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Morphometric Analysis of Papillary Muscles in Both Ventricles of Hearts

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Abstract: ***Objective****: To measure the length and breadth and attachment of papillary muscles in both ventricles of human hearts.*
Introduction: *The papillary muscles of heart are conical in projections into the respective chamber of myocardium covered by endocardium. Functionally the papillary muscles are important part of the respective valve complex. They prevent the cusps of a valve from being everted when ventricle contracts**.** Contraction of papillary muscle prevents backward flow of ventricular blood into the atria by bracing the atrioventricular valves. This is due to high pressure of blood flow through the ventricles. During this process over a period the papillary muscle fibers tend to undergo wear and tear and sometimes detach themselves from the ventricular walls. In many cases rupture of papillary muscle may be caused by a heart infarct and ventricular dysfunction and resulting in ischemia and a long term complication such as prolapse of atrioventricular valves.*
Materials & Methods: *One hundred adult human hearts irrespective of age and sex were used for the present study after obtaining necessary clearances from the Institutional Review Board and Institutional Ethical Committee of VMKV Medical College Salem, Tamilnadu, India for conducting the study.*
Results: *The origin of septal papillary muscle was found to be attached below the anteroposterior commissure in 2%, below the posteroseptal commissure in 15% and 83% origin from near the anteroseptal commissure of ventricle of the heart.In the present study the length of left posteromedial papillary muscle was longer than the anterolateral papillary muscle. The length ranged from 9.19 to 28.98 mm with a mean of 18.89 mm ± 4.28.In the present study the breadth of left anterolateral papillary muscle was higher than all other papillary muscles in both ventricles. The breadth ranged from 2.94 mm to 12.76 mm with a mean of 6.89 mm ± 1.95.*
Conclusion: *The mean length of posterior papillary muscle of the left ventricle was 18.89mm ±4.3 longer than the right ventricle papillary muscles which was statistically significant (p=0.01) .The breadth of the anterior papillary muscle of the left ventricle was more than all other papillary muscles. So the morphometric measurements of papillary muscles which will provide ready guides for the operating surgeon.*
Running Title*: Morphometry of papillary muscles*
Keywords*: Ventricles, Papillary muscle bellies,*

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I. Introduction

The papillary muscles of heart are conical projections into the respective chamber of myocardium covered by endocardium. Functionally the papillary muscles are important part of the respective valve complex. They prevent the cusps of a valve from being everted when ventricle contracts**.**

Contraction of papillary muscle prevents backward flow of ventricular blood into the atria by bracing the atrioventricular valves. This is due to high pressure of blood flow through the ventricles. During this process over a period the papillary muscle fibers tend to undergo wear and tear and sometimes detach themselves from the ventricular walls. In many cases rupture of papillary muscle may be caused by a heart infarct and ventricular dysfunction and resulting in ischemia and a long term complication such as prolapse of atrioventricular valves.

Numerically five papillary muscles exist, three in the right ventricle and two in the left ventricle. The two major papillary muscles in the right ventricle are situated in anterior and posterior aspect. A third smaller muscle has present in medial position together with several smaller and variable muscles attached the ventricular septum.

The papillary muscles play an important role in right ventricular contraction by drawing tricuspid annulus toward the apex thereby causing shortening of the long axis and sphericity of the chamber for ejecting blood Hashimoto K et.al (2001).

The anterior papillary muscle of the right ventricle is the largest. Its base arises from the right anterolateral ventricular wall below the anteroinferior commissure of the inferior cusps and it also blends with the right end of the septomarginal trabaculae. The posterior or inferior papillary muscle arises from the myocardium below the inferoseptal commissure and is frequently bifid or trifid. The septal or medial papillary muscle is small but typical and arises from the posterior septal limb of the septomarginal trabaculae.

In the left ventricle, the two muscles supporting the cusps of the mitral valve also vary in length and breadth and may be bifid. The anterolateral muscle arises from the sternocostal mural myocardium; the posteromedial arises from the diaphragmatic region.

There are two papillary muscles anterior and posterior. The anterior is attached to the anterior part of the left wall. The posterior arises from the inferior wall further posteriorly. Each papillary muscle sends chordae tendinae to both cusps of the left atrioventricular valve. G.J.Romanes (1986).

