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A STUDY OF PAPILLARY MUSCLES OF THE LEFT VENTRICLE IN THE ADULT HUMAN CADAVERS

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ABSTRACT

Introduction: Normal valve function depends upon the anatomic and mechanical integrity of the atrioventricular ring, the valve leaflets, the chordae tendineae and papillary muscles. Papillary muscle rupture and dysfunction can lead to complications of prolapsed mitral valve and mitral regurgitation.

Materials and Methods: The material for present study consisted of 50 formalin fixed adult apparently normal cadaveric hearts belonging to either sex obtained from the Department of Anatomy, Govt. Medical College, Amritsar. These hearts were dissected to open the left ventricle and to expose the papillary muscles. Different morphological features of papillary muscles were noted and measurements were taken.

Results: The anterolateral papillary muscle usually said to be single bellied was found so in majority of the hearts (86%) being double bellied in the rest of 14% hearts. However, the posteromedial papillary muscle usually said to be double bellied was found so only in 56% of the hearts, being 3 bellied in 20%, 4 bellied in 10% & single bellied in 14%. Negligible text is available about the number of heads of papillary muscles. It varied from 1- 6 and 1- 5 in anterolateral & posteromedial papillary muscles respectively which is another notable variation. Different shapes and pattern of papillary muscles have also been identified. An additional divison of study was measurement of lengths of papillary muscles which thus provides a base line data for further detailed studies based upon a larger data base.

Conclusion: In this study, observations of more number of bellies of anterolateral papillary muscle and posteromedial papillary muscle instead of the only twos, are important and demand a modification in standard textbooks of anatomy. Notable variations of papillary muscles are important for scientists worldwide in order to ascertain the reason behind each specific architechtural arrangement. This will enable the cardio thoracic surgeons to tailor the surgical procedures according to the individual papillary muscle pattern.

KEY WORDS: Papillary muscles, Left ventricle, Mitral valve, Heart.

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INTRODUCTION

A large proportion of human population suffers from valvular heart diseases, leading to increased morbidity and mortality. These valvular heart diseases are more common on left side involving the mitral valvar complex [1]. The mitral valvar complex comprises the mitral orifice and its annulus, valvular leaflets, chordae tendineae and papillary muscles [2].

Normal valve function depends upon the anatomic and mechanical integrity of the atrioventricular ring, the valve leaflets, the chordae tendineae and papillary muscles [3]. The left ventricular papillary muscles are two in number i.e. anterolateral (Alpm) and posteromedial (Pmpm). The Alpm arises from sternocostal mural myocardium and the Pmpm arises from diaphragmatic region [2]

Papillary muscle contraction, occuring synchronously with ventricular contraction supports the chordae tendineae and prevents prolapse of the mitral leaflets during ventricular systole [4]. In papillary muscle dysfunction, contraction is absent or ineffective. The chordae tendinae slacken as the left ventricular apex moves towards the annulus in systole. The leaflets lose their support and prolapse into the atrium [5]. Regurgitation also occurs in rupture of papillary muscle. The specific anatomic site at which papillary muscle rupture occurs is an important determinant of the magnitude of regurgitation and the subsequent clinical course [6].

The distance between the apex and the base of the left ventricle does not shorten during contraction of the ventricle. The atrioventricular region moves upwards and backwards but length of cavity remains constant. This makes it easier to understand how the comparatively small contraction of the papillary muscles is able to ensure efficient closure of the valve [7].

The function of papillary muscles to restrain the mitral valves is obvious. However the dynamic nature of this function is not always appreciated. Failure of one or both papillary muscles to shorten during the ejection phase of ventricular systole, fibrosis, and atrophy of a papillary muscle or centrifugal migration of the papillary muscles due to left ventricular dilatation result in mitral incompetence [3].

Left ventricular papillary muscles appear to be the last portion of the heart to be perfused by coronary arterial blood. As a consequence, they are sensitive anatomic markers of myocardial ischemia. Foci of necrosis or fibrosis are therefore commonly seen in these structures, particularly posteromedial papillary muscle, which has poorer blood supply than does the anterolateral muscle [8]. Many operative procedures involving papillary muscles such as resection, repositioning and realignment, are carried out to restore its normal physiological function [1]. Thus a detailed knowledge of anatomical characteristics of papillary muscles is necessary because of their clinical and surgical significance. The purpose of present study is to extend concepts previously presented as well as to overcome deficiencies in our knowledge of anatomy of papillary muscles in North Indian population.

