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## Anatomical consideration of the number and form of the papillary muscle in the left ventricle

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### ABSTRACT

Our results were obtained by dissection of 56 cords, with presented at the papillary muscle of the left ventricle, 106 muscular bodies and from those, 58 muscular bodies were for the anterior papillary muscle and 48 for the posterior papillary muscle. Anterior papillary muscle was studied on 32 cords, and the posterior papillary muscle on 24 cases. Of the 106 papillary muscles we analyzed, unique papillary muscle was encountered in 16 cases, 10 being at the anterior papillary muscle and 6 cases at the posterior papillary muscle..

The papillary muscle formed of two muscular bodies (double) presented a number of 64 muscular bodies, 36 being at the anterior papillary and 28 at the posterior papillary. In cases of triple papillary muscle, from 18 muscular bodies, 12 were from the anterior papillary and 6 were from posterior papillary. In the two cases of quadruple papillary muscle the 8 muscular bodies belonged to the posterior papillary muscle.

Among the total muscular bodies, most frequently they had a conical shape, aspect found in 67 cases, 33 cases being seen in the anterior papillary muscle and 34 in the posterior papillary. In 20 cases the muscular bodies were cylindrical, 18 cases were found in the anterior papillary and 2 in the posterior papillary muscle. In 10 cases the muscular bodies were arcuated, 4 cases being to anterior papillary and 6 cases to the posterior papillary muscle. In 8 cases the bodies were fusiform, 4 cases being to the anterior papillary and 4 to the posterior papillary

muscle. In one case to an unique posterior papillary muscle we found a particular form of the muscular body, which we called „the torch” or the „beacon” that have the muscular body thinner at the lower half and the size increasing in width, reaching a maximum width at its upper extremity, from where are detaching four extra muscles that gave birth to beams of valvular chordage.

In case of papillary muscles with two muscular bodies, they can sometimes be linked by a muscular bridge, transverse or oblique, making characteristic features. Thus, in 6 cases, the muscular bridges realized the H” letter appearance, 4 cases being at the anterior papillary muscle and 2 at the posterior papillary. In 4 cases only at the anterior papillary the bridges formed „N” letter aspect, 2 cases were at the anterior papillary and 2 in the posterior papillary muscle. Also in 4 cases, the presence of the bridges achieve the appearance of reversed „N” letter, 2 cases were in the anterior papillary and 2 in the posterior papillary.

Keywords: anatomical forms papillary muscles left ventricle

### Introduction

The inner surface of the ventricles, contrary to their outer surface which is smooth, has a system of protrusions and muscular extensions, which are crossed in all directions, giving the ventricular wall a cellular and cross-linked aspect [1].

These protrusions are called fleshy columns [1] or fleshy trabeculae [2].

After their disposal they are classified into three orders, the first order being called papillary

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muscles [2] or pillars [1,3,4,5], attaching themselves to the ventricular wall by their lower end (base). The other end is free and gives rise to the cordage tendons that will insert to the appropriate cusps of the atrioventricular valve. The left ventricle presents two papillary muscles, anterior and posterior [1, 3, 4, 5]. Those two papillary muscles are stronger than those of the right ventricle [6, 7], considering the higher labor they perform. They can arise with many roots [3, 6, 8, 9] or they can have mamillary ends [4, 10], most commonly the posterior one [11, 12]. Sometimes there may be more than two papillary muscles, one of them showing more than one muscular body [9, 10, 13].

Therefore, some authors believe that there is an anterior papillary group and a posterior one, the muscular body of the papillary muscles are more or less reunited by the base and branched at the top [10, 14]. The shape of the papillary muscles of the left ventricle is described very differently by the authors. Following [3], anterior papillary is irregular, conical or cylindrical, and the posterior one has the front face excavated, whose concavity adapts to the convex posterior face of the anterior papillary. To [4] anterior papillary the tip is conical, more or less rounded, and the posterior papillary muscle has the form of a gutter, whose concavity during systole match perfectly to the convexity of the anterior papillary. [15] states that in the left ventricle the majority papillary muscles have conical form. [10] finds papillary muscles of conical shape with one end rounded.

After [8, 13] unique papillary muscle may be conical, mammillated, flattiped (beveled), stepped, wavy, curved, angled or saucerized, or may be groove shaped. When single describes a type of papillary muscle showing from the muscular body side an extension, called „glove finger”.

