

Study of Papillary Muscles of Tricuspid Valve in Central Indians

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ABSTRACT

Introduction: Thorough knowledge of the normal Anatomy and normal variations is very important for accurate interpretation of information by echocardiography and for surgical repair in valvular diseases. The present study was carried out with the aim to know the morphology of Papillary Muscles of Tricuspid valve in Central Indians and to classify certain prominent normal variations.

Material and Methods: The present study was carried on 100 normal human hearts from both sexes of different age. The Tricuspid valve complex was dissected very carefully to avoid cutting of papillary muscles and chordae tendinae attached to these. The morphological study of papillary muscles of Tricuspid valve was done. The anterior and posterior papillary muscles were located in all the cases. Additionally septal, extra-anterior and extra-posterior papillary muscles were looked in for.

Result: Extra-anterior papillary muscles were found in 35% hearts while extra-posterior papillary muscles were found in 83% hearts. Septal Papillary muscles were present in 62% hearts. The total number of papillary muscles present in Tricuspid valve of hearts ranged from 2 to 11 with an average of 5.05 per heart.

Conclusion: Extra-posterior papillary muscles are present in most of the hearts. Small septal papillary muscles are present but they could be absent. Extra-anterior papillary muscles also have been found.

Keywords: Anterior and Posterior papillary muscles, Extra-anterior and Extra-posterior papillary muscles, Septal papillary muscles.

INTRODUCTION

According to Wooley¹ the Anatomists had been recording their observations on the structure of cardiac valves since 4th century. King T.W.², in 1837, published a work concerning the anatomic features and functions of the tricuspid valve in which he paid emphasis on the role of this valve in maintaining uni-directional blood flow. The accurate interpretation of information by visualization of tricuspid valve with non-invasive imaging requires detailed knowledge of its morphology and normal variations. Matsumoto and Matsuo³ have described the echocardiographic appearances of the tricuspid valve. The visualization of the tricuspid valve by non-invasive imaging was commonplace and was done with remarkable accuracy and in details by Brown and Anderson⁴ and Tei et al⁵ Wooley¹ and Hauck et al⁶ have mentioned that renewed clinical interest in the disease processes involving the tricuspid valve had arisen. According to François Haddad et al⁷ in echocardiography the morphological features that best differentiate the right ventricle include the following: (1) the more apical hinge line of the septal leaflet of the tricuspid valve relative to the anterior leaflet of the mitral valve; (2) the presence of a moderator band; (3) the presence of more than 3 papillary muscles; (4) the trileaflet configuration of the tricuspid valve with septal papillary attachments; and (5) the presence of coarse trabeculations.

Detailed knowledge of normal anatomy and normal variations is vital for accurate interpretation of information by echocardiography and for surgical repair in valvular diseases.

Detailed study of tricuspid valve was carried out to obtain morphological structure in the Central Indian subjects and to try to classify certain prominent normal variations in the light of available literature.

MATERIAL AND METHODS

The present study was carried on 100 normal human hearts at Netaji Subhash Chandra Bose Medical College and Hospital, Jabalpur.

Group I:- Eight hearts (2 female and 6 male) of children in the age group of 1 to 8 years.

Group II:- Twenty nine female hearts in the age group of 16 to 80 years.

Group III:- Sixty three male hearts in the age group of 16 to 61 years.

These hearts were obtained from the post-mortem room and preserved in 5% formalin solution. The Tricuspid valve complex was dissected very carefully to avoid cutting of papillary muscles and chordae tendinae. The anterior, posterior and septal muscles were observed. Extra anterior or extra-posterior muscles were looked in for. The directions of the anterior and posterior papillary muscles towards the antero-posterior and postero-septal commissures have been used for their identification.

In the present study the following classification was adopted:

- A. Anteriorly placed papillary muscles consisting of
 1. Anterior
 2. Extra-anterior
- B. Posteriorly placed papillary muscles consisting of
 1. Posterior
 2. Extra-posterior
- C. Septal papillary muscles consisting of
 1. Septal infundibular
 2. Septal inferior

STATISTICAL ANALYSIS

Descriptive statistics like mean and percentage were used to calculate the results. Microsoft office 2007 was used to generate tables.