MATERIALS AND METHODS

The material for the present study consisted of 50 formalin fixed adult apparently normal cadaveric hearts belonging to either sex obtained from the Department of Anatomy, Govt. Medical College, Amritsar. Left ventricle was opened along obtuse margin and mitral valve was cut through the mid-region of the posterior leaflet thus exposing the papillary muscles fully. Different morphological features of these were observed and morphometric measurements were taken by using vernier calliper, graduated metric scale and surgical silk thread as follows:

1. Papillary muscles were seen whether present or absent.

2. Number of bellies & their Origin: Number of bellies of both anterolateral and posteromedial papillary muscles were noted. Their origin was seen whether from middle 1/3rd, lower 1/3rd or upper 1/3rd of sternocostal surface or diaphragmatic region of mural myocardium.

3. Shape was noted whether conical, mammilated, flat topped, grooved, stepped, wavy, arched, sloped, saucerized, two tired , interlinked, parallel, V, Y or H-shaped (Victor & Nayak [9]).

4. Number of heads were noted whether 2-3 or more.

5. Length of Anterolateral and Posteromedial papillary muscles were measured with the help of vernier caliper which was noted from origin of muscles to their tips. (AB & CD resp. in Fig. 1)

OBSERVATIONS

Table 1: Showing distribution of no. Of bellies, origin & protrusion of anterolateral and posteromedial papillary muscles.

Papillary muscles	No. of bellies/heart	No. of Hearts (%)	Total no. of bellies	Origin [n(%age)]			Protrusion [n(%age)]		
				Upper 1/3	Middle 1/3	Lower 1/3	Intra-luminal	Mixed	Sessile
Anterolateral	1	43 (86%)	43	4(9%)	33(77%)	6(14%)	35(81.4%)	7(16.3%)	1(2.3%)
	2	7 (14%)	14	6(43%)	7(50%)	1(7%)	5(36%)	6(43%)	3(21%)
Posteromedial	1	7(14%)	7	-	5(71%)	2(29%)	2(28.6%)	-	5(71.4%)
	2	28(56%)	56	2(3.6%)	51(91%)	3(5.4%)	40(71%)	9(16%)	7(13%)
	3	10(20%)	30	3(10%)	23(77%)	4(13%)	23(77%)	3(10%)	4(13%)
	4	5(10%)	20	1(5%)	17(85%)	2(10%)	16(80%)	2(10%)	2(10%)

Shape of papillary muscles: Table 2 shows the different shapes of papillary muscles as observed in the present study and compared the same with the only available study by Victor & Nayak [9].

Table 2: Showing comparison of shapes of papillary muscles in left ventricle.

No. of Bellies	Pattern	Anterolateral Group (n= no. of hearts)		Posteromedial Group	
		Victor & Nayak [9]	Present study [n (%age)]	Victor & Nayak [9]	[n (%age)]
Single	Conical	32	14 (32.5%)	12	-
	Conical + grooved	-	4 (9.4%)	-	1 (14.2%)
	Mamillated	14	5 (11.6%)	12	-
	Mamillated + grooved	-	3 (7%)	-	-
	Flat topped	9	3 (7%)	8	2 (28.5%)
	Flat topped + grooved	-	1 (2.3%)	-	-
	Grooved	10	6 (14%)	6	2 (28.5%)
	Stepped	2	-	5	1 (14.2%)
	Wavy	-	-	3	-
	Arched	-	-	2	
	Sloped	-	5 (11.6%)	1	-
	Saucerised	-	1 (2.3%)	1	1 (14.2%)
	Saucerised + grooved	-	1(2.3%)	-	-
	Total		43 (100%)		7 (100%)
Two	Two tiered	11	-	9	-
	Conical	-	-	-	7 (25%)
	Conical + grooved	-	1 (14.2%)	-	1 (3.6%)
	Conical+ flat topped	-	-	-	3 (10.7%)
	Interlinked	4	-	10	2 (7%)
	Interlinked+ flat topped	-	1 (14.2%)	-	2 (7%)
	Parallel	7	-	6	-
	Arched	1	-	5	3 (10.7%)
	Arched+ Interlinked	-	1 (14.2%)	-	1 (3.6%)
	Arched+ conical	-	1 (14.2%)	-	-
	Arched + grooved	-	-	-	1 (3.6%)
	V	1	1 (14.2%)	4	1 (3.6%)
	Y	1	-	1	2 (7%)
	1 Y + 1 going directly to scallop	-	1 (14.2%)	-	-
	H	2	-	2	-
	Mammilated +fused at apex	-	1 (14.2%)	-	1 (3.6%)
	Mammilated + flat topped	-	-	-	2 (7%)
	Sloped & grooved+ sloped	-	-	-	1 (3.6%)
	1 Grooved,stepped+ 1 small	-	-	-	1 (3.6%)
	Total		7 (100%)		28 (100%)
Three	Parallel	2	-	3	-
	2 conical+ 1 Flat topped	-	-	-	1 (10%)
	Interlinked	-	-	5	1 (10%)
	Two interlinked+ 1 separate	2	-	-	3 (30%)
	Arched	-	-	1	-
	Arched + interlinked	-	-	-	1 (10%)
	Two tiered + 1 separate	-	-	1	-
	2V +1 separate	-	-	-	2 (20%)
	2 Y+ 1 conical	-	-	-	1 (10%)
	2H+ arched	-	-	-	1 (10%)
	Total				10 (100%)
Four	Parallel	-	-	2	-
	Parallel +interlinked + H pattern	-	-	-	2 (40%)
	2V + 2 conical	-	-	-	1 (20%)
	Conical	-	-	-	1(20%)
	1 arched + 1 conical+ 2 sessile	-	-	-	1 (20%)
	Interlinked	1	-	1	-
	Total				5 (100%)

