

A MORPHOMETRIC STUDY OF THE PAPILLARY MUSCLES OF THE RIGHT VENTRICLE OF HUMAN CADAVERIC HEARTS IN NORTH-WEST INDIAN POPULATION

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ABSTRACT

BACKGROUND

Atrioventricular (AV) valvular apparatus comprises of AV orifice and its annulus, valvular leaflets, chordae tendineae and papillary muscles. The study was done with a purpose to find out the gross morphology of papillary muscles of right ventricle and to compare any gender differences. This is helpful in understanding right atrioventricular valve dysfunction like regurgitations and also helpful in valve repair surgeries.

The aim of this study was

1. To note the shape, origin, number of heads and other gross features of papillary muscles of right ventricle.
2. To find out sexual difference in the gross morphology of papillary muscles of right ventricle.

MATERIALS AND METHODS

The study was carried out in 30 apparently normal cadaveric hearts after fixing in 10% formalin. The right ventricle was opened after giving an incision and gross morphology of papillary muscles of right ventricles was studied by using Vernier calliper.

Statistical Analysis- In statistical analysis SPSS software was used and unpaired 't' test was used. P value less than 0.05 was taken as significant.

RESULTS AND CONCLUSIONS

It was found that anterior and posterior papillary muscles of right ventricle were always present while septal group of papillary muscles were absent in 10% cases. Number of heads of papillary muscles ranged from 1 to 4 in right ventricle. Length of anterior papillary muscle was more in males while rest of the papillary muscles of right ventricles were longer in females. The origin of the Anterior Papillary Muscle (APM) was mainly from lower 1/3 of the ventricular wall (80.5%). In rest of the cases (19.5%) the muscle took origin from middle 1/3 of the right ventricular wall. Muscle belly of APM was intraluminal in all the cases. No mixed or sessile types were found.

KEYWORDS

Atrioventricular Valve, Papillary Muscles, Right Ventricle.

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BACKGROUND

Atrioventricular (AV) valvular apparatus comprises of AV orifice and its annulus, valvular leaflets, chordae tendineae and papillary muscles.¹ Tricuspid valve complex comprises of tricuspid AV orifice and its associated annulus, valvular leaflets or cusps, chordae tendineae of various types and papillary muscles.² Tricuspid valve orifice is the largest valve orifice with an average circumference of 11.4±1.1 cm in males and 10.8±1.3 cm in females.³ Valvular orifice is surrounded by a uniform ring of collagenous tissue (annulus). Papillary muscles in right ventricle comprise of anterior, posterior and septal muscles.² Anterior papillary muscle (APM) is the largest and occasionally bifid. Its base arises from the right anterolateral ventricular wall below the anteroposterior

commissure and blends with the right end of the septomarginal trabecula. Posterior papillary muscle (Ppm) arises from the ventriculoseptal myocardium below the posteroseptal commissure. It is frequently bifid or trifid. The papillary muscles supporting septal leaflet have been classified into 2 groups.⁴ These are medial papillary complex (MPC) and septal papillary muscles (SPM).

Normal valve function depends upon the anatomic and mechanical integrity of the atrioventricular ring, the valve leaflets, the chordae tendineae and the papillary muscles, as well as upon proper integration of the time relations between contraction of the papillary muscle and contraction of the free ventricular wall.¹ Papillary muscle contraction normally continues synchronously with ventricular contraction and thereby supports the chordae tendineae and prevents overshoot of the leaflets during ventricular systole.⁵ In papillary muscle dysfunction, contraction is absent or ineffective. Rupture of one or more chordae tendineae results in acute loss of leaflet support leading to abrupt onset of mitral regurgitation. Regurgitation also occurs in rupture of papillary muscle.^{6,7}

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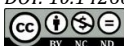
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The gross features of papillary muscles are very important for cardiac surgeons for the valvular surgeries like valve repair and replacement.

Aims

1. To note the shape, origin, number of heads and other gross features of papillary muscles of right ventricle.
2. To find out sexual difference in the gross morphology of papillary muscles of right ventricle.