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RESULT

A total number of 38 extra-anterior papillary muscles were found in 35 hearts and a total number of 141 extra-posterior papillary muscles were found in 83 hearts.

In Group I (children) one extra-anterior papillary muscle was present in 1 heart (12.50%). Thus a total number of 9 papillary muscles were found placed anteriorly in 8 hearts. No extra-posterior papillary muscle was present in 1 heart (12.50%), one of these was present in 4 hearts (50%) and 2 of these were present in 3 hearts (37.50%). A total number of 10 extra-posterior papillary muscles were present in 7 hearts and a total number of 18 papillary muscles were found placed posteriorly in 8 hearts.

The per case averages of anteriorly and posteriorly placed papillary muscles in hearts were 1.12 and 2.25 respectively (table-1). Only 1 papillary muscle was present anteriorly in 7 hearts (87.50%) and 2 papillary muscles were present anteriorly in 1 heart (12.50%). Only 1 papillary muscle was present posteriorly in 1 heart (12.50%) whereas 2 papillary muscles were present posteriorly in 4 hearts (50%) and 3 papillary muscles were present posteriorly in 3 hearts (37.50%).

In Group II (female), no extra-anterior papillary muscle was found in 18 hearts (62.06%). One extra-anterior papillary muscle was present in 11 hearts (37.93%). A total number of 40 papillary muscles were found placed anteriorly in 29 hearts. No extra-posterior papillary muscle was found in 7 hearts (24.13%). Both 1 and 2 extra-posterior papillary muscles were present in 9 hearts (31.03%) each; both 3 and 4 extra-posterior papillary muscles were present in 2 hearts (6.89%) each. Thus a total number of 41 extra-posterior papillary muscles were present in 22 hearts and a total number of 70 posteriorly placed papillary muscles were found in 29 hearts.

The per case averages of anteriorly and posteriorly placed papillary muscles were 1.33 and 2.41 respectively. One papillary muscle was placed anteriorly in 18 hearts (62.06%) and 2 papillary muscles were placed anteriorly in 11 hearts (37.93%). In 7 hearts (24.13%) only 1 papillary muscle; in 9 hearts (31.03%) each 2 papillary muscles and 3 papillary muscles; and in 2 hearts (6.89%) each 4 papillary muscles and 5 papillary muscles were present posteriorly.

In Group III (male), no extra-anterior papillary muscle was found in 40 hearts (63.49%). In 20 hearts (31.74%) one extra-anterior papillary muscle was present and in the remaining 3 hearts (4.76%) two of these were present. A total number of 26

extra-anterior papillary muscles were present in 23 hearts and thus 89 papillary muscles were placed anteriorly in 63 hearts. In 9 hearts (14.28%) no extra-posterior papillary muscles was present. In 24 hearts (38.09%) each 1 and 2 extra-posterior papillary muscles were present. In the remaining 6 hearts (9.52%) 3 of these were present. A total number of 90 extra-posterior papillary muscles were present in 54 hearts and 153 posteriorly placed papillary muscles were present in 63 hearts in this group.

An average number of 1.41 papillary muscles were placed anteriorly and 2.42 papillary muscles were placed posteriorly. In 40 hearts (63.49%) only 1 papillary muscle was placed anteriorly; in 20 hearts (31.74%) two papillary muscles were placed anteriorly and in the remaining 3 hearts (4.76%) three papillary muscles were placed anteriorly. In 9 hearts (14.28%) only 1 papillary muscle was placed posteriorly; in 24 hearts (38.09%) each 2 and 3 papillary muscles were placed posteriorly and in the remaining 6 hearts (9.52%) four papillary muscles were placed posteriorly.

Situation of extra-anterior papillary muscles

In Group I (children), in 1 heart the 1 extra-anterior papillary muscle present was situated on the right side of anterior papillary muscle.

In Group II (female), out of the 11 hearts in which 1 extra-anterior papillary muscle was present, in 7 hearts it was present on the right side of the anterior papillary muscles, in 3 hearts it was present on the left side of the anterior papillary muscles and in the remaining 1 heart it was present anterior to the anterior papillary muscles.