Presence or absence: In all the 50 hearts of the present study, there were seen two groups of papillary muscles in the left ventricle i.e. anterolateral papillary muscle (Alpm) and posteromedial papillary muscle (Pmpm). However the number of bellies varied (vide infra).

No. of bellies, origin and protrusion: Table 1 depicts the no. of bellies, their origin and extent of protrusion of the two groups of papillary muscles as observed in the left ventricles of the present study.

No. of heads and length of papillary muscles: Table no. 3 depicts the no. of heads and length of papillary muscles of left ventricles as observed in the present study.

Table 3: Showing distribution of number of heads and mean value & range of length of different bellies of papillary muscles in left ventricle.

Papillary muscle	No. of bellies {no. of hearts in which present (%)}	Heads of bellies		Length of bellies (cm)
		No. of Heads	No. of cases [n (%age)]	Mean (Range)
Anterolateral group	1{43(86%)}	1	27 (63%)	2.4 (1.6-3.4)
		2	12 (28%)	2.4 (1.7-3.4)
		3	3 (7%)	2.0 (1.2-3.1)
		4	1 (2%)	1.6 (1.4-1.9)
	2{7(14%)}	1	1 (14.3%)	3.3
		2	4 (57.1%)	2.2 (1.1-2.9)
		5(4+1)	1 (14.3%)	2.2 (2.2-2.4)
		6(5+1)	1 (14.3%)	2.1 (1.8-2.5)
Posteromedial group	1{7(14%)}	1	3 (43%)	2.0 (1.7-2.4)
		2	2 (28.5%)	2.4(2.0-3.0)
		3	2 (28.5%)	2.6(1.9-3.0)
	2{28(56%)}	2	28 (100%)	2.1(1.0- 3.2)
	3{10(20%)}	3	9 (90%)	2.0(1.1-3.2)
		5	1 (10%)	2.1(1.2-2.8)
	4{5(10%)}	4	5 (100%)	1.7(1.1-3.2)

Fig. 1: Showing Grooved (Gr) Anterolateral papillary muscle (Alpm) having 3 heads (H_{1-3}) and Posteromedial papillary muscle (Pmpm) having 3 bellies (B_1-$_3$), one large belly (B_1),grooved (gr) with 3 heads (h_1-$_3$) & 2 small bellies (B_2 & B_3), interlinked (IL).

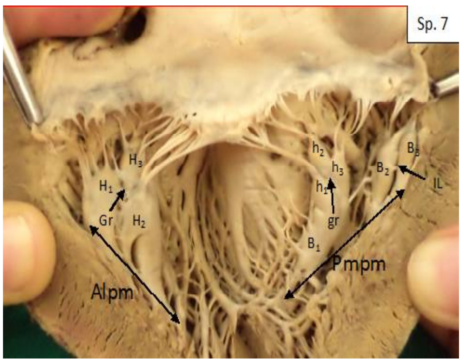


Fig. 2: Showing Antero lateral papillary muscle (Alpm) saucerised and Posteromedial papillary muscle (Pmpm) has 3 bellies (B_{1-3}) which are interlinked (IL); B_1 & B_2- conical, B_3- flat topped.