MATERIALS AND METHODS

The present study was carried out in 30 apparently normal cadaveric hearts, which were available in the museum of the Department of Anatomy, Govt. Medical College and Hospital and Postgraduate Institute of Medical Education and Research, Chandigarh. The ages of the cases ranged from 17 to 75 years. There were 17 male and 13 female hearts. The hearts, which were fixed in 10% formalin, were washed under running tap water.

Right ventricle was opened along its acute margin by an incision from the right atrium to the apex of the right ventricle. The section passed near anteroposterior commissure of right AV valve to avoid sectioning the papillary muscles. The hearts were opened and washed under running tap water to remove blood clots. Gross morphology of the papillary muscles of the right ventricles was studied and noted.

Morphology of the papillary muscles of the right ventricle was noted which included number of heads, length, shape, origin and other gross features. The papillary muscles were studied and measured in situ with the help of a Vernier calliper. A head of a papillary muscle is defined as a muscle that is directly attached to the ventricular wall and its length was measured from this origin to the highest point of the muscle. The maximum length was taken. All measurements were made twice and the mean values were recorded. The site of the origin of the papillary muscles from the ventricular wall was also observed.

The values obtained from various measurements were tabulated and averages were calculated. Statistical analysis was done using unpaired 't' test to compare lengths of papillary muscles. The present observations were compared

with the other studies available in the literature to note any differences.

RESULTS

The incidence, length, number of heads, origin, protrusion of muscle bellies were observed in the papillary muscles of right ventricle.

Right Ventricle

There are three groups of papillary muscles in the right ventricle. These are anterior, posterior and papillary muscles of septal group.

Anterior Papillary Muscle (APM)

APM is the largest of the papillary muscles in the right ventricle. It arises from the right anterolateral ventricular wall. The length, origin, protrusion of muscle of bellies attached to anterior papillary muscles are tabulated in Table 1.

APM was present in all the cases.

In 63.3% cases, the muscle arose as a single head whereas in 36.7% cases there were two heads. In males, the incidence of single head was 70.6% and in females, it was 53.8%. Conversely, double APM was more common in females (46.2%) than in males (29.4%) (Table 2).

Mean length of APM was 16.33 mm with a range of 2.5 mm-26.6 mm. The mean length of APM was more in males than in females (Table 1). Single head of APM was always longer as compared to double heads (Table 3).

The origin of the APM was mainly from lower 1/3rd of the ventricular wall (80.5%). In rest of the cases (19.5%), the muscle took origin from middle 1/3rd of the right ventricular wall. APM did not arise from upper 1/3rd of right ventricular wall.

Muscle belly of APM was intraluminal in all the cases. No mixed or sessile types were found. There was no predominant shape observed in APM. It was conical in 26.7%, parallel in 20% and mamillated in 20% cases. In rest of the cases, it was flat, interlinked, V shaped, H shaped and two tiered (Table 4).

Papillary Muscles	Present	No. of Heads Range	Length (mm)		No. of C.T. Range	Origin			Protrusion			
			Range	Mean		Upper 1/3 rd	Middle 1/3 rd	Lower 1/3 rd	Intraluminal	Mixed	Sessile	
Anterior (APM)	Total	100.0%	1-2	2.5-26.6	16.33 ± 5.53	3-13	0.0%	19.5%	80.5%	100.0%	0.0%	0.0%
	Male	100.0%	1-2	2.5-26.6	16.94 ± 6.79	3-13	0.0%	18.2%	81.8%	100.0%	0.0%	0.0%
	Female	100.0%	1-2	9.9-22.1	15.63 ± 3.61	4-10	0.0%	21.1%	78.9%	100.0%	0.0%	0.0%
	P-value	-	0.363	-	0.456	-	-	0.669	0.646	-	-	-
Posterior (Ppm)	Total	100.0%	1-3	1.2-24.2	10.58 ± 4.86	1-7	17.2%	59.4%	23.4%	100.0%	0.0%	0.0%
	Male	100.0%	1-3	1.2-22.3	10.38 ± 4.86	2-7	16.7%	58.3%	25.0%	100.0%	0.0%	0.0%