When there are two muscular bodies, they can be parallel, or they can be linked at different levels to form different configurations: V,Y, or H. When there are three muscular bodies, they can be parallel, or linked to each other, or they can form arcuate arrangements. with the third muscular body that is separate. Sometimes, two muscular bodies are interconnected to each other or they form with the third one, which is separated, an arrangement. When there are four or five muscular bodies they can

be parallel or linked to each other [13]. Gunnal [8] identifies four different forms of papillary muscles: conical, wide tip (flat), pyramidal or fan-shaped. Also describes various models of papillary muscles: separate base and flat tip, single base and peak divided, „small projections” of papillary muscles, long papillary muscles, „puncture” papillary muscles and papillary muscles with the base attached to a large muscle bridge. Berdajs [17] describes three groups of papillary muscles in the left ventricle. From group I the base and the peak were undivided. In group II there are two types of muscular bodies, describing two subgroups: in subgroup II/0 the base of papillary muscle was undivided and in subgroup II/B the base was consisted of two separate parts. In group III the papillary muscle have three bodies describing three subgroups: subgroup III/A base was undivided, subgroup III/B the base was consisted of two parts and III/C of three parts.

## **Material and methods:**

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Our results were obtained by analysis of 56 cords, which presented 106 muscular bodies at the papillary muscles of the left ventricle, including 58 muscle bodies for anterior papillary muscles and 48 muscular bodies for the posterior papillary muscles.

The study was performed by dissecting both fresh cords and formalined cords, aiming: the number of the muscular bodies of each papillary muscle, the form of the muscular body, the way implants the base of the muscular body on the ventricular wall, and how the valvular extremity of it, ends.

## **Results**

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The 106 of left ventricle papillary muscles

were from a number of 56 cords, the anterior papillary muscle was pursued on 32 cords (57,14% of cases) and the posterior papillary on 24 cases (42,86% of cases). The unique papillary muscle was found on 16 cord (28,57% of cases), the anterior one being single in 10 cases (17,86% of total cords and 31,25% of the anterior papillary muscle), and the posterior in 6 cases (10,71% of all cords and 25% of cases of posterior papillary muscle). Left double papillary muscle we found in 32 cords (57,14% of cases) the anterior one being double in 18 cords ( 56,25% of all cords and 56,25% of cases of the anterior papillary), the posterior one in 14 cases (25% of all cords and 58,33% of the posterior papillary muscle).

Triple left papillary muscle we found in 6 cords (10,71% of cases), the anterior one being triple in 4 cords (7,14% of all cords and 12,5% of cases of anterior papillary muscles) and the posterior one in 2 cases (3,57% of all cords and 8,33% of posterior papillary muscles). The quadruple left papillary muscle we found in two cords (3,57% of all cases) aspect found only at the posterior papillary ( 8,33% of posterior papillary muscle)

From 106 muscular bodies of the left ventricle the papillary muscles that we analyzed on 56 cords, we found unique papillary muscle in 16 cases (15,09% of cases), 10 cases being at the anterior papillary muscle (17,24% of anterior papillary muscle) and 6 cases at the posterior papillary muscle ( 12,5% of the posterior papillary muscle).



*Figure 1. Unique anterior papillary muscle, conical shape*



*Figure 2. Anterior papillary muscle, with two conical muscular bodies, dispose one anterior to the other*

The 2 cases of papillary muscle with two muscular bodies (double) present a total of 64 muscle bodies (60,38% of muscle bodies), 36 being at the anterior papillary muscle (62,07% of the anterior muscular bodies ) and 28 bodies at the



posterior papillary muscles (62,07% of posterior papillary muscle bodies). In case of triple papillary muscles from 18 muscle bodies (16,98 % of all muscular bodies), 12 bodies were at the anterior papillary (20,69% of all anterior muscular bodies) and 6 muscular bodies were at the posterior papillary muscle (12,5% of all posterior muscular bodies). The 2 cases with quadruple papillary presented 8 muscular bodies (7,55% of all muscular bodies), all of them being found at the posterior papillary (16,67% of all posterior bodies). Of the total of muscular bodies, most frequently they had conical shape, aspect found in 67 cases (63,21% of total muscular bodies), 33 cases being found at the anterior papillary (56,90% of all anterior muscle bodies) and 34 cases at the posterior papillary (70,83% of all posterior muscle bodies).