The apical areas and the papillary muscles are the first regions of each ventricle to undergo contraction. The atrioventricular valve leaflets are therefore initially drawn into the ventricle by the chordae tendineae upon the shortening papillary muscles.

Mitral commissural valvotomy used to be treatment of choice for mitral regurgitation in earlier days. However this surgery was not foolproof as there was some amount of residual regurgitation in the mitral valve. Transplantation of papillary muscles from their customary position and relocating it is known as Ventricular remodeling surgery. This type of surgery is usually done when there is dilated cardiomyopathy, particularly of the left ventricle. In some cases replanting the papillary muscles in a different location may be cause alleviation of symptoms in a dilated cardiomyopathy. (Kron *et al*., 2002).

Rupture of right ventricular papillary muscle is rare but can cause massive tricuspid regurgitation and right ventricular failure. Total tear of the papillary muscles of the left ventricle results in sudden death due to a rapid and sudden mitral regurgitation. Resection of myocardium is done by cardiothoracic surgeons combined with repositioning the papillary muscles. Incomplete tear of the papillary muscle will cause minimal mitral regurgitation and is not life threatening. However prolonged and unrecognized shearing or rupture may be fatal. This partial rupture or shearing can also cause myocardial infarction. (Nishimura *et al*., 1985).

This study aims to highlight the attachment of papillary muscles and the morphometric measurements which will provide ready guides for the operating surgeon.

II. Materials And Methods

Collection Of Specimens:

One hundred adult human hearts irrespective of age and sex were used for the present study after obtaining necessary clearances from the Institutional Review Board and Institutional Ethical Committee of VMKV Medical College Salem, Tamilnadu, India for conducting the study.

Out of 100 hearts, 50 were fresh adult human hearts specimens obtained from the Department of Forensic Medicine during postmortem procedure and the other 50 heart specimens were obtained from cadavers available with the Department of Anatomy VMKV Medical College & Hospitals, Salem.

The collected heart specimens were immersed in the preservative 10% formalin solution containing (10 liters of normal saline with 1 liter of formaldehyde and 50 ml of glycerin and 5 Gms of powdered thymol were added).

The parameters of the study were attachment of the papillary muscle (fig .1); in both ventricles. (fig.1a,b).The length of the papillary muscle was measured from the point of origin to the insertion (fig. 2) and the breadth of the papillary muscle was taken at the middle part of the papillary after measuring the length (fig.3).

Materials:

a. Dissecting instruments; **b.** Digital Vernier calipers; **c.** Hand lens

Inclusion criteria for collection of specimens

Visibly normal looking hearts without any gross abnormalities of papillary muscles.

Exclusion criteria

1. Hearts specimens with deformities visible on inspection.
2. Enlarged hearts.
3. Hearts affected by the following diseases:-

a. Cardio myopathy;
b. Valvular abnormalities;
c. Coronary artery disease.

The dissection procedure was followed by Cunningham manual (Romanes., 1986).

Morphological observations of the papillary muscles included their site of origin and insertion. Data regarding the size of the papillary muscle measured with the help of a digital vernier caliper. (fig.2, 3).

The right ventricle contains three papillary muscles. Based on their position and site of attachment, they are named as anterolateral, posteromedial and septal papillary muscles. Measurement of the both ventricle papillary muscles for length was from its inferior part to its superior part. (fig.2)
The breadth was measured from taking a midpoint on the line for length of muscle. Morphometric measurement was done using digital vernier caliper (fig. 3).

Stastical Analysis
The measurements were subjected to statistical analysis using SPSS software version 16. The range, standard deviation and mean were calculated. Chi square test was done to compare the variables.

III. Result

Papillary Muscle Attachments:
Origin Of Papillary Muscles:

In the present study, the anterior papillary muscle of the right ventricle took origin from below the anteroposterior commissure in 70% below the posteroseptal commissure in 20% and near the anteroseptal commissure in 10% of the heart specimens. The right posterior papillary muscle was found to be attached below the anteroposterior commissure in 25%, below the posteroseptal commissure in 60% and near the anteroseptal commissure in 15% of the heart specimens (table: 1).
The septal papillary muscle was found to be attached below the anteroposterior commissure in 2%, below the posteroseptal commissure (fig.4) in 15% and 83% origin from near the anteroseptal commissure of ventricle of the heart.
In the present study the left anterior papillary muscle took origin from sternocostal mural in 82% and 18% muscle bellies took origin from the diaphragmatic wall of the ventricle. The left posterior papillary muscle also took origin from sternocostal mural area in 10% and origin from the diaphragmatic wall in 90% of left ventricles (Table:2)