	Female	100.0%	1-3	3.2-24.2	10.84±4.49	1-7	17.9%	60.7%	21.4%	100.0%	0.0%	0.0%	
	P-value	-	0.896	-	0.715	-	0.913	0.845	0.806	-	-	-	
Papillary muscles of Septal Group	Septal Papillary Muscles (SPM)	Total	83.3%	0-4	1.4-9.0	4.24±1.88	1-7	39.5%	53.5%	7.0%	84.0%	4.0%	12.0%
		Male	82.4%	0-4	1.7-9.0	4.23±1.97	1-5	37.0%	51.9%	11.1%	92.9%	0.0%	7.1%
		Female	84.6%	0-2	1.4-7.7	4.26±1.78	1-7	43.8%	56.2%	0.0%	72.7%	9.1%	18.2%
		P-value	0.875	0.326	-	0.957	-	0.861	0.589	0.234	0.187	0.268	0.420
	Medial Papillary Complex (MPC)	Total	80.0%	0-4	1.2-13.0	4.83±2.56	0-6	96.9%	3.1%	0.0%	83.3%	4.2%	12.5%
		Male	76.5%	0-4	1.2-9.2	4.74±2.30	0-6	100.0%	0.0%	0.0%	92.3%	0.0%	7.7%
		Female	84.6%	0-2	2.4-13.0	4.96±2.95	1-4	92.9%	7.1%	0.0%	72.7%	9.1%	18.2%
		P-value	0.596	0.954	-	0.815	-	0.522	0.287	-	0.217	0.287	0.461

Table 1. Measurements of Papillary Muscles in Right Ventricle

Papillary Muscles		No. of Heads												
		Absent		1		2		3		4		6		
		No. of Cases	% Age	No. of Cases	% Age	No. of Cases	% Age	No. of Cases	% Age	No. of Cases	% Age	No. of Cases	% Age	
Anterior (APM)	Total	-	-	19	63.3%	11	36.7%	-	-	-	-	-	-	
	Male	-	-	12	70.6%	5	29.4%	-	-	-	-	-	-	
	Female	-	-	7	53.8%	6	46.2%	-	-	-	-	-	-	
	P-value	0.629												
Posterior (Ppm)	Total	-	-	6	20.0%	14	46.7%	10	33.3%	-	-	-	-	
	Male	-	-	2	11.8%	11	64.7%	4	23.5%	-	-	-	-	
	Female	-	-	4	30.8%	3	23.1%	6	46.1%	-	-	-	-	
	P-Value	0.666												
Papillary Muscles of Septal Group	Septal Papillary Muscles (SPM)	Total	5	16.7%	11	44.0%	11	44.0%	2	8.0%	1	4.0%	-	-
		Male	3	17.6%	5	35.7%	6	42.9%	2	14.3%	1	7.1%	-	-
		Female	2	15.4%	6	54.5%	5	45.5%	-	-	-	-	-	-
		P-value	0.561											
	Medial Papillary Complex (MPC)	Total	6	20.0%	18	75.0%	5	20.8%	-	-	1	4.2%	-	-
		Male	4	23.5%	10	76.9%	2	15.4%	-	-	1	7.7%	-	-
		Female	2	15.4%	8	72.7%	3	27.3%	-	-	-	-	-	-
		P-value	0.978											

Table 2. Distribution of Number of Heads of Papillary Muscles in Right Ventricle

Papillary Muscles		No. of Heads	Length (mm)		
			Min	Max	Mean
Anterior (APM)		1	7.3	26.4	18.09
		2	2.5	26.6	14.81
Posterior (Ppm)		1	9.7	24.2	13.27
		2	3.9	22.3	12.4
		3	1.2	16.2	8.3
Septal	Septal Papillary Muscles (SPM)	1	1.4	9	4.2
		2	1.8	8.9	4.5
		3	1.7	6	3.8
		4	2.6	4	3.5
	Medial Papillary Complex (MPC)	1	1.2	13	5
		2	2.5	8.3	4.6
		3	-	-	-
		4	2.8	9.2	4.6