*Figure 3. The anterior papillary muscle with two muscular bodies, with almost same sizes, both in archway, one left and other right*

On 20 cases (18,87% of cases, the muscular bodies were cylindrical, 18 cases being found at the anterior papillary muscle (31,03% of all anterior muscular bodies); in case of the posterior papillary

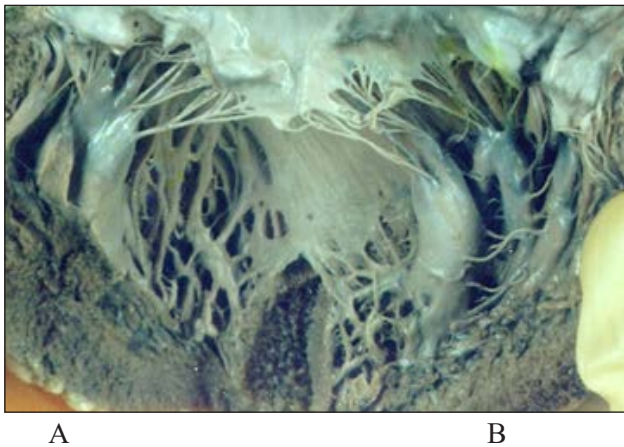
muscles found only two cases (4,17 % of all posterior muscular bodies). In 10 cases (9,43% of all 106 cases) the muscular bodies were arcuated, 4 cases being at the anterior papillary muscle (6,90% of all anterior muscular bodies) and 6 cases at the posterior papillary muscle (12,5% of all posterior muscular bodies). In 8 cases (7,55% of cases), the muscular bodies were fusiform, 4 cases at the anterior papillary muscle (6,90% of all anterior muscular bodies) and 4 at the posterior papillary (8,33% of posterior muscular bodies). In only one case (0,94% of cases) at an unique posterior papillary muscle (2,08% of all posterior muscular bodies) we found a particular form of the muscular body, and we called it „torch” or „beacon”, that had the muscular body thinner in the lower half, its size increasing in width, reaching a maximum width at its upper extremity, from where broke-loose four extra muscles that gave birth to beams of valvular cordages.



*Figure. 4. A. left anterior papillary muscle with two parallel bodies, the right one bigger and conical and the other left, fusiform. B. left posterior papillary muscle formed by three muscular bodies, one right (cylindrical, less volume), inner (cylindrical, thinner) and left (conical, shorter and thick)*

Frequently, the base of the muscular bodies was punched, presenting one or two oval slots, thus implanting at the ventricular wall by two or three

roots.



*Figure 5. A. left anterior papillary with 3 muscular bodies, 2 anterior and conical and the third, posterior; being cylindrical (thicker). B. left posterior papillary muscle with 3 muscular cones: right (conical) thicker, inner (arcuated, situated on a posterior plan to others) and left cylindrical (thinnest).*

At their valvular extremity, the muscular bodies give insertion to cordage tendons, wich can be drawn directly from their peak or from 2-4 small cones posed on upper extremity of the muscular bodies.

At different levels of the muscular body are detaching parietal cordage tendons (for the ventricular wall) or intermuscular cordage tendons between the muscular bodies of the same papillary muscle, or, more rarely, between the muscular bodies of the two papillary muscles of the left ventricle.

In case of the papillary muscle with two muscular bodies, those can be linked by a muscular bridge, transverse or oblique, carrying out various aspects.



*Figure 6. Double left papillary muscles. A. anterior with the reversed 'N' letter; B. the 'H' letter".*

Thus, in 6 cases (10,71% of the 56 cases), muscular bridges realized the letter „H” appearance, 4 casea being at the anterior papillary muscle (18,75% of the anterior papillary muscle) and 2 cases at the posterior papillary (16,67% of the posterior papillary muscles).



