

## A COMPARATIVE STUDY OF NUMBER AND POSITION OF PAPILLARY MUSCLES AND CLINICAL SIGNIFICANCE

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### ABSTRACT

**Introduction:** Papillary muscles are the conical muscle masses project into the cavity of ventricle and are inserted into the valve cusps by chordae tendinae. They prevent the cusps from being forced back into the atrium during ventricular contraction. Their number and positions are highly variable. An anomalous papillary muscle can act as an ectopic foci. Hence these variations should be assessed before any operative intervention on the valve. Present study aim to analyse these variations in detail.

**Materials and Methods:** This is a descriptive observational study to analyse the variations in number and position of papillary muscles in ventricles of 100 adult human hearts ranging in age from 17 to 80 years obtained from autopsy specimens. The methodology used was the dissection method according to standard autopsy techniques. The data obtained were quantified as frequencies (in %).

**Results:** Of the 100 hearts studied, the right ventricle consisted of the usual three groups of papillary muscles in 84% of hearts whereas the remaining 16% of hearts had only two groups (rudimentary SPMs). The left ventricle consisted of two groups of papillary muscles in 73% of hearts; three groups in 23%; four groups in 4% and none of the hearts contained single papillary muscle. Regarding the positions, the right ventricle had APMs in anterobasal position, the PPMs in posterobasal position and SPMs was located close to ventricular septum and no extra group of papillary muscles were found. In left ventricle, 73% of hearts had APMs and PPMs in anterolateral and posteromedial positions respectively, whereas in 27% (23% and 4%) hearts, the extra group of papillary muscles (third group and fourth group) were interlinked to PPMs and was situated in posterolateral position.

**Conclusion:** These findings suggest that the variations in number and positions of papillary muscles should be anticipated before any operative intervention on the valvular apparatus.

**KEY WORDS:** Anterior Papillary Muscle, Posterior Papillary Muscle, Septal Papillary Muscle.

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### INTRODUCTION

Papillary muscles are the conical muscle masses project into the cavity of ventricle and are inserted into the margins and ventricular surfaces of two adjacent cusps of atrioventricular valves by tendinous strands (chordae tendinae). On contraction, they draw the margins of the adjacent cusps together and prevent the cusps from

being forced back into the atrium as the intra-ventricular pressure rises which in turn increases the efficiency of the ventricular contraction and permits the atrium to fill completely while the ventricle is contracting. The number and positions of papillary muscles can vary significantly which are important in anticipating various subvalvular techniques during valve repair.

Papillary muscle rupture is an uncommon life threatening complication of acute myocardial infarction usually 2-7 days after an acute infarct. Without surgical intervention, mortality is estimated to be 50% in the first 24 hours and could reach 90% by one week. An increase in number and size of papillary muscles in the left ventricle can cause Left Ventricular Outflow Tract (LVOT) obstruction. An anomalous papillary muscle can be an ectopic foci in the heart as right branch of conducting system blends with it. Knowledge of these variations would be useful in surgical techniques like papillotomy and commissurotomy in rheumatic lesions, leaflet resection in advanced myxomatous lesions, excision of infective vegetation, transfer and rotation of leaflet segments in traumatic conditions and in correction of functional Tricuspid Regurgitation.

**Aim:** Present study aim to analyse the variations in number and position of papillary muscles of right and left ventricles in detail.

## MATERIALS AND METHODS

This is a descriptive observational study to analyse the variations in number and position of papillary muscles in ventricles of 100 adult human hearts (70 males and 30 females) ranging in age from 17 to 80 years obtained from autopsy specimens, Dept of Forensic Medicine, Govt. Medical College, Kozhikode (with permission).

**Inclusion criteria:** Adult human hearts obtained with no gross anomalies or no pathological changes were included.

**Exclusion criteria:** Hearts with ventricular wall thickness of more than 15 mm were excluded.

**Materials used:** Gloves, Dissection box, Brain knife, Vernier caliper, Camera

**Methodology: Dissection method** [1] Dissection was performed according to standard autopsy techniques.

(1) Using scissors, the initial cut was made between the ostia of both vena cavae to the right atrial appendage. Right atrium was opened and cleaned with water to remove any blood clots so as to visualise the tricuspid orifice from above. Then we opened the right ventricle with a V-shaped cut along its right margin and across

the anterior wall of the right ventricle.