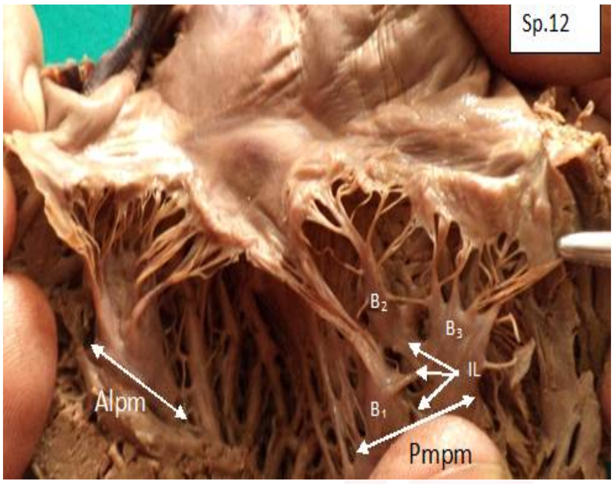


Fig. 3: Showing mamillated & grooved (gr) Anterolateral Papillary muscle (Alpm) & 2 arched (ar) bellies (B_1 & B_2) of Postero medial papillary muscle (Pmpm) which are interlinked (IL).

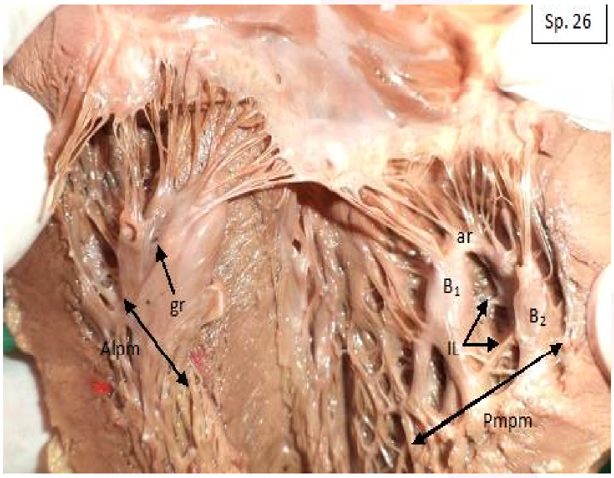


Fig. 4: Showing single grooved (gr) Anterolateral papillary muscle (Alpm) with 4 heads (H_{1-4}), Posteromedial papillary muscle (Pmpm) having 3 bellies (B_{1-3}), B_1 is intraluminal, conical, B_2 & B_3 Interlinked (IL) to form H shaped pattern.

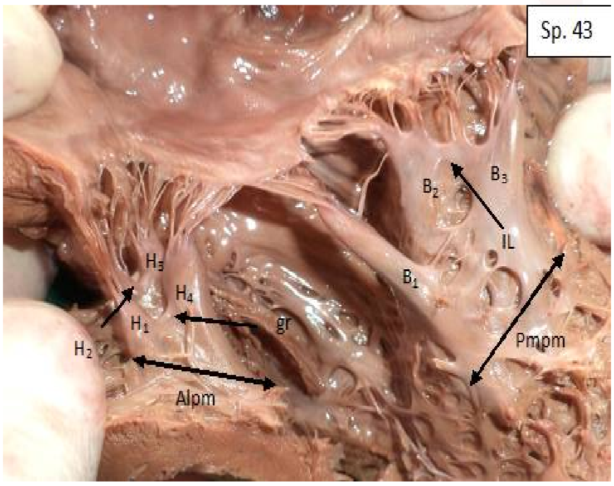


Fig. 5: Showing Anterolateral papillary muscle (Alpm) with 2 bellies (B_1, B_2), B_1 has 5 heads (H_{1-5}), B_2 is sessile & grooved (gr); Postero medial papillary muscle (Pmpm) having 2 bellies (b_1,b_2), interlinked (IL) forming H shaped pattern.