Table 3. Distribution of Length of Papillary Muscles in Right Ventricle

No. of Heads	Pattern	Anterior		Posterior		Papillary Muscles of Septal Group			
		No. of Cases	% Age	No. of Cases	% Age	SPM		MPC	
						No. of Cases	% Age	No. of Cases	% Age
1	Conical	8	26.7%	3	10.0%	9	36.0%	11	45.8%
	Mamillated	6	20.0%	-	-	1	4.0%	-	-
	Arched	-	-	1	3.3%	1	4.0%	-	-
	Sloped	-	-	1	3.3%	-	-	2	8.3%
2	2 Tiered	1	3.3%	-	-	-	-	-	-
	Interlinked	2	6.7%	2	6.9%	-	-	-	-
	Parallel	6	20.0%	10	33.4%	11	44.0%	4	16.7%
	V	1	3.3%	1	3.3%	-	-	1	4.2%
	H	1	3.3%	1	3.3%	-	-	-	-
3	Parallel	-	-	3	10.0%	2	8.0%	-	-
	Interlinked	-	-	1	3.3%	-	-	-	-
	2 Interlinked + 1 Separate	-	-	1	3.3%	-	-	-	-
	2 Tiered + 1 Separate	-	-	1	3.3%	-	-	-	-
	V + 1 Separate	-	-	3	10.0%	-	-	-	-
	H + 1 Separate	-	-	1	3.3%	-	-	-	-
4	Parallel	-	-	-	-	1	4.0%	1	4.2%

Table 4. Shape of Papillary Muscles in Right Ventricle



Figure 1. Mamillated Anterior Papillary Muscle

Posterior Papillary Muscle (Ppm)

Ppm arises from ventriculoseptal myocardium below posteroseptal commissure. It is frequently bifid or trifid.

The various parameters of posterior papillary muscle are tabulated in Table 1.

Ppm was present in all the cases. Number of heads ranged from 1 to 3. Incidence of double heads was more than single or triple heads. In males, single head was present in 11.8%, double heads in 64.7% and triple heads in 23.5% cases. In

females, the incidence was 30.8%, 23.1% and 46.1% respectively (Table 2).

Mean length of Ppm was 10.58 mm and ranged from 1.2 to 24.2 mm. Mean length of Ppm was more in females (10.84 mm) than in males (10.38 mm) (Table 1). Mean length of Ppm with single head was more as compared to that with double heads, which in turn was more than that of the triple heads (Table 3). Ppm took origin mainly from middle 1/3rd of right ventricle (59.4%). Number of cases of Ppm taking origin from middle 1/3rd of right ventricle was more in females (60.7%) than in males (58.3%). In rest of the cases, the muscle took origin from lower 1/3rd or upper 1/3rd of right ventricle. Muscle belly of Ppm was intraluminal in all cases. No mixed or sessile types were found.

Muscle bellies were predominantly parallel in arrangement (43.4% cases). The rest were conical, flat topped, arched (Fig. 3), sloped, interlinked, V shaped, H shaped, two interlinked + 1 separate, two tiered + 1 separate, V + 1 separate, H + 1 separate (Table 4).



Figure 2. Arched Posterior Papillary Muscle of Right Ventricle



Figure 3. V-shaped Posterior Papillary Muscle of Right Ventricle

Papillary Muscles of Septal Group

It comprises of two groups, septal papillary muscles (SPM) and medial papillary complex (MPC). SPM mostly support the mid portion of septal leaflet of tricuspid valve while MPC supports the anterosuperior portion of the septal leaflet of tricuspid valve. The most anterior and prominent muscle of MPC is known as Lancisi's muscle.

The various parameters of papillary muscles of septal group are listed in Table 1.

Septal Papillary Muscles (SPM)

SPM was present in 83.3% cases.

Number of heads ranged from 1 to 4. Single head of SPM was more common in females (54.5%) than in males (35.7%). Double heads of SPM were present in 42.9% cases in males and 45.5% cases in females. 3 and 4 heads of SPM were seen only in males (Table 2).

Mean length of SPM was 4.24 mm with a range of 1.4 to 9 mm. Mean length of SPM was more in females (4.26 mm) than in males (4.23 mm) (Table 1). Mean length of SPM was found to decrease as the number of heads increased except in the case of single and double heads. Mean length of double heads was more than that of single head (Table 3).

Origin of septal papillary muscle was from upper 1/3rd of right ventricle in 37.0% cases, middle 1/3rd in 51.9% and lower 1/3rd in 11.1% cases in males. The values for females were 43.8% from upper 1/3rd and 56.3% from middle 1/3rd of right ventricle. In females, SPM did not arise from lower 1/3rd of right ventricle.