In Group III (male), 1 extra-anterior papillary muscles was situated on the right side of anterior papillary muscles in 15 hearts, on the left side of anterior papillary muscles in 4 hearts and anterior to anterior papillary muscle at a higher level in the remaining 1 heart. Two extra-anterior papillary muscles were present on the right side of a papillary muscle in 3 hearts.

Thus out of overall 38; twenty-nine extra-anterior papillary muscles were present on the right side; 7 extra-anterior papillary muscles were present on the left side and 2 extra-anterior papillary muscles were present anterior to the anterior papillary muscles.

Situation of Extra-posterior papillary muscle

In Group I (children), 1 extra-posterior papillary muscle was present on the right side of posterior papillary muscles in 3

Groups	Anterior	Extra-anterior	Total anteriorly placed	Average per heart	Posterior	Extra-posterior	Total posteriorly placed	Average
I (children)	8	1	9	1.12	8	10	18	2.25
II (female)	29	11	40	1.37	29	41	70	2.41
III (male)	63	26	89	1.41	63	90	153	2.42

Table-1: Number of papillary muscles in tricuspid valve complex (excluding septal papillary muscles)

Groups – No. of hearts	No. of Extra-anterior papillary muscles			No. of Extra-posterior papillary muscles				
	0	1	2	0	1	2	3	4
I (children)	7	1	0	1	4	3	0	0
II (female)	18	11	0	7	9	9	2	2
III (male)	40	20	3	9	24	24	6	0

Table-2: Number of extra-anterior and extra-posterior papillary muscles in different groups

hearts and it was present on the left side of posterior papillary muscles in 1 heart.

Two extra-posterior papillary muscles were present on the right side of posterior papillary muscles in 2 hearts and on the left side of it in 1 heart.

In Group II (female), 1 extra-posterior papillary muscle was present on the right side of posterior papillary muscles in 5 hearts, 1 extra-posterior papillary muscle was present on the left side of posterior papillary muscles in 3 cases and in the remaining 1 heart the extra-posterior papillary muscle was situated in front of the posterior papillary muscle. Two extra-posterior papillary muscles were present on the right side of the posterior papillary muscles in 7 hearts, two extra-posterior papillary muscles were present on the left side of the posterior papillary muscle in 1 heart and in the remaining 1 heart showing the presence of 2 extra-posterior papillary muscles, 1 was present on either side of posterior papillary muscle. Three extra-posterior papillary muscles were present on the right side of posterior papillary muscle in 1 heart. In the other heart which showed the presence of 3 extra-posterior papillary muscles, 2 were present on the right side and 1 was present on the left side of posterior papillary muscle. Out of the 2 hearts in which 4 extra-posterior papillary muscles were present, in 1 heart 3 were present on the right side and 1 was present on the left side of posterior papillary muscle and in the other heart 2 were present on either side of posterior papillary muscle.

In Group III (male), one extra-posterior papillary muscle was present on the right side of posterior papillary muscles in 12 hearts and 1 was present on the left side of posterior papillary muscles in 12 hearts. Out of the 24 hearts which showed the presence of 2 extra-posterior papillary muscles, in 9 hearts both of these were present on the right of the posterior papillary muscles; in 2 hearts both of these were present on the left side of posterior papillary muscles; in 12 hearts 1 extra-posterior papillary muscle was present on the either side of posterior papillary muscles and in the remaining 1 heart both of these were present anterior to the posterior papillary muscle. Out of the 6 hearts in which 3 extra-posterior papillary muscles were found, in 2 hearts these were present on the right side of posterior papillary muscles; in 2 hearts these were present

on the left side of the posterior papillary muscles; in 1 heart 2 extra-posterior papillary muscles were present on the right side of the posterior papillary muscle and 1 extra-posterior papillary muscle was present on the left side of posterior papillary muscle and in the remaining 1 heart 2 extra-posterior papillary muscles were present on the left side of posterior papillary muscles and 1 extra-posterior papillary muscle was present on the right side of posterior papillary muscle.