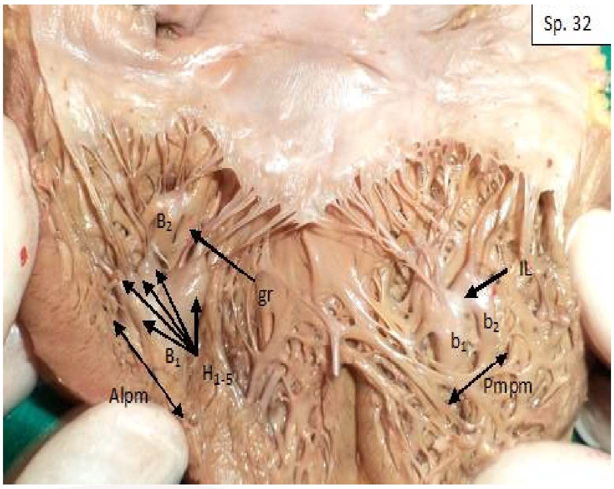
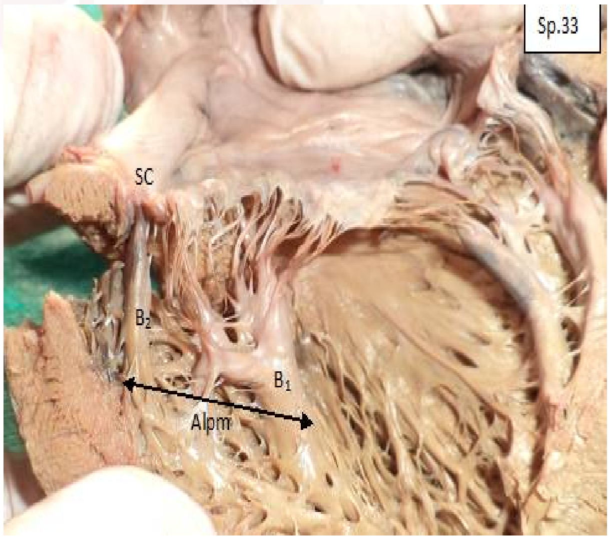


Fig. 6: Showing Anterolateral papillary muscle (Alpm) having 2 bellies (B_1, B_2), B_1 bifurcated apically to give Y shaped pattern with each limb of Y further bifurcating; Postero Medial papillary muscle (Pmpm) having 4 bellies (b_{1-4}), b_1& b_2 Interlinked (IL_1), b_3& b_4 interlinked (IL_2) to form H shaped pattern.



DISCUSSION

Presence or absence: In all the hearts of the present study, there were two groups of papillary muscles in left ventricle i.e. anterolateral papillary muscle (Alpm) and posteromedial papillary muscle (Pmpm). This was in consonance with Gabella et al [2], Rusted et al [10], Burch et al [3], Ranganathan & Burch [11], Victor & Nayak [9], Gatzoulis [12] and Kanjanauthai et al [13] who reported papillary muscles to be two in number. Workers like Oosthoek et al [14], Madu et al [15] and Gunnal et al [1] encountered more than two papillary muscles but they were silent about the increased number of bellies as was observed in our study.

Clinical implications: An increased number and size of the papillary muscles, as well as their malformation, may cause left ventricular outflow tract obstruction and mitral regurgitation. When there are only two papillary muscles in the left ventricle, half the chordae are under the control of one single papillary muscle, in such cases of an ischaemic event affecting the base of the papillary muscle will render half the chordae dysfunctional, leading to mitral valve prolapse and severe mitral regurgitation. However myocardial infarction will not affect the functions of the mitral valve insofar as there are more papillary muscles that are in groups. This results in the group being partially affected, and consequently, fewer dysfunctional chordate [1].

Parachute mitral valve is a congenital condition characterized by only one papillary muscle to which all mitral chordae tendinae are attached. The resultant mitral valve is usually stenotic [16], but it may be purely incompetent or may function normally [17].

Single papillary muscle is usually associated with other malformations like supramitral valve ring, diffuse subaortic stenosis, coarctation of aorta [16], valvular aortic stenosis, VSD and valvular pulmonary stenosis [17].

There may be an accessory papillary muscle which is usually of no functional significance but it has been seen with congenital mitral regurgitation [18].

Each of the papillary muscle may be congenitally abnormally large and malpositioned so that the primary orifice of the valve is narrowed [19,20].

