Cardiovascular Pathology 34 (2018) 22–27

Contents lists available at ScienceDirect

Cardiovascular Pathology

Original Article

Papillary muscles of right ventricle—morphological variations and its clinical relevance☆,☆☆

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ARTICLE INFO

Article history:
Received 20 September 2017
Received in revised form 11 January 2018
Accepted 16 January 2018

Keywords:
Heart
Right ventricle
Papillary muscle
Variations

ABSTRACT

Introduction: Papillary muscle plays an important role in stabilizing the position of the tricuspid valve. Several pathologies can result in anatomical and functional abnormalities of the papillary muscles. The aim of the study is to deliberate the morphometry of papillary muscles in tricuspid valve and to analyze with the eminent research works previously done.
Materials and methods: The study was carried out in 52 formalin-fixed adult apparently normal cadaveric hearts belonging to either sex obtained from the Department of Anatomy. These hearts were dissected carefully to open the right ventricle and to expose the papillary muscles. Different morphological features of papillary muscles were noted, and measurements were taken.
Result: The classical picture of three papillary muscles existed in 23.07% of the specimens. Anterior papillary muscle was in all hearts, but posterior and septal muscle was off in 15.38% and 55.76%, respectively. Double and triple papillary muscles were seen too. Anterior and posterior muscle appeared predominantly flat-top and arose from the middle third (mostly), while septal muscle was chiefly conical and originated basically from the upper third of the ventricular wall. Chordopapillary relationship with tricuspid valve leaflets was beyond conventional. Mean length and breadth of anterior muscle were 2.19±0.59 cm and 0.76±0.26 cm, those of posterior muscle were 1.39±0.63 cm and 0.67±0.43 cm, and those of septal papillary muscle were 0.95±0.38 cm and 0.59±0.09 cm.
Conclusions: Detailed knowledge of normal and variable anatomy of papillary muscles is not only necessary for better understanding of tricuspid pathologies but also valuable for successful newer surgical approaches in cardiac treatment.

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1. Introduction

Papillary muscles play an important role in atrioventricular valve closure to maintain the unidirectional blood flow of the heart. Right ventricle accommodates three types of papillary muscles: anterior papillary muscle (APM), posterior papillary muscle (PPM), and septal papillary muscle (SPM). APM is the largest among all, which arises from right anterolateral ventricular wall, frequently being unique, and gives chordae to the anterior and the posterior valve leaflets. PPM appears from the myocardium below the inferior-septal commissure, is often bifid or trifid, and provides chordae tendon to the posterior and septal valve leaflets. Septal or medial papillary muscle, however, is the smallest but typical and arises from the posterior septal limbs of septomarginal trabeculae which usually supports septal and anterior leaflets via chordae, though the septal leaflet is often underpropped by chordae that directly arise from the ventricular septum. Usually, tricuspid valve function depends upon the maintenance of the proper spatial relationship between the papillary muscles, chordae tendineae, and valve leaflets through all phases of the cardiac cycle [1]. In a normal-sized heart, the long axis of papillary muscle is aligned almost right angle to the atrioventricular ring. This orientation provides a mechanical advantage as the tension developed within the papillary muscles that applied, is almost perpendicular to tricuspid valve leaflets [2]. In fact, papillary muscle plays a major role in right ventricular contraction by drawing the annulus towards apex, thereby shortening the long axis and chamber becomes spherical for ejecting blood [3]. Contraction of papillary muscles commences just prior to the onset of right ventricular systole so as to maximize coaptation of three cusps and reduce regurgitation [4]. When dynamic nature of this function is unsatisfactory, it leads to papillary muscle dysfunction [2].

The right side of heart as the cause of pulmonary emboli is not a new concept; various primary and secondary cardiac tumors have shown to

☆ Conflicts of interest: We have nothing to declare about any conflicts of interest.
☆☆ Sources of research support, if any, including funding, equipment, and drugs: none to declare.

