ORIGINAL PAPER

Considerations on the left papillary muscles microangioarchitecture

M. C. RUSU[1)], CODRUŢA ILEANA PETRESCU[2)], V. NICULESCU[2)], N. IONESCU[3)], M. VLAD[1)]

[1)]*Department of Anatomy and Embryology, "Carol Davila" University of Medicine and Pharmacy, Bucharest*
[2)]*Department of Anatomy, "Victor Babeş" University of Medicine and Pharmacy, Timişoara*
[3)]*Department of Histology, Faculty of Dental Medicine, "Carol Davila" University of Medicine and Pharmacy, Bucharest*

Abstract

The aim of the present study was to bring macroscopic and microscopic evidence on the left papillary muscles blood supply in human hearts. For the study were used human adult hearts from patients without clinically known cardiac ischemic history. Ten hearts were used for injecting China ink in the coronary arteries and other twenty hearts were dissected to evidence the characteristics of the main arteries of the left papillary muscles. Pieces – left papillary muscles – were drawn from the injected hearts and diaphanised. In all dissected hearts the left anterolateral papillary muscles were supplied by the left coronary system: anterior interventricular artery, second diagonal branch and left (obtuse) marginal artery. In 70% the left posteromedial papillary muscles were supplied by the right coronary system (posterior interventricular artery, left retroventricular artery) and in 30% by the left coronary system (circumflex artery). The left papillary muscles were supplied each by one or two main arteries that penetrated the muscles longitudinally. The ventricular wall attaching the papillary muscles was supplied by the subepicardial vessel sending the main arteries of the papillary muscles but also by neighbor subepicardial vessels distributed in that wall. The mural vessels were finer than the papillary muscles main arteries. Injected papillary muscles presented each with two systems of blood perfusion: one represented by segmental centers of arterial branching and distribution of the main arteries of the muscle and other represented by capillary extensions of the mural networks at that level. From the segmental branching centers were perfused the neighbor segments of the papillary muscles and intrasegmental anastomoses were recognized. The microvascular study of the left papillary muscles proves the usual overlapping of sources for segmental supply; this overlapping is reinforced by the high capillary density to ensure the vascularisation of the papillary muscles.

***Keywords*:** coronary arteries, heart, left ventricle.

Introduction

The cardiac microcirculatory bed is essential for the heart function. In the heart an increase in coronary perfusion results in an increase in cardiac oxygen consumption and strength of contraction (cardiac contractility) [1].

The papillary muscles are protrusions on the ventricular walls, inserted at one end onto the ventricular wall and continuous at the other end with collagenous cords, the *chordae tendineae*, inserted on the atrioventricular valves. The anterolateral papillary muscles of the left ventricle arise from the sternocostal mural myocardium and the posteromedial – from the diaphragmatic region [2].

Extensive anatomic studies on the microvasculature of the papillary muscles were reported in 1885 from the Anatomic Academy of Florence and later by Gross, Spalteholz and Esthes EH *et al.* [3]. Esthes EH *et al.* describe the left papillary muscles as supplied by larger arborizations (Class B) of subepicardial vessels, less frequently divided, penetrating the