Number of bellies, origin and protrusion: Table 1 depicts the number of bellies, sites of their origin & modes of their protrusion in ventricular cavity in case of both anterolateral & posteromedial papillary muscles as observed in the present study. As evident from the table the anterolateral papillary muscle was composed of a single belly in 43(86%) hearts and two bellies in 7(14%) hearts. Earlier Ranganathan & Burch [11] and Victor & Nayak [9] had also found the Alpm to have one or two distinct bellies in majorities of the hearts but they occasionally encountered > 2 bellies as well. This was not so in the present study.

In majority [33 (77%)] of hearts with single belly, the later took origin from middle 1/3 of ventricular wall; from lower 1/3 in 6 (14%) & upper 1/3 in 4 (9%) hearts. In rest of 7 hearts which had 2 bellies each (total no. of bellies being 14), 7 (50%) bellies arose from middle 1/3 followed by 6 (43%) from upper 1/3 & 1 (7%) from lower 1/3. Thus commonest site of origin was middle 1/3, whether single or double bellied hearts. Earlier Victor & Nayak [9] and Gunnal et al observed middle 1/3 as site of origin in 79.5% and 95% hearts respectively followed by upper 1/3 in 19% and 5% respectively. But they are silent about single or doubled bellied hearts. We encountered an origin from lower 1/3 in a greater number (14% of single bellied & 7% of double bellied hearts) as compared with their study (1.5%).

Out of the 43 (86%) single bellied hearts (43 bellies), 35 (81.4%) projected in the lumen, 1 (2.3%) was sessile while 7 (16.3%) were a conglomeration of the two (mixed). In two bellied [7 (14%)] hearts, out of 14 bellies, 5 (36%) were intraluminal, 6 (43%) were mixed & 3 (21%) were sessile. Thus in single bellied hearts, the bellies are predominantly intraluminal while in double bellied, the intraluminal & mixed types are almost equally observed.

Earlier Victor & Nayak [9] found mixed type to be predominant (73.5 %). But they were silent about its segregation into single or double bellied hearts. It is probable that tethered or sessile type has more abundant blood supply than fingerlike or intraluminal [8].

Table 4: Showing comparison of incidence of no. of bellies of PMPM.

Sr. No.	No. of bellies	Percentage Incidence		
		Rusted et al [10]	Victor & Nayak [9]	Present study
1	1	30%	50%	14%
2	2	26.50%	36%	56%
3	3	37%	11%	20%
4	4	6%	3%	10%

As far as posteromedial papillary muscle is concerned, the number of its bellies ranged from 1 to 4 being 2 each in 28 (56%) hearts followed by 3 in 10 (20%), 1 in 7 (14%) & 4 in 5 (10%) hearts. Table 4 compares the incidence of number of bellies of posteromedial papillary muscle with earlier authors.

It is evident that in the present study double bellies of Pmpm were seen more frequently as compared with triple bellied by Rusted et al[10] & singled bellied by Victor & Nayak [9]. Thus multiple muscle bellies are seen in Pmpm. These tend to cause gaps between groups of chordae arising from them and these gaps are larger than when a single muscle is present [10].

In majority of the hearts [5 (71%)] with single belly, the later took origin from middle 1/3 of ventricular wall followed by lower 1/3 in 2 (29%). Amongst the double bellied hearts [28 (the number of bellies being 56)], the majority of bellies [51 (91%)] again arose from middle 1/3 of the ventricular wall followed by 3 (5.4%) & 2 (3.6%) from lower & upper 1/3 respectively. Similarly amongst the 3 bellied & 4 bellied hearts the middle 1/3rd of the ventricular wall was the commonest site to give origin to bellies of Pmpm (Table 1). It was in consonance with Victor & Nayak [9] who found 92.5% of bellies arising from middle 1/3 and only 6% & 1.5% from upper & lower 1/3rd respectively.

Earlier Brock [6] reported left ventricular papillary muscles arising from ventricular wall at junction of apical & middle thirds. Levy & Edwards [21] commented that above position permits the contracting papillary muscle to exert a desirable vertical force on the chordae tendinae during isovolumetric contraction.

In present study single bellies of Pmpm were sessile in majority (71.4%) of cases followed by intraluminal in 28.6% of cases. On the contrary, double bellies were mainly intraluminal in majority of cases (71%), followed by mixed in 16% & sessile in 13%. Similarly majority of bellies in triple & tetra bellied hearts were also intraluminal (Table 1). It was not toeing in line with Victor & Nayak[9] who observed mixed in 69.5%, intraluminal in 11% & sessile in 19.5%.