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https://doi.org/10.1016/j.carpath.2018.01.007
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Table 1
Numbers and arrangements of different papillary muscles in 52 specimens

			APM *n* (%)	PPM *n* (%)	SPM *n* (%)
No. of muscle	Present	Single	41 (78.84%)	25 (48.07%)	14 (26.92%)
		Double	08 (15.38%)	14 (26.92%)	09 (09.61%)
		Triple	03 (05.76%)	05 (09.61%)	00
	Absent		00	08 (15.38%)	29 (55.76%)
Arrangement of extra muscles	Double	Parallel	03 (37.50%)	09 (64.28%)	09 (100%)
		Interlinked	05 (62.50%)	05 (35.71%)	00
	Triple	Parallel	01 (33.33%)	04 (80%)	00
		Two interlinked & one separated	02 (66.66%)	01 (20%)	00
		Three interlinked	00	00	00

be a potential source. Not only that, an aberrant papillary muscle complex is also thought to be the root of recurrent pulmonary embolus due to stasis of blood around these structures [5].

The focus of the study was to explore and document the architecture of right ventricular papillary muscles concerning numbers, shapes, positions, and arrangements and contrast the result with previous reports in an aim to overcome the lacunas.

2. Methods and materials

The study was carried out on 52 formalin-fixed human hearts obtained from cadavers who had passed away of nonvascular causes. Dissection was performed according to standard dissection techniques. Tricuspid valve was opened by giving an incision from right atrium to the apex along the acute margin of heart followed by an extension into anterior interventricular groove. Care was taken not to damage any papillary muscle of the right ventricle. Interior of the heart was washed to remove blood clots. This exposed the papillary muscles and chordae tendineae of the right ventricle clearly. The morphometric and morphological parameters were evaluated. Presence of accessory papillary muscles was also noted. The analysis was done without any grouping of age and sex. Morphological features of each muscle were examined as follows:

1. Number of papillary muscle present in each wall of ventricle: single muscle or more than one (double, triple) as accessory muscles.
2. Arrangement of papillary muscles (if more than one present): whether completely separated and parallel or interconnected/interlinked with each other by muscular bridge/bridges at different levels.
3. Shape of each papillary muscle by its tip or apex:
   a) Conical: classical muscle (broad base with single narrow pointed head/ apex).
   b) Flat-top: broad flatten apex.
   c) Bifurcate: apex divided and separated into two heads.
   d) Trifurcate: apex divided and separated into three heads.
   e) Truncated: apex divided into more than three heads.
4. Site of origin from ventricular wall (upper one third, middle one third or lower one third).
5. Number of chordea attached at each papillary muscle.
6. Attachment of each papillary muscle with leaflets.

Furthermore, by using Vernier caliper and malleable millimeter ruler, the following morphometric parameters of papillary muscles were measured:

a) Length of the muscle: from basal attachment at ventricular wall to apex.
b) Breadth of the muscle: at its origin from ventricular wall.

All data were documented and summarized by descriptive statistics. Mean, median, standard deviation (S.D.), 95% confidence interval (CI), and a *P* value of muscles were calculated, and results were tabulated. *P* value <.05 was considered as significant. All the statistical calculations were performed using software SPSS for Windows.

3. Result

In the present study, number of papillary muscles was frequently seen as 3–4, though range was 2–7 irrespective of their positions within the ventricle. Conventional picture of right ventricular papillary muscles

Table 2
Shape, origin, number of chordae attached, and relation with leaflets of muscle

		APM *n* (%)	PPM *n* (%)	SPM *n* (%)
Total number of muscle bellies (including accessory muscles) in 52 ventricles		66	68	32
Shape of Individual muscle belly	Conical	08 (12.12%)	02 (02.94%)	29 (90.62%)
	Flat-top	34 (51.51%)	60 (88.23%)	03 (09.37%)
	Bifurcated	08 (12.12%)	04 (05.88%)	00
	Trifurcated	05 (07.57%)	00	00
	Truncated	11 (16.66%)	02 (02.94%)	00
Site of origin from ventricular wall	Upper one third	06 (09.09%)	17 (25%)	26 (81.25%)
	Middle one third	43 (65.15%)	41 (60.29%)	06 (18.75%)
	Lower one third	17 (25.75%)	10 (14.70%)	00
Number of chordea attached	Range	02-20	02-14	1-7
	Mean	11	6	05
Attachment with leaflets	Only anterior	15 (22.72%)	–	–
	Only posterior	–	31 (45.58%)	–
	Only septal	–	–	10 (31.25%)
	Both anterior & posterior	25 (37.87%)	25 (36.76%)	–
	Both posterior & septal	–	12 (17.64%)	16 (50%)
	Both anterior & septal	11 (16.66%)	–	08 (25%)
	All three: anterior, posterior, & septal	15 (22.72%)	–	––

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