(2) The left atrium was opened between the superior pulmonary veins. Then we extended the cut to inferior pulmonary veins and to the left atrial appendage. A knife was passed between the two leaflets of mitral valve so as to pierce the apex and sliced upward parallel to the interventricular septum along the left heart border to open the cavity of left ventricle. Any residual clots were removed with water.

(3) The papillary muscles of both ventricles were inspected and noted the number of groups and positions.

Photographs were taken to document the important findings. The results obtained were tabulated in groups and expressed as percentage (%).

## RESULTS

**Number of groups of papillary muscles:** The two major papillary muscles in the right ventricle are located in anterior and posterior positions. The third, smaller muscle has a medial position together with several smaller and variable muscles attached to the ventricular septum. The two muscles supporting the leaflets of mitral valve are the anterolateral and posteromedial groups. Of these, the anterolateral papillary muscles arise from the sternocostal mural myocardium and the posteromedial group from the diaphragmatic region.

**Table 1:** Number of groups of papillary muscles in ventricles.

No. of groups of PM	RV (frequency in %)	LV (frequency in %)
1	0	0
2	16	73
3	84	23
4	0	4

Of the 100 hearts analysed, the right ventricle consisted of three groups of papillary muscles (APM, PPM and SPM) in 84 hearts (84%) (Fig 1) whereas the remaining 16 hearts (16%) had only rudimentary septal papillary muscles. (Fig 2).

The left ventricle consisted of two groups of papillary muscles in 73 hearts (73%) (Fig 3) and three groups in 23 hearts (23%) (Fig 4). In 4 % of hearts, we observed four groups of papillary muscles (Fig 5) whereas none of the hearts contained single papillary muscle.



**Position of papillary muscles:** The relative positions of papillary muscles could be assessed better in their functional state by standard transthoracic two dimensional echocardiography (than in autopsy study).

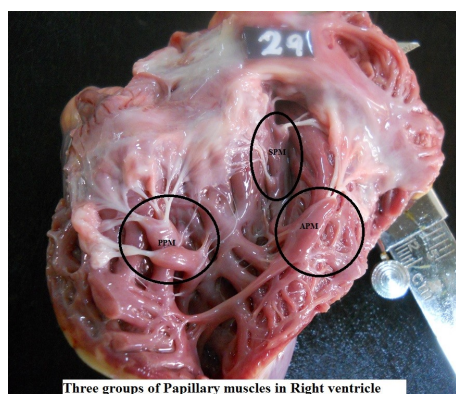
In Right ventricle, of the 84% hearts with three groups of papillary muscles, all the anterior group of muscles was located anterobasally and posterior group of muscles was situated posterobasally in the normal anatomical position of heart. Another group of small papillary muscles near to interventricular septum were considered as septal group of muscles which were positioned more medially. However, in 16% of hearts, septal group of papillary muscles were not seen in our study.

In Left ventricle, of the 73% of hearts with two groups of papillary muscles, the anterior group of muscles was situated anterolaterally and posterior group of muscles was located posteromedially in the normal anatomical position of the heart. In 23% of hearts, in addition to that, we found another distinct group of muscles interlinked to the normal posterior group by narrow muscular strands which were considered as the third group of muscles. In the remaining 4% of hearts, we noticed one more muscle group in the same pattern attached to the posterior cusp of the valve which were considered as the fourth muscle group. Both of these muscle groups were positioned posterolaterally when we hold the heart in the anatomical position.

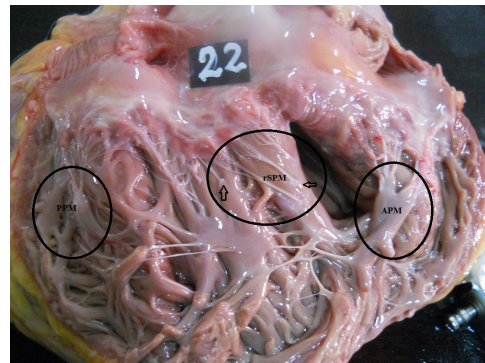
**Table 2:** The relative positions of papillary muscles in ventricles of heart.