Thus out of overall 141; eighty-eight extra-posterior papillary muscles were present on the right side, 50 extra-posterior papillary muscles were present on the left side and 3 extra-posterior muscles were present anterior to the posterior papillary muscles

The number of papillary muscles present in the tricuspid valve is ranging from 2 to 11. Most of the hearts (93) have shown the presence of 3 to 8 papillary muscles whereas 2 papillary muscles are found in 4 hearts, 9 papillary muscles are found in 2 hearts and 11 muscles are found in 1 heart only (table-3).

Septal papillary muscles

In Group I (children), the septal papillary muscles were present in 5 hearts. Out of these, in 3 hearts 1 septal papillary muscle was present and in 2 hearts, 3 septal papillary muscles were present. Thus 9 septal papillary muscles were found in 5 hearts. In 3 hearts the septal papillary muscles were absent. An average number of 1.12 septal papillary muscles were present per case, in this group.

In Group II (female), septal papillary muscles were present in 18 hearts. Out of these 8 hearts had 1 septal papillary muscle; 5 hearts had 2; 3 hearts had 3 and the remaining 2 hearts had 4 septal papillary muscles. A total number of 35 septal papillary muscles were found. These muscles were absent in 11 cases. An average number of 1.20 septal papillary muscles were present per heart in this group.

In Group III (male), septal papillary muscles were absent in 24 hearts and were present in 39 hearts. Out of these, 21 hearts had 1 septal papillary muscle; 5 hearts had 2; 4 hearts had 3; 6 hearts had 4; and the remaining 3 hearts had 5 septal papillary muscles. A total number of 82 septal papillary muscles were found in 39 hearts. An average number of 1.30 septal papillary muscles

Number of Papillary muscles	2	3	4	5	6	7	8	9	11
Number of hearts	4	14	29	18	12	12	8	2	1

Table-3: Papillary muscles in the tricuspid valve (Septal papillary muscles included)

Septal papillary muscles	Group I		Group II		Group III	
	No. of hearts	%	No. of hearts	%	No. of hearts	%
Absent	3	37.50	11	37.93	24	38.09
Present	5	62.50	18	62.06	39	61.90

Table-4: Number and Percentage of hearts showing absence and presence of Septal papillary muscles

Number of muscles	Group I		Group II		Group III	
	No. of hearts	%	No. of hearts	%	No. of hearts	%
1	3	37.50	8	27.58	21	33.33
2	0	0	5	17.24	5	7.93
3	2	25	3	10.34	4	6.34
4	0	0	2	6.89	6	9.52
5	0	0	0	0	3	4.76

Table-5: Number and percentage of hearts showing presence of different number of septal papillary muscles

were present in this group.

Thus in 38 hearts no septal papillary muscle was found. 1, 2, 3, 4 and 5 septal papillary muscles were found in 32, 10, 9, 8 and 3 hearts respectively.

Two types of septal papillary muscles were observed, Infundibular and Inferior. The infundibular septal papillary muscles were attached to the infundibular septal wall while the inferior septal papillary muscles were attached at a lower level on the inter-ventricular septum.

In Group I (children), in the 3 hearts which showed the presence of 1 septal papillary muscle, all of these were infundibular. In both the hearts which had 3 septal papillary muscles, 1 was infundibular and 2 were inferior. Out of the total 9 septal papillary muscles 5 were infundibular and 4 were inferior septal papillary muscles.

In Group II (female), 8 hearts showed the presence of 1 septal papillary muscle. Out of these, in 7 hearts the septal papillary muscles were infundibular and in the remaining 1 heart the septal papillary muscle was inferior. Five hearts showed the presence of 2 septal papillary muscles. Out of these, in 4 hearts 1 infundibular and 1 inferior septal papillary muscle were present and in 1 heart both septal papillary muscles were inferior. Three hearts showed the presence of 3 septal papillary muscles. In 2 hearts 1 septal papillary muscle was infundibular and 2 septal papillary muscles were inferior. In 1 heart all the 3 septal papillary muscles were inferior. In both the hearts which had 4 septal papillary muscles, 1 infundibular and 3 inferior septal papillary muscles were present. Thus out of 35 septal papillary muscles present in this group, 15 were infundibular and 20 were inferior septal papillary muscles.