Muscle bellies of septal papillary muscle were intraluminal in 92.9% and sessile in 7.1% cases in males. In females, the muscle bellies were intraluminal in 72.7%, sessile in 9.1% and mixed in 18.2% cases.

The arrangement of muscle bellies was predominantly parallel (52%) and conical (36%). In rest of the cases, they were mamillated and arched in a small number of cases (Table 4).



Figure 4. Septal Papillary Muscles (SPM) supporting Mid-portion and Medial Papillary Complex (MPC) supporting the Anterosuperior Portion of Septal Leaflet of Tricuspid Valve

Medial Papillary Complex (MPC)

MPC was present in 80% cases.

Number of heads of MPC ranged from 1 to 4. Incidence of single head was 75%, double heads 20.8% and 4 heads in 4.2% cases. 4 heads were present in only one male heart. Two heads were found more frequently in females than in males (Table 2).

Mean length of MPC was 4.83 mm with a range of 1.2 to 13 mm. Mean length in males was less as compared with that in females (Table 1). Mean length of single head of MPC was more than that of double or 4 heads (Table 3).

Origin of medial papillary complex was from upper 1/3rd of right ventricle in all the cases in males. In females, the origin of medial papillary complex was mainly from upper 1/3rd of right ventricle (92.9%) and in rest of the cases from middle 1/3rd (7.1%).

Muscle bellies of medial papillary complex were intraluminal in 92.3% and sessile in 7.7% cases in males. In females, the muscle bellies were intraluminal in 72.7%, sessile in 9.1% and mixed in 18.2% cases. The shape of muscle bellies was predominantly conical (45.8%), flat topped (20.8%) and parallel (16.7%). The rest were sloped or V shaped. All the muscle bellies in the case with 4 heads were parallel (Table 4).

CONCLUSIONS

The present study was conducted on 30 human cadaveric hearts of north-west Indians to note the morphology and morphometry of papillary muscles of right ventricle. There were 17 male and 13 female hearts ranging in age from 17 to 75 years in age. The incidence, number of heads, length, shape, origin, protrusion of muscle bellies of papillary muscles of right ventricle were noted in detail in both males and females in an attempt to find gender differences in papillary muscles. The origin of all the three papillary muscles of the right ventricle from the ventricular wall was observed in the present study. The protrusion of muscle bellies in the ventricular cavity was also observed.

In the present study, the origin of anterior papillary muscle was mainly from lower 1/3rd of the wall; the origin of posterior and septal papillary muscles was mainly from the middle 1/3rd of the ventricular wall. Anterior and posterior papillary muscle bellies were intraluminal in all the cases. Septal papillary muscle was also mainly intraluminal although a small number of mixed and sessile types were also found.

A study by Restivo et al⁴ has reported the topography of medial papillary complex from septal papillary muscles.

Anterior Papillary Muscle (APM)

APM was present in all the cases in the present study as has also been reported in literature.^{2,8,9,10}

The percentage of incidence of heads of APM is variable. APM has been described, as being occasionally bifid.² Single head was found in 70.6% cases in males and 53.8% cases in females in the present study. The difference was not statistically significant. Nigri et al⁸ described presence of single head in 79% cases (77% in males and 95% in females).

Shape of APM was conical (61%), flat topped (24.4%) or mamillated (14.6%). These values are almost similar to those found by Nigri et al⁸. However, these authors⁸ also found arched and wavy type of APM in 4.3% and 1% of cases respectively. The present study did not come across these shapes.

In the present study, mean length of single head of APM was 18.09 mm and of double heads was 14.81 mm. The corresponding figures in the Caucasian study are 20.2 mm and 13.70 mm respectively. Both the studies have found that the single head of APM is always longer as compared to double head.

Posterior Papillary Muscle (Ppm)

Ppm was present in all the cases in the present study as well as the other reports.^{2,8,9,10}

Number of heads ranged from 1 to 3 in the present study which is in conformation with the standard text books of anatomy.^{2,9,10} Four heads of Ppm were seen only in the study by Nigri et al.⁸ The incidence of two heads of Ppm is the most common arrangement found in the present study as well as others.⁸ The incidence of 3 heads was 33% in the present study, which is higher as compared to the Caucasian study⁸ (20%). There are some variations in the incidence of heads in males and females but no statistically significant difference was found.