Ventricle	APM	PPM	SPM	EPM	
Right	Anterobasal	Posterobasal	Septal	-	-
Left	Anterolateral	Posteromedial		Posterolateral (third group)	Posterolateral (fourth group)

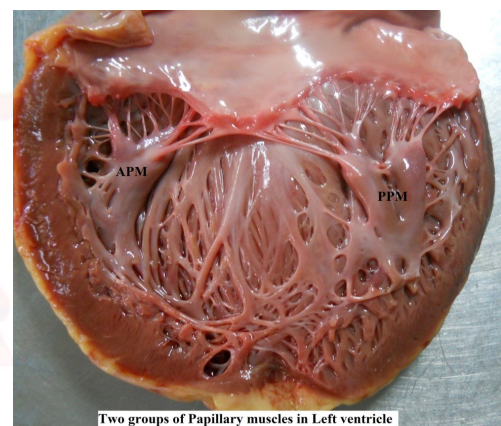
**Fig 1:** Three Groups of Papillary muscles in Right ventricle.



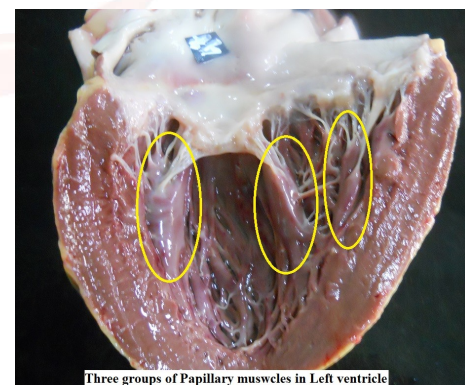
**Fig 2:** Well developed Anterior (APM) and Posterior (PPM) Papillary muscles and rudimentary septal Papillary muscle (rSPM) in the Right ventricle.



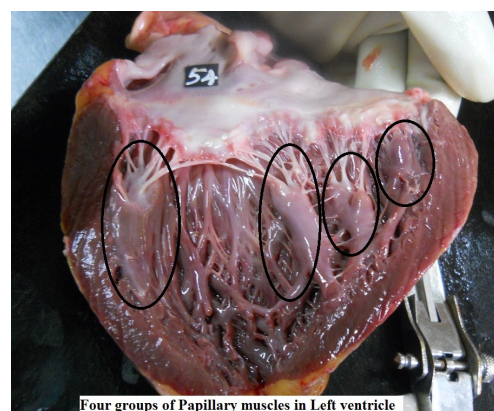
**Fig 3:** Well developed Anterior (APM) and Posterior (PPM) Papillary muscles and rudimentary septal Papillary muscle (rSPM) in the Right ventricle.



**Fig 4:** Three Groups of Papillary muscles in the Left ventricle.



**Fig 5:** Four Groups of Papillary muscles in the Left ventricle.



## DISCUSSION

An increase in number and size of papillary muscles could precipitate ventricular outflow tract obstruction and severe valvular regurgitation. Therefore it is important to look for the number of groups of papillary muscles.

**Number of groups of papillary muscles in Right Ventricle:** Nigri et al [2] in 2001 observed 3 groups of papillary muscles in 78.5% of cases and 2 groups in 21.5% in a sample of 79 normal human hearts.

In 2003, Jezyk et al [3] noticed 3 groups of papillary muscles in 70% of hearts and in the remaining 30%, they observed 4 groups of muscles in a sample of 111 normal human hearts.

Ekin Aktas et al [4] in 2004 examined the papillary muscles in 200 autopsy cases and noticed 3 groups of muscles in 170 hearts (85%) and 2 groups of muscles in the remaining 15%.

Another study in 100 normal human hearts by Loukas et al [5] in 2009 observed 3 groups of papillary muscles in 58% of cases and in the remaining 42%, they noticed 4 groups of muscles.

In 2014, Harsha B R et al [6] noted 3 groups of papillary muscles in 73 (76%) and 2 groups in 23 (24%) in a sample of 96 normal human hearts.