*Figure 7. The posterior papillary in the 'torch' shape.*





*Figure 8 Posterior papillary muscle with 2 muscular bodies, cylindrical and unequal*



*Figure 9. The left posterior papillary muscle with four parallel muscular bodies: right (conical) thicker (perforated base), second (first in middle, arcuated, found on posterior plan then the other three), third (second in middle, thinner, conical elongated), and left conical*

In other 4 cases (7,14% of 56 cases), aspect

encountered only to the anterior papillary muscle (12,5% of anterior papillary) the presence of muscular bridges achieve the appearance of the „N” letter. Also in 4 cases the muscular bridges achieve the appearance of reversed „N” letter, 2 cases being at the anterior papillary muscle (6,25% of anterior papillary muscles) and 2 cases at the posterior papillary muscles (8,33% of posterior papillary)

## Discussions

The name of anterior and posterior [18], shows that classical descriptions were made on append cords on the anterior face and upside down. If we turn the cord with the long axis inferior and oblique and to the left, we see that the anterior papillary muscle is actually antero-lateral, and the posterior papillary muscle is inferior and right (postero-septal or postero-medial).

*Table I The number of the muscular bodies at the level of the two papillary muscles of the left ventricle*

author	unique	double	triple	4 bodies	5 bodies	6 bodies
Gunnal	46,55%	43,11%	31,90%	21,55%	-	-
Ozan	43,3%	30%	26,7%	-	-	-
Kavimani	-	-	-	7%	4%	2%
Personel cases	28,57%	57,14%	10,71%	3,57%	-	-

The number of the muscular bodies at the level of the two papillary muscles of the left ventricle.

It is noted that [19] does not find other papillary muscles but only with 3 muscular bodies, [8, 9] with 4 muscular bodies and only [9] finds at the left papillary muscle 5 and even 6 muscular bodies, and this in latter point only in oane case, to the postero-medial papillary muscle.

In case where each papillary muscle is represented by a single muscular body, our results are lower compared with the results of [8] with 17,98%, compared to [19] lower by 14,73%.

We found frequent cases when one of the papillary muscle consists of two muscular bodies, and our statistic is higher by 14,03% compared to [8] and by 27,14% compared to [Ozan]. There are differences in case the papillary muscle presents three muscular bodies, our results being lower by 15,99% compared to [19] and by 21,19% to [8]. We haven't found a papillary muscle consists more than 4 muscular bodies, this being present only on postero-medial papillary.

Hosapatna [15] finds that in the most cases in the left ventricle exists only two papillary muscles, cases when only one of the two left ventricle papillary muscles presents two bodies being redeuced. Spreeuwers [10] finds only 2-3 muscular bodies for a papillary, the cases with multiple muscular bodies are rare.

*Table II. the number of the muscular bodies at the antero-lateral papillary muscle of the left ventricle.*

author	unique	double	triple	4 bodies	5 bodies	6 bodies
Solomon	67%	27%	4%	1%	1%	-
Kavimani	62%	31%	2%	2%	2%	-
Gunnal	68%	29%	4%	-	-	-
Roberts	75%	-	-	-	-	-
Personal cases	31,25%	56,25%	12,50%	-	-	-

In case of the antero-lateral papillary muscle with single muscular body (unique), we find that our results are much lower of those of the consulted literature, and that are differences between 30,75% [9] and 43,75% [20], to [13, 8] differences being 35,75% and 36,75%. We have encountered a high percentage in case of the papillary muscle with two muscular bodies, the differences being greater in our statistics by 29,25% [13] and by 25,25% to [9], compared with the results of [Gunnal] by 27,25%. [15] finds a reduced number number of such cases. In those cases, the two muscular bodies can be joined by muscular bridges (strips) realizing various characteristic aspects. In four cases (7,14% of all cords and 22,22% of double antero-lateral papillary muscle) they presented „H” letter aspect, [8, 9] encountered this aspect in 2% of cases.

In four cases (7,14% of all cords and 22,22%

on double antero-lateral papillary muscle) the two muscle bodies with strip made the appearance of the „N” letter, and in two cases (11,11% of double antero-lateral papillary muscle) realized reversed „N” letter, issues that we have not found cited in consulted literature. In other cases, the two muscular bodies were parallel and could present intermuscular cordage tendons between them. Gunnal and Kavimani [8, 9] cite cases with attained appearance of the „V” or „Y” letter, wich we have not encountered in our study. In cases when the antero-lateral papillary consists 3 muscular bodies, the number of cases that we found is higher by 8,5% to [13, 8] and by 10,5% to [9]. In one of two cases, 2 muscular bodies (middle and left ) were connected by a muscular bridge, making the appearance of reversed „N” letter (4,17% of cases of posterior papillary with 3 muscular bodies). We haven't found antero-lateral muscle with more than 3 muscular bodies, Solomon [13] encountered 4 cases (1% of cases ) and with 5 muscular bodies (1% of cases ). Kavimani [9] finds antero-lateral papillary formed by 4 and 5 muscular bodies in 2% of cases.