Morphometry Of The Papillary Muscles:
Papillary Muscles Breadth:
In the present study the length of right anterolateral papillary muscle ranged from 9.23 to 33.72 mm with a mean of 14.89 ± 4.19. In right posteromedial papillary muscle length ranged from 6.12 to 22.15 mm with a mean of 14.86± 4.05. The length of right septal papillary muscle ranged from 4.45 to 17.0 mm with a mean of 10.27± 3.28 (table: 3).
Length of the left anterolateral papillary muscle ranged from 6.30 to 27.55 mm with a mean of 18.80 mm ± 3.97. The left posteromedial papillary muscle length ranged from 9.19 to 28.98 mm with a mean of 18.89 mm ± 4.28 (fig. 5).

Papillary Muscles Breadth:

In the present study the breadth of left anterior papillary muscle ranged from 2.94 mm to 12.76 mm with a mean of 6.89 mm ± 1.95. The left posterior papillary muscle breadth ranged from 2.30 mm to 11mm with a mean of 6.25mm ± 2.08 (fig. 6a).
The breadth of right anterior papillary muscle ranged from 0.50mm to 11.06mm with a mean of 4.66 mm ± 1.60. Right posterior papillary muscle ranged from 2.17mm to 11mm with a mean of 4.96mm ± 1.71. The right septal papillary muscle breadth ranged from 1.20 mm to 6.86mm with a mean of 3.25mm ± 1.15 (fig.6b).

IV. Discussion

Harsha *et al.,* (2014) observed that the right anterior papillary muscle which was largest was found attached to the anterior aspect of the right ventricle wall with chordae tendinae inserted to the posterior and anterior cusps of the tricuspid valve. Two or more parts of the right posterior papillary muscle was attached to the inferior wall of the right ventricle with chordae inserted to the posterior and septal cusps, and a variable group of small septal papillary muscles which was attached to the interventricular septum with chordae inserted to the anterior and septal cusps.

According Joudinaud *et al*., (2006) have proposed the functional terminology for the tricuspid valve: the papillary muscles can be grouped according to the distribution of their cords to a definite commissure and its contiguous main leaflets. Therefore the anterior papillary muscle becomes the anteroposterior, the posterior papillary muscle the posteroseptal and the septal papillary muscle the anteroseptal papillary muscle respectively.

In the present study the left anterior papillary muscle took origin from sternocostal mural in 82% and 18% muscle bellies took origin from the diaphragmatic wall of the ventricle. The posterior papillary muscle also took origin from sternocostal mural area in 10% and origin from the diaphragmatic wall in 90% of left ventricles (Table: 2)

Victor *et al*., (1995) observed that anterolateral papillary muscle of left ventricles took origin from the upper part of the ventricle in 19% of the specimens. In 79.5 % of the specimens the origin was from the middle part of the ventricle. In remaining 1.5% of papillary muscle bellies took origin from the inferior part of ventricle. The posterior papillary muscle was found to arise from upper part 6% from middle part 92.5% and lower part 1.5% the left ventricle respectively.

In the present study the length of right anterolateral papillary muscle ranged from 9.23 to 33.72 mm with a mean of 14.89 ± 4.19. In right posteromedial papillary muscle length ranged from 6.12 to 22.15 mm with a mean of 14.86± 4.05. The length of right septal papillary muscle ranged from 4.45 to 17.0 mm with a mean of 10.27± 3.28 (table: 3).

Length of the left anterolateral papillary muscle ranged from 6.30 to 27.55 mm with a mean of 18.80 mm ± 3.97. The left posteromedial papillary muscle length ranged from 9.19 to 28.98 mm with a mean of 18.89 mm ± 4.28 (fig.5).

In the present study the length of left posteromedial papillary muscle was longer than the anterolateral papillary muscle.

Fumimato *et al*., (2008) have opined that in cases of mitral regurgitation of the papillary muscle carried out surgical repositioning of both the anterior and posterior papillary muscles are sutured. This is done to give a better grip and hitch even if there is any variation present in the papillary muscle. When stitching the papillary muscle in spite of the differences in the attachments, shape and size will improve the function.