In the present study, we observed the classical 3 groups of papillary muscles (APM, PPM and SPM) in majority (84%) of cases and 2 groups of muscles (rudimentary or absent SPM) in the remaining 16%. None of the hearts contained a single group of muscle. Present study closely resembled to that of Ekin Aktas et al (2004) [4].

**Table 3:** Comparison of Number of groups of papillary muscles in Right ventricle from various studies.

Year of study	Author	Population	Sample size	No of groups of PMs in RV (Incidence in %)			
				1	2	3	4
2001	Nigri et al[2]	American	79	0	21.5	78.5	—
2003	Jezyk et al[3]	Italian	111	0	—	70	30
2004	E Akts et al[4]	Arabian	200	0	15	85	—
2009	Loukas et al[5]	Italian	100	0	—	58	42
2014	Harsha B R et al[6]	Indian	96	0	24	76	—
Present study			100	0	16	84	—

**Number of groups of papillary muscles in Left Ventricle:** In 1962, Carney E K et al [7] reported

about occurrence of accessory papillary muscles in the left ventricle and its association with congenital Mitral Regurgitation in 9 patients.

In 1963, Shone and Seller et al [8] observed that occurrence of a single papillary muscle as the most common congenital anomaly affecting the left ventricular papillary muscles. They noted that all the mitral chordae were attached to this single muscle (parachute mitral valve) and was usually associated with other malformations including a supramitral valve ring, diffuse subaortic stenosis or coarctation of the aorta.

William Robert et al [9] in 1972 noticed single papillary muscle in the left ventricle in 20 cases of the 47 patients studied.

Victor S, Nayak V M et al [10] observed 2 groups of papillary muscles in 84 hearts (84%) and 3 groups of muscles in the remaining 16% in a sample of 100 normal human hearts in the year 1995.

Alper Ucak et al [11] in 2010 noted an accessory papillary muscle in the left ventricle with its chordae in the subaortic area, precipitating outflow tract obstruction and severe aortic insufficiency in a young adult.

Kuo-Tzu Sung et al [12] in 2014 observed hypertrophied anterolateral and posteromedial papillary muscles together with a large, third accessory papillary muscle causing mid cavity obstruction in the left ventricle in an adult.

In 2013 S A Gunnal et al [13] studied papillary muscles of mitral valve complex in 116 human cadaveric hearts and noted 2 groups of papillary muscles in 50 (43.11%) hearts, three groups in 37 (31.9%), four groups in 25 (21.55%) and only two papillary muscles ('classical') in 4 (3.44%) hearts.

A cadaveric study of papillary muscles of left ventricle in 50 formalin fixed adult human hearts in 2014 by Hosapatna M et al [14] cited 2 groups of papillary muscles in 46 (92%) hearts and in 4 (8%) hearts, they observed 3 groups of muscles<sup>63</sup>. Another case reported by Kotaro Oe et al [15] in 2015 noticed abnormally high number of papillary muscles in the left ventricle of an adult (accessory papillary muscles) causing left ventricular outflow tract obstruction. In the present study, we noted 2 groups of papillary muscles in 73 (73%) hearts, 3 groups



in 23 (23%), 4 groups in 4 (4%) of cases in a sample of 100 normal human hearts. None of them contained a single group of papillary muscle or classical type (only two papillary muscles).

**Table 4:** Comparison of Number of groups of papillary muscles in Left ventricle from various studies.

Year of study	Author	Population	Sample size	No of groups of PMs in LV (Incidence in %)				
				1	2	3	4	'classical'
1972	William Robert et al[9]	British	47	20	—	—	—	—
1995	Victor S et al[10]	Indian	100	—	84	16	—	—
2013	S A Gunnal et al[13]	Indian	116	—	43.11	31.9	21.55	3.44
2014	Hosapatna M et al[14]	Indian	50	—	92	8	—	—
	Present Study	Indian	100	—	73	23	4	—

### **Congenital absence of papillary muscles:**

Hashimoto K et al [16] in 2001 reported a case of congenital mitral regurgitation in a young patient occurred due to the absence of the anterolateral papillary muscle and the corresponding marginal chordae. They corrected this abnormality (by anterolateral commissural annuloplasty and by insertion of an artificial chordae to prevent prolapse of the anterior leaflet) with good postoperative outcome.