In Group III (male), 21 hearts showed the presence of 1 septal papillary muscle. Out of these, in 12 hearts the septal papillary muscle was infundibular and in 9 hearts it was inferior. Five hearts showed the presence of 2 septal papillary muscles. Out of these, in 3 hearts 1 infundibular and 1 inferior septal papillary muscle were present. In 1 heart both septal papillary muscles were infundibular, and in the remaining 1 heart both septal papillary muscles were inferior. Four hearts showed the presence of 3 septal papillary muscles. Out of these, in 1 heart all the 3 were infundibular and in 1 heart all the 3 were inferior. In 1 heart 1 infundibular and 2 inferior septal papillary muscles were present and in the remaining 1 heart 1 inferior and 2 infundibular septal papillary muscles were present. Six hearts had 4 septal papillary muscles. Out of these in 2 hearts 1 septal papillary muscle was infundibular and 3 were inferior. In 4 hearts all the 4 septal papillary muscles were inferior. In 3 hearts in which 5 septal papillary muscles were present, in 2 hearts 1 was infundibular and 4 were inferior septal papillary muscles. In the remaining 1 heart all the 5 were inferior septal papillary muscles. Thus out of 82 septal papillary muscles present in this group, 27 were infundibular and 55 were inferior septal papillary muscles.

DISCUSSION

In the 37th edition of Grays Anatomy⁸ it is mentioned that the papillary muscles comprised of two principal, anterior and posterior, and smaller, variable, septal muscles. The posterior papillary muscle arises from the ventriculo-septal myocardium below the postero-septal commissure. "Accessory" septal

Groups	Septal Papillary muscles	Infundibular	Inferior
I	1 (3 hearts)	3	0
	3 (2 hearts)	2	4
II	1 (8 hearts)	7	1
	2 (5 hearts)	4	6
	3 (3 hearts)	2	7
	4 (2 hearts)	2	6
III	1 (21 hearts)	12	9
	2 (5 hearts)	5	5
	3 (4 hearts)	6	6
	4 (6 hearts)	2	22
	5 (3 hearts)	2	13

Table-6: Types of septal papillary muscles

papillary muscles may be absent or merely irregular fibrous cords. More often a group of small papillary projections arise from the infundibular septal wall below the crista supra-ventricularis and reach the apical aspect of antero-septal commissure, tethering adjacent parts of the anterior and septal leaflets, the highest muscle is often termed as muscle of conus. In Gray's Anatomy(40th ed.)⁹ it is mentioned that two major papillary muscles are located in anterior and posterior positions. A third smaller muscle has a medial position together with several smaller, and variable, muscles attached to the inter-ventricular septum.

In Gray's Anatomy¹⁰ for students 3rd ed 2015 it is mentioned that the anterior papillary muscle is largest and most constant papillary muscle arising from the anterior wall; the posterior papillary muscle may consist of 2 or 3 structures, with some chordae tendinae arising directly from the ventricular wall; the septal papillary muscle is the most inconstant papillary muscle, being either small or absent with chordae tendinae emerging directly from the septal wall.

In Cunningham's Manual of Practical Anatomy¹¹ it is mentioned that there are three muscles in Right Ventricle. A large posterior papillary muscle sending chordae tendinae to posterior and septal cusps; A larger anterior papillary muscle sending chordae tendinae to posterior and anterior cusps and several small septal papillary muscles sending chordae tendinae to anterior and septal cusps or simply chordae tendinae from inter-ventricular septum to anterior and septal cusps.

According to B.D. Chourasia¹² the septal papillary muscle is divided into a number of little nipples while according to Vishram Singh¹³ it is divided into 2 or 3 nipples. However, according to Inderbir Singh¹⁴ small septal papillary muscles are present. All of them have described the presence of a larger anterior and a small posterior papillary muscle.

Vishram Singh¹³ has mentioned that the papillary muscles prevent the prolapse of atrio-ventricular valves into the atria during ventricular systole. The rupture of a papillary muscle, following an adjacent myocardial infarction, will allow the prolapse of attached cusp to occur into the Right Atrium during each systole.