The shape of Ppm was conical in 75% hearts. A few cases of flat topped (9.4%), mamillated (7.8%), arched (6.2%) and sloped (1.6%) muscles were also observed. When compared to the Caucasian study⁸ the observations were almost similar. The other defined shapes such as grooved and stepped types were not found in the present study.

Mean length of Ppm with single head was less in the present study than that found in Americans.⁸ Mean length of Ppm with single head was more as compared to that with double heads which in turn was more than that of the triple heads. Similar findings were reported by Nigri et al.⁸

Papillary Muscles of Septal Group

Papillary muscles of septal group have been described under one heading⁸ or separately as septal papillary muscle (SPM) and medial papillary muscles (MPC).^{4,11} Wafae et al¹² has described these as septal inferior papillary muscle and septal

infundibular papillary muscle. The muscles in the present study have been described as SPM and MPC respectively.

Septal Papillary Muscles (SPM)

The complete absence of SPM was discussed by various authors.^{2,8,10} According to standard textbooks of anatomy, SPM may be absent or exist merely as irregular fibrous cords². Nigri et al⁸ reported absence of SPM in 21% cases. In the present study MPC was absent in 20% cases and SPM was absent in 16.7% cases. Both the groups were absent in 10% of cases.

Number of heads ranged from 1 to 4. Single, triple and quadruple heads were more common in Caucasians⁸ than in north-west Indians while double heads were found more frequently in the present study.

Conical muscle bellies of SPM showed a higher incidence in the present study as compared to the study of Nigri et al⁸ while a lower incidence of flat topped bellies was observed. Mamillated and arched types of bellies were found in almost equal numbers in the present study and study by Nigri et al.⁸

Mean length of single head of SPM was less in the present study than the mean length found by Nigri et al⁸. Mean length of double heads of SPM was slightly more in the present study than that of Nigri et al⁸. Mean length of SPM was found to decrease as the number of heads increased except in the case of single and double heads. Mean length of double heads was more than that of single head in the present study. But in the case of study by Nigri et al⁸ mean length decreased as number of heads of SPM increased in all the cases.

Medial Papillary Complex (MPC)

A few studies have been done on medial papillary complex,^{4,11} but they have focused only on the location and the development of the medial papillary complex. According to Wenink,¹¹ morphology of MPC changes with increasing age with changes in haemodynamics of the heart.

Some authors^{4,13} describe the Lancisi's muscle as the most prominent muscle in MPC. According to them, this muscle has been described in literature but the knowledge of its anatomy is very limited. MPC is located in immediate sub-infundibular position. These studies are mainly focused on the variations found in location of MPC.

In the present study, origin of medial papillary complex was mainly from upper 1/3rd of right ventricle and only in a small number from middle 1/3rd of right ventricle. It did not arise from the lower 1/3rd of right ventricle.

The present study was done with a purpose to find out the gross morphology and size of papillary muscles in right ventricles and compare our findings with other studies and note any gender differences among them. The morphometry of papillary muscles is very useful during mitral and tricuspid valve repair.

Anterior and posterior papillary muscles of right ventricle were always present while both groups of papillary muscles of septal group were absent in 10% cases.

Number of heads of papillary muscles ranged from 1 to 4 in right ventricle. Single head was more common in case of anterior papillary muscle (APM) of right ventricle. In case of Ppm, double heads were more common.

In the right ventricle, anterior papillary muscle was longer in males than in females while rest of the papillary muscles of right ventricle were longer in females. The differences were not statistically significant.

Mean length of papillary muscles was found to decrease in the present study as the number of heads increased except in the case of SPM. Mean length of double heads of SPM was more than that of single head in the present study.

There is a trend of upward shift of origin of papillary muscles in the right ventricle from anterior papillary muscle, posterior papillary muscle, septal papillary muscle to medial papillary complex.

The mean length of single head of papillary muscles of right ventricle was less in north-west Indian hearts as compared to Caucasian hearts⁸. The length of double or more heads was more in the present study than in Caucasian study⁸ except in case of 3 or 4 heads of SPM.

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