*Table III The number of muscular bodies of postero-medial papillary muscles in left ventricle*

author	unique	double	triple	4 bodies	5 bodies	6 bodies
Solomon	50%	36%	11%	3%	-	-
Kavimani	49%	42%	4%	2%	2%	2%
Gunnal	49%	29%	-	-	-	-
Roberts	75%	-	-	-	-	-
Personal cases	25%	58,33%	8,33%	8,33%	-	-

In cases with postero-medial papillary muscle consists only one muscular body, the results we found are lower than those we find in the consulted literature by 24% to [5, 8], by 25% to [13] and by 50% to [20]. In most of one cases postero-medial papillary muscle was composed of three muscular bodies, personal percentages being higher by 29,33% to [8 ], by 22,33% to [13] and by 16,33% to [9].

As with the anterolateral papillary muscle, the parallel muscle bodies can be interconnected with eachother by muscular bridges (strips), realizing the form of capital letters. The form of the „H” letter we encountered in 2 cases (8,33% of posteromedial

papillary muscles) aspect that [8, 9] find in 2% of cases, the reversed „N” letter form we found in 2 cases, aspect that we didn't found in the consulted literature. Also to this papillary muscle are cited forms of „V” and „Y” letters without being specified percentages.

Posteromedial papillary muscle formed by 3 muscular bodies we found in a higher percentage by 4,33% to Kaimani and lower by 2,67% to [Solomon]. Our results in case of the papillary muscles formed by 4 muscular bodies are higher by 5,33% to [13] and by 6,33% to [9]. We did not find posteromedial papillary muscles consisting more than 4 muscular bodies.

Only Kavimani [9] describes cases with 5 or 6 muscular bodies, each variant by 2% of cases.

The shape of the muscular bodies of the papillary muscles varies and is described differently in the special literature. So, the conical shape that we found most frequently (63,21% of cases), is mentioned by [8] in a smaller percentage by 12,21% at the anterolateral papillary muscle and by 25,90% to [9], and at the posteromedial papillary higher by 50,83% to [9]. Arcuated shape of the muscular body, found in 9,43% of cases is more frequent by 5,43% than [8], that finds this only at the posteromedial papillary, but we find it in both papillary muscles of the left ventricle, in our statistics being more frequently by 8,25% to [8]. Cylindrical shape of the muscular body, found in 18,87% of cases, we associated with the shape of the flat end muscular body, described by [8, 9]. We found it being more frequently only by 0,87% to [8] and by 7,87% to [9].

For [15] the muscular bodies of the papillary muscles in the left ventricle are always conical.

## Conclusions

This study is useful for the anatomists, cardiologists and cardiac surgeons. The normal function of the mitral valve depends on anatomical and mechanical integrity of the papillary muscles.

Cardiac surgery needs to improve the knowledge of precise anatomy of papillary muscles, chordae tendineae and the mitral valve, of the anatomical variant of those, aspects that have a considerable importance because of the role they have in the surgical treatment of the mitral valve prolapse and replacement of it [9]. After [9] the reconstruction of the subvalvular mechanism in the left ventricle, needs a very good knowledge of the morphology of the papillary muscles, with a special importance in describing the clinical syndromes of the dysfunction of the papillary muscles, hypertrophic papillary muscles, atrophy of papillary muscles, disruption of papillary, all these increasing the clinical semification of the papillary muscles. After [11, 21, 22] the posteromedial papillary muscle, probably because of the lower blood supply, it breaks frequently then the anterolateral papillary.

The shape of the papillary muscles influences the blood circulation, the chances of the obstruction in left ventricle being higher in the fan shape papillary hypertrophy (aspect that we didn't find) and to wide apex papillary. The papillary muscle, that facilitates the cardiovascular physiology is the conical shape one, inserted on the ventricular wall, that leaves empty the center of the cavity [8].

Solomon [13] that studied the variations of the papillary of the mitral valve on 100 cases, states that the mitral mechanism, including the papillary muscles, is unique for each subject such as own mark.

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