S Y Ho and P Nihoyannopoulos¹⁵ have mentioned that the septal leaflet is distinctive of the tricuspid valve and this has multiple tendinous cords attaching it directly to the ventricular septum. This feature, together with its hingeline being closer to the ventricular apex than that of the mitral valve, the septal leaflet allows the echocardiographer to designate the ventricle

as having right morphology. At its antero-superior part, the hingeline bisects the membranous septum dividing it into atrioventricular and interventricular portions. A small papillary muscle, the medial papillary muscle supports the “commisure” between the septal and antero-superior leaflets. The latter leaflet is large and deeper than the septal leaflet. It is supported in its mid portion by a large papillary muscle that usually arises from the moderator band close to its insertion to the parietal wall. The inferior leaflet (the mural or posterior leaflet) is supported by several small papillary muscles which arise from the diaphragmatic wall of the right ventricle.

The variability of the papillary muscles is a normal characteristic of the tricuspid valve. They can number from 2-9, but usually 2 or 3 papillary muscles often bifid or trifid. The septal papillary muscle is the least prominent and sometimes can be even absent, with the multiple chordal attachments arising directly from the ventricular wall.¹⁶

Wafae et al¹⁷ in a study carried out on 50 hearts found an average number of 3.86 papillary muscles per heart. They found an average number of 4 papillary muscles in 46% hearts. They mentioned that variability in the number and localization of papillary muscles is well known. They adopted the following classification of these muscles.

1. Anterior
 2. Posterior- consisting of postero-lateral, postero-medial and posterior
 3. Septal- consisting of septal infundibular and septal inferior.
- Secombe et al¹⁸ agreed with the naming of anterior and posterior papillary muscles with the following exceptions. According to them the muscles supplying the antero-posterior commissure are commonly multiple, rather than being a single large structure. In these instances this collection of papillary muscles is termed the posterior papillary muscle group. The collections or groupings of neighboring basal papillary muscles in the vicinity of postero-septal commissure are referred to as the deep postero-septal papillary muscle group. Identification of these papillary muscles was cumbersome yet it aided in the identification of the postero-septal commissure. They had not made any mention about the septal papillary muscles. They had stated that the chordae tendinae tethering the posterior half of the anterior leaflet and anterior half of posterior leaflet arise from a prominent anterior papillary muscle. The remainder of the posterior leaflet and a small portion of septal leaflet receive chordae tendinae from the posterior papillary muscles or a single prominent posterior papillary muscle. Waller et al¹⁹, however, mentioned that three papillary muscles are present in the right ventricle. The anterior papillary muscle is largest and found below the antero-posterior commissure. The posterior papillary muscle lies beneath the junction of posterior and septal leaflets. A small septal papillary muscle, originating from the wall of the infundibulum, tethers the anterior and septal leaflets high up against the infundibular wall. At times this muscle is absent and the chordae tendinae arise from a small tendinous connection to the infundibulum.

In the present study an average number of 5.00 and 5.14 papillary muscles are observed in the valves of female (Group II) and male (Group III) hearts respectively. The average number of papillary muscles present per case is 5.05 which is greater than the average number 3.86 mentioned by Wafae et al (1990).

Extra-posterior papillary muscles were found in 83% of hearts,

these were mostly situated on the right(lateral) and left(medial) sides of the posterior papillary muscle. Septal papillary muscles consisting of infundibular and inferior were found in 62% hearts and are absent in 38% cases. One septal papillary muscle is found in 32% cases and 2 to 5 septal papillary muscles are present in 30% cases. However, in the earlier study done by Waller et al¹⁹ they had mentioned about the presence of only one septal papillary muscle when present. In the present study out of the 126 septal papillary muscles 47 (37.30%) are infundibular and 79 (69%) are inferior.

CONCLUSION

In the tricuspid valve extra-anterior and extra-posterior papillary muscles are present. Two to 11 papillary muscles are present with an average of 5.05. Extra-posterior papillary muscles are present in most of the hearts. Extra-anterior muscles could also be present. Small Septal papillary muscles, infundibular and inferior are present. The septal papillary muscles could be absent.

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