Comparison of the papillary muscle length of the present study with the previous studies is given in the (table:4).

While comparing the length of left and right papillary muscles the left posteromedial papillary muscle was found to be longer than all the other papillary muscles. **So the left papillary muscle length was statistically significantly longer in X^2 test is shown in the (table 5).**

In the present study the breadth of left anterior papillary muscle ranged from 2.94 mm to 12.76 mm with a mean of 6.89 mm ± 1.95. The left posterior papillary muscle breadth ranged from 2.30 mm to 11mm with a mean of 6.25mm ± 2.08 (fig. 6a).

The breadth of right anterior papillary muscle ranged from 0.50mm to 11.06mm with a mean of 4.66 mm ± 1.60. Right posterior papillary muscle ranged from 2.17mm to 11mm with a mean of 4.96mm ± 1.71. The right septal papillary muscle breadth ranged from 1.20 mm to 6.86mm with a mean of 3.25mm ± 1.15 (fig.6b).

In the present study the breadth of left anterolateral papillary muscle was higher than all other papillary muscles in both ventricles.

V. Conclusion

The mean length of posterior papillary muscle of the left ventricle was 18.89mm ±4.3 longer than the right ventricle papillary muscles which was statistically significant (p=0.01) .The breadth of the anterior papillary muscle of the left ventricle was more than all other papillary muscles. This data will be helpful and relevant for cardiac surgeons performing mitral valve and tricuspid valve homograft implantation procedures.

Figures and Tables

Fig :1. ATTACHMENT OF PAPILLARY MUSCLE

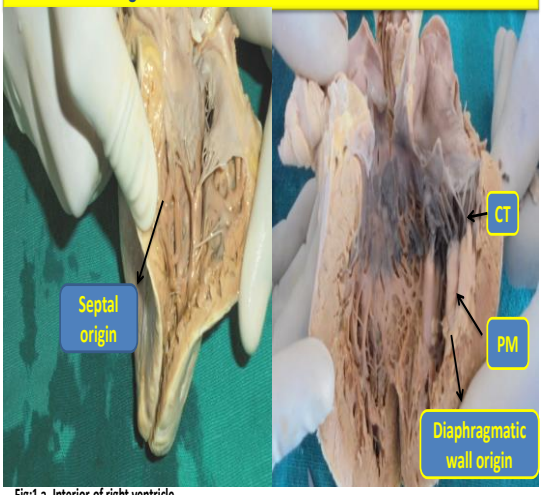

Fig:1 a. Interior of right ventricle
AIVS – Anterior Interventricular Sulcus
CT – Chordae tendineae
PM – Papillary Muscle

