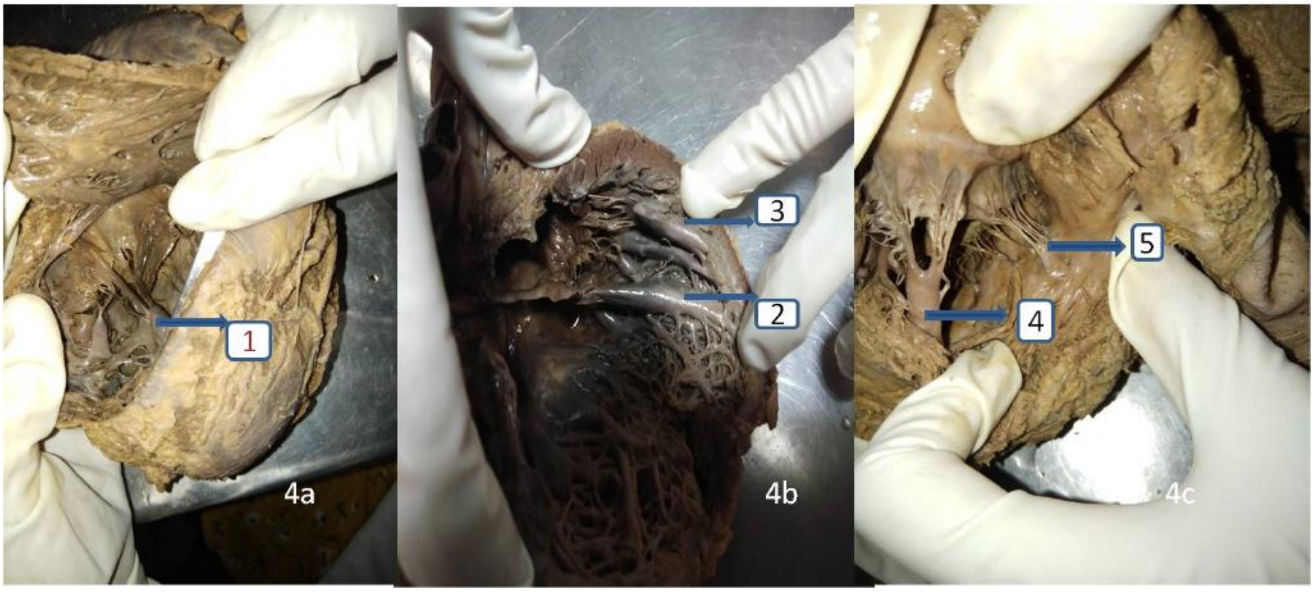

Fig. 4: Showing patterns of papillary muscles in right and left ventricle; **4a:** 1= Single base and divided apex, **4b:** 2= Base attached to a large bridge, 3= divided base and fused apex, 4= long papillary muscle, **4c:** 5= Small projections of papillary muscles

Table 1: Frequency distribution of different variables of right and left ventricular papillary muscles

Variables		Right (N=140) Frequency	%	Left (N=120) Frequency	%	P-Value
Position	Anterior	44	31.4	50	41.7	<0.001
	Posterior	48	34.3	70	58.3	
	Septal	48	34.3	0	0.0	
Number	Classical	90	64.3	66	55.0	<0.077
	2 Groups	14	10.0	34	28.3	
	3 Groups	4	2.9	4	3.3	
	4 Groups	2	1.4	0	0.0	
	Multiapical	30	21.4	16	13.3	
Shape	Conical	62	44.3	40	33.3	<0.001
	Pyramidal	72	51.4	36	30.0	
	Broad	6	4.3	44	36.7	
Pattern	Separate Bases And Fused Apex	34	24.3	53	44.1	<0.005
	Single Base and Divided Apex	78	55.7	51	42.5	
	Small Projections of Papillary Muscles	6	4.3	0	0.0	
	Long Papillary Muscles	0	0.0	8	6.7	
	Base Attached to a Large Bridge	22	15.7	8	6.7	

Table 2: Thickness of both ventricles in cm(N=40)

Variable	Right Mean± SD Range	Left Mean± SD Range	P- Value
Thickness	1.17±0.31 (0.40-1.70)	2.16±0.32 (1.50-2.70)	<0.001

Table 3: Lengthof papillary muscles in cm (N=40)

Variables	Right Mean±SD Range	Left Mean±SD Range	P-Value
Anterior	1.27±0.45 (0.60-2.30)	2.13±0.44 (1.20-2.70)	<0.001
posterior	1.36±0.52 (0.40-2.40)	1.76±0.46 (0.70-2.70)	0.004
Septal	0.92±0.54 (0.30-2.60)		NA

three groups (18.33%)> multiapical (3.33%) > four groups (1.67%) left ventricle. Gunnal et al found pattern like two groups (43.11%)> three groups (31.90%)> four groups (21.55%)> classic 13.44%.[9]

In present study, we observed single base and divided apex (55.7%) >separate bases and fused apex (24.3%)> base attached to a large bridge in (15.7%) > small projections of papillary muscles (4.3%) and of heart specimens in right ventricle whereas separate bases and fused apex in 45%, single base and divided apex in 43.3%, long papillary muscles in 8.3% and base attached to a large bridge in 8.3% of heart specimens in left ventricle. Thus, the commonest variety in the right ventricle was single based and divided apex while the commonest variety in left ventricle was separate bases and fused apex. This finding in the present study differs from that of Bose et al.[10] The p-value was significant (Table 1, Figure 4). Whereas Gunnal et al.[9] reported single base divided apex (21.55%) = single base focused apex (21.55%)> perforated papillary muscles (8.62%)> small projections of papillary muscles (6.03%)> base attached to a large bridge (2.58%)> long papillary muscles (1.72%) in left ventricle. Bose et al[10] also found different pattern of papillary muscles, the commonest of which was separate bases and fused apex variety (36.66%). The other types observed by them includes long papillary muscles (30.83%)> small projections of papillary muscles (14.17%)> perforated papillary muscles (9.17%)> base attached to a large bridge (7.5%)> single base and divided apex (1.66%) in the left ventricle.