In 2010, W B Christopher et al [17] reported a case of congenital absence of posteromedial papillary muscle and the corresponding chordal apparatus to the anterior leaflet of mitral valve causing prolapse of anterior leaflet and severe Mitral Regurgitation in a 6 year old child (visualised by echocardiography).

In 2010, Fumiaki Shikata et al [18] noted a case of hypoplastic anterior papillary muscle with absent chordae resulting in isolated congenital Tricuspid Regurgitation (TR) in an adult.

**Anomalies in position of papillary muscle:** In 1969, Castaneda and Anderson et al [19] observed abnormally large and malpositioned papillary muscles in the left ventricle causing narrowing of orifice of the mitral valve in young adults.

Maron B J, Njshimura R A et al [20] evaluated two patients in 1997, who had an anomalous papillary muscle inserting directly into the anterior mitral leaflet, producing significant midcavity obstruction. This anomaly was challenging to identify with echocardiography because the exaggerated anterior displacement

of hypertrophied papillary muscles closely resembled the systolic anterior motion of mitral valve or congenital malformation of mitral valve apparatus. This should always be anticipated before any operative intervention (Standard Myotomy / Myectomy). Kotaro Oe et al [15] in 2015 reported a case of left ventricular outflow tract obstruction caused by two anteriorly displaced papillary muscles in the left ventricle.

Teo E P et al [21] in the same year noticed anterior displacement of papillary muscles along with degenerative leaflet changes on mitral valve and aberrant chordal attachments in patients with left ventricular outflow tract obstruction.

In our study, the right ventricle consisted of the usual three groups of papillary muscles in majority of hearts (84%). Of these, all the anterior group of muscles was situated anterobasally and posterior group of muscles was located posterobasally in the normal anatomical position of heart. This is because of the fact that the anterior and posterior cusps of tricuspid valve are more nearly horizontal than vertical. Another group of muscles situated close to interventricular septum were considered as the septal group which were positioned more medially. In the remaining 16% of hearts, septal group of papillary muscles were not developed in our study. In Left ventricle, majority of hearts (73%) had two groups of papillary muscles, of which the anterior group of muscles was situated anterolaterally and posterior group of muscles was located posteromedially in the normal anatomical position of the heart. In 23% of hearts, in addition to that, we found another distinct muscle group interlinked to the normal posterior group by narrow muscular strands which were considered as the third group of muscles. In the remaining 4% of hearts, we noted one more muscle group in the same pattern attached to the posterior cusp of the valve which were considered as the fourth muscle group. Both of these muscle groups were positioned posterolaterally when we hold the heart in the anatomical position.

### **CONCLUSION**

In the present study, the Right ventricle consisted of the usual 3 groups of muscles in 84% of hearts and 2 groups in the remaining 16%.

The Left ventricle had the usual 2 groups of muscles in 73% of hearts, 3 groups in 23% and 4 groups in the remaining 4% of hearts. Regarding the positions of papillary muscles, the right ventricle had APMs in anterobasal position, the PPMs in posterobasal position and SPMs was located close to ventricular septum and no extra group of papillary muscles were found. In left ventricle, 73% of hearts had APMs and PPMs in anterolateral and posteromedial positions respectively, whereas in 27% (23% and 4%) hearts, the extra group of papillary muscles (third group and fourth group) were interlinked to PPMs and was situated in posterolateral position.

These variations should be anticipated in patients who present with symptoms suggestive of decreased cardiac output (while performing standard two dimensional transthoracic echocardiography) before planning any surgical interventions on the valvular apparatus. An anomalous papillary muscle can act as an ectopic foci in heart that can precipitate conduction blockade. This should be kept in mind before doing any ablation procedure.

## ABBREVIATIONS

**RV** - Right Ventricle

**LV** - Left Ventricle

**PM** - Papillary Muscle

**APM** - Anterior Papillary Muscle

**PPM** - Posterior Papillary Muscle

**SPM** - Septal Papillary Muscle

**rSPM** - rudimentary Septal Papillary Muscle

**EPM** - Extra Papillary Muscle.

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**Conflicts of Interests: None**

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