Clinical implication: Papillary muscles serve an important land mark for the surgeons to reach the commissures. It is specially true of the anterolateral papillary muscle which usually has only one belly [22].

Shape: Table 2 shows comparison of the incidence of different shapes of anterolateral & posteromedial papillary muscle as observed in the present study with the only earlier study by Victor & Nayak [9]. The shape of single bellied Alpm was predominantly conical [Sp. No. 9] in 14(32.5%) hearts followed by grooved [Sp. No. 15] in 6 (14%) and mamillated [Sp. No. 23] & sloped [Sp. No. 27] in 5 (11.6%) each. It was in consonance with Victor & Nayak [9] who also observed conical shapes to be the commonest followed by mamillated & grooved. As far as double bellied hearts are concerned, different shapes were seen in all the hearts (Table 2).

Shape of single belly of Pmpm was predominantly flat topped [Sp. No. 23] & grooved in 2 (28.5%) specimens each followed by conical + grooved, stepped & saucerised [Sp. No. 15] in one (14.2%) specimen each. Victor & Nayak [9] found single belly to be mostly conical or mamillated. This difference could be because of small number of hearts (7) in the present study showing single bellied Pmpm.

In present study, double bellies were predominantly conical. Amongst 3 bellies, two were interlinked & one separate and amongst 4 bellies, these were predominantly parallel & interlinked forming H pattern [Sp. No. 33]. The other patterns are shown & compared with Victor & Nayak [9] in Table 2.

A notable variation was seen in one case (2%) [Sp. 33] in which we found the direct insertion of papillary muscle into the cusp without intervening chordae tendineae. Gunnal et al[1] also reported two such cases (1.72%) in their study. Klues et al [23] observed this type of muscle; which is rare anomaly in only one of the 100 valves of control patients while in a group of 78 patients with Hypertrophic cardiomyopathy they noted 10 such aberrant papillary muscles. All 10 of these observed subjects in Klues' study had a marked obstruction to their ventricular outflow. Although the anomaly had been primarily presented as a cause of left ventricular outflow obstruction, it has been described as also causing mitral regurgitation [24]. The anomaly appears to result from an arrest of valvular apparatus development at approximately 12 weeks gestation, when papillary muscles are contagious with the mitral leaflet [14].

Clinical implication: The shape of papillary muscles affects the passage of blood flow. Papillary Muscles are usually described as conical- shaped in standard textbooks. The papillary muscles that best facilitates cardiovascular physiology by posing minimum obstruction to blood flow is conical shaped, broad based, attached to the ventricular wall away from the centre of cavity [1]. Papillary muscle realignment and repositioning is the treatment of choice for symptomatic left ventricular tract obstruction [14,25,26].

Number of heads and Length: Table 3 shows distribution of number of heads of different bellies of anterolateral & posteromedial papillary muscle. In case of anterolateral papillary muscle, out of 43 hearts with single belly, in 27 (63%) the belly terminated into one head, in 12 (28%) it bifurcated to form 2 heads, in 3 (7%) it formed 3 & in 1 (2%) it formed 4 heads. Amongst the 2 bellied hearts [7 (14%)] in 1 heart [Sp. No. 28] the 2 bellies joined to form 1 head, in 4 heart (57.1%), these terminated as 2 heads, in one each, the 2 bellies terminated as 5 (4+1) & 6 (5+1) heads [Sp. No. 33 & 32 resp.].

Similarly in case of Posteromedial papillary muscle, out of 7 hearts with single belly, in 3 hearts (43%) it terminated as single head, in 2 (28.5%) hearts each, it bifurcated & trifurcated to end in 2 & 3 heads respectively. Out of 28 hearts with 2 bellies each (total number of bellies being 56), all of these bellies ended as single head each; out of 10 hearts with 3 bellies each (total number of bellies being 30), in 9 (90%), these (27 bellies) terminated as single head each, & in one the three bellies formed 5 heads (3+1+1) [Sp. No. 7]. Out of 5 hearts with 4 bellies each, all the bellies ended into single heads. Table 3 also shows length of papillary muscle in present study. In Alpm mean length of single bellies with one head was 2.4 cm (Range= 1.6- 3.4 cm). The mean length of 2 heads was 2.4 cm (Range=1.7- 3.4 cm), of 3 heads was 2.0 cm (Range= 1.2- 3.1 cm), of 4 heads was 1.6 cm (Range= 1.4-1.9 cm). Mean length of double bellies with one head was 3.3 cm, of 2 heads was 2.2 cm (Range= 1.1- 2.9 cm), of 5 heads was 2.2 cm (Range= 2.2 – 2.4 cm), of 6 heads was 2.1cm (Range= 1.8- 2.5 cm). Thus the mean length of anterolateral muscle bellies decreased as the number of heads increased.