Aktas et al., have documented a single anterior papillary muscle, with a length ranging between 11.45 - 45.3 mm which was more than that of a double one ranging between 7.2-25.15 mm[7]. In current study, the length of anterior papillary muscle in the left ventricle ranged from 1.20-2.70 cm and mean length was 2.13±0.44 cm, while the posterior papillary muscle varied in length from 0.70-2.70 cm and mean length was 1.76±0.46 cm. In the right ventricles, the length of anterior papillary muscle ranged from 0.60-2.30 cm with a mean length of 1.27±0.45 cm, while that of the posterior papillary muscle ranged from 0.40-2.40 cm with mean length of 1.36±0.52 cm and that of septal papillary muscle ranged from 0.30-2.60 cm with a mean length of 0.92±0.54 cm. The p-value was significant (Table 3).

In histo-morphometric study, S. Kavitha et al. studied in 50 cadaveric heart specimens and analysed features of the papillary muscles in both ventricles and found that the length of papillary myocytes were smaller than the cardiac wall myocytes. They have also mentioned that nuclear size in majority of papillary myocytes were smaller than the cardiac myocytes. The myocytes were binucleated and the nucleus was elongated.[11]

In our study, we observed that the thickness of the right ventricle varies from 0.40 to 1.70 cm with a mean thickness of 1.17±0.31 cm whereas in left ventricle it varies from 1.50 to 2.70 cm with a mean value of 2.16±0.32 cm. The p-value was significant (Table 2). The understanding of morphology of moderator band is helpful in surgical corrections related to interventricular septal defect. In present study, in the right ventricle, we found variations in the attachments of moderator band to anterior and posterior papillary muscle. We observed both increase in number and size of the papillary muscles in both ventricles, which is often found related to mitral regurgitation and left ventricular outflow tract obstruction. We know that there are only two papillary muscles in left ventricle. So, in case of ischemia affecting the base of papillary muscle, half the chordae will be rendered dysfunctional because half of them are under control of a single papillary muscle. This results in mitral valve prolapse and severe mitral regurgitation. In cases where there are groups of papillary muscles, the severity of infraction is comparatively less because the papillary muscles in groups is only partially affected. As a result of which, there are fewer dysfunctional chordae. In present study, we found classical papillary muscles more in both ventricles. In such cases, the severity of infraction is much more. The shape of the papillary muscles affects the blood flow. In the papillary muscles with broad apex, the chances of left ventricular outflow tract obstruction are higher. The most ideal shape of the papillary muscles which provides minimum obstruction to the blood flow is conical-shaped, broad-based attached to the ventricular wall away from the centre of cavity. In present study, we observed that in the left ventricle, there are more number of broad papillary muscles which leads to left ventricular outlet obstruction while in the right ventricle, we observed more conical and pyramidal shape of papillary muscles. The treatment of choice for symptomatic left ventricular outflow tract obstruction and dysfunction is usually the realignment and repositioning of the papillary muscles.[12–14] The papillary muscle hypertrophy, which is defined when at least one of the two papillary muscles is more than 1.1cm in either vertical or horizontal diameter, has been recently shown to be a phenotypic variant of Hypertrophic Cardiomyopathy. In cases of dilated cardiomyopathy, the affected endocardium is found to be several millimeters thick. This thickening affects the papillary muscles and it usually extends into the trabecular ridges. The histological evidence of myocardial hypertrophy and fibrosis has been documented previously. The left ventricle mid-cavity obstruction due to hypertrophy of the papillary muscle may be asymptomatic or presents as various clinical manifestation such as dyspnoea, angina, syncope and even sudden cardiac death. The present study shows multiple variations in the morphology and length of the papillary muscles.

5. Conclusion

In the left ventricle, the mean length of papillary muscle (both anterior and posterior) was longer in many heart specimens as compared to the right ventricle. Double anterior and posterior papillary muscles were found in both ventricles. The classical type of papillary muscle was observed maximally in both the ventricles. Maximum number of conical and pyramidal apex papillary muscles was found in right ventricle while the broad apex papillary muscles were observed more in left ventricle. In both ventricle, different pattern of papillary muscles were observed. In cases of hypertrophy of both ventricles, the papillary muscles were also hypertrophied. So, we would like to conclude that these various anatomical variations of the papillary muscles may prove beneficial to cardiac surgeons during surgeries done for mitral and tricuspid valve replacement as well as during papillary muscle realignment and relocation done for symptomatic left ventricular outflow tract obstruction and dysfunction. It may also benefit anatomist to help in understanding the embryological development.

6. Source of Funding

None.

7. Conflict of Interest

The authors declare no conflict of interest.

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