Fig:1 b. Interior of left ventricle
CT – Chordae Tendineae
PM – Papillary muscle

Fig: 2 . MEASURING LENGTH OF PAPILLARY MUSCLE

Measuring length of papillary muscle using digital vernier caliper

Fig: 3 . MEASURING BREADTH OF PAPILLARY MUSCLE

Measuring Breadth of Papillary Muscle Using Digital Vernier Caliper

Fig: 4 Origin of papillary muscles in right ventricle

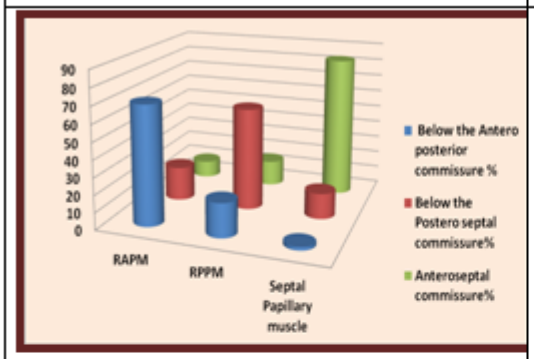

Fig: 5 Length of papillary muscles in both ventricle

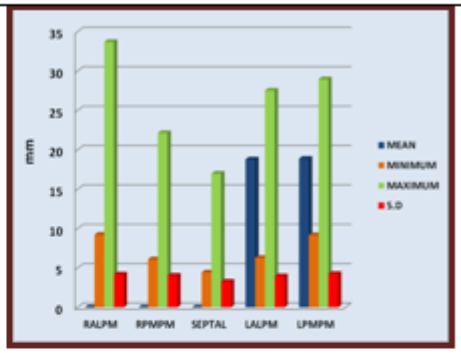

Fig: 6a: Breadth of left papillary muscle

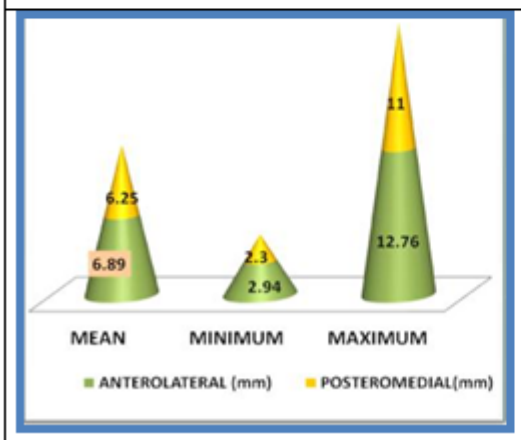

Fig:6b:Breadth of right papillary muscle

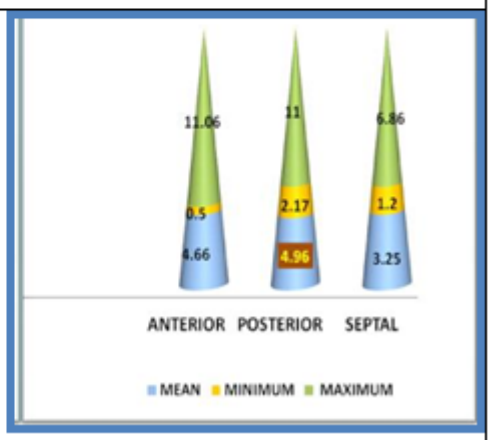

Table: 1. ORIGIN OF PAPILLARY MUSCLES IN RIGHT VENTRICLE

Papillary muscle (N=100 Hearts)	*Below the Antero-posterior commissure (%)*	*Below the Postero - septal commissure (%)*	*Antero-septal commissure (%)*
Ant. Papillary muscle	70	20	10
Post. Papillary muscle	20	60	15
Septal papillary muscle	2	15	83

Table: 2. ORIGIN OF PAPILLARY MUSCLE IN LEFT VENTRICLE

Papillary muscle (N=100 Hearts)	Sternocostal wall (%)	Diaphragmatic wall (%)
Ant. Papillary muscle	82	18
Post. Papillary muscle	10	90

Table : 3. LENGTH OF PAPILLARY MUSCLES IN BOTH VENTRICLES		
PAPILLARY MUSCLE (N= 100)	MEAN ± SD (mm)	RANGE
Right anterolateral	14.89±4.19	9.23 - 33.72
Right posteromedial	14.86± 4.05	6.12 - 22.15
Septal	10.27± 3.28	4.45 -17.0
Left anterolateral	18.80± 3.97	6.30 - 27.55
Left posteromedial	18.89± 4.27	9.19 - 28.98

TABLE: 4 COMPARISON OF THE LENGTHS OF PAPILLARY MUSCLES CITED FROM PREVIOUS STUDIES

Sl. No	Author / Year/ Race	Country	No. of heart studied	Right ventricle papillary muscle length (mm)			Left ventricle papillary muscle (mm)	
				RAPM	RPM	SEPTAL	LAPM	LPPM
1.	Gerola /2001 / Hispanic	Brazil	50	9± 2	-	-	-	-
2.	Nigri /2001 / Hispanic	Boston (USA)	79	19.16	11.53	5.59	-	-
3.	Harsha /2014/ Asian	South India	96	14.9± 4.0	-	-	-	-
4.	Hosapatna /2014 / Asian	South India	15	13± 4.0	9.8±40	5.5±2.0	16.3±0.5	21.4±0.6
5.	Present study/ 2018 / Asian	South India	100	14.89 ±4.19	14.86 ±4.05	10.27±3 .28	18.80± 3.97	18.89±4. 28

Table: 5. STATISTICAL COMPARISION OF LENGTH OF PAPILLARY MUSCLES OF RIGHT AND LEFT VENTRICLES X^2- TEST					
	Right ant. Length	Right post. Length	Right septal length	Left ant. Length	Left post. Length
Chi-Square	42.560[a]	30.798[b]	45.920[c]	26.000[d]	28.400[e]
Df	53	49	56	62	59
Asymp. Sig.	.847	.980	.830	1.000	1.000

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