In Pmpm the mean length of single bellies with one head was 2.0 cm (Range= 1.7-2.4 cm), of 2 heads was 2.45 cm (Range=2.0- 3.0), of 3 heads was 2.67 cm (Range= 1.9-3.0 cm). Mean length of double bellies with two heads was 2.16 cm (Range= 1.0- 3.2 cm). Mean length of three bellies with three heads was 2.05 cm (Range=1.1- 3.2 cm), of 5 heads was 2.1 cm (Range= 1.2- 2.8 cm). Mean length of 4 bellies with 4 heads was 1.78 cm (Range= 1.1- 3.2 cm). In Pmpm the mean length of bellies shows decreased pattern as number of heads increases from 2 bellies to 4 bellies but in single belly the length of single head was lesser than of other heads.

Only few studies regarding the length of papillary muscle of left ventricle was found in the accessible literature. Gatzoulis [12] describes left ventricular papillary muscle as varying in length and breadth but no values have been given. According to Roberts & Cohen [8] anterolateral papillary muscle is slightly longer than posteromedial one. The same is confirmed in the present study but varied with Hosapatna et al [27] who found the average length of the Alpm and Pmpm to be 1.63± 0.50 cm and 2.14 ± 0.60 cm respectively. However they are silent about the length of different bellies which may be the reason for variable values.

Clinical implications: The variations in papillary muscle and the chordae arising from these would influence the pathophysiological effects of various disorders. During surgery the chordae can be studied by traction on the concerned papillary muscle [9].

In mitral valve replacement, retention of chordopapillary support is being favoured to preserve optimum function of left ventricle. However, if the native valve has too many chordae and papillary muscle bellies, these may interfere with the function of the disc or the ball, especially if they were mostly intraluminal.

Replacement of the mitral valve with mitral homograft is emerging as a surgical alternative [28]. It is preferable to use it with a single Alpm and Pmpm rather than multiple which would be cumbersome to fix. Similarly, very long chordae in a homograft may be prone to rupture and very short chordae may favour early fibrous fusion between the papillary muscle and the leaflet tissue [9].

CONCLUSION

To conclude considerable variations in the number, shape, pattern and position of the papillary muscles have been found in the present study. Majority of the results of present study were in consonance with the standard text books of anatomy but some interestingly different observations were also made. The anterolateral papillary muscle usually said to be single bellied was found so in majority of the hearts (86%) being double bellied in the rest of 14% hearts. However, the posteromedial papillary muscle usually said to be double bellied was found so only in 56% of the hearts, being 3 bellied in 20%, 4 bellied in 10% & single bellied in 14%. Thus the observations on number of bellies of posteromedial papillary muscle are important and demand a modification in textbooks of anatomy.

Negligible text is available about the number of heads of papillary muscles. Majority of bellies of both Alpm & Pmpm terminated into single head with some terminating into two heads. In specimen no. 33 & 32, one belly each of Alpm terminated in 4 & 5 heads respectively. It varied from 1- 6 and 1- 5 in anterolateral & posteromedial papillary muscles respectively which is another notable variation.

The described anomaly of direct insertion of papillary muscle into anterior mitral valve clearly cause left ventricular outflow tract obstruction and leads to sudden cardiac death. Such a notable vaiation is extremely important for cardiothoracic surgeons and physicians.

As mitral valve apparatus, including the papillary muscles, is as unique to each individual as one's own fingerprints, in view of this, there is a clear need to conduct future large- scale studies in different regions of the world in order to investigate the reasons behind each specific pattern. On the basis of variations reported in present study, further modification of text is required. Thus the current study has achieved the aim of providing a systematized database for future study on the North Indian population for anatomists and cardiothoracic surgeons.

Conflicts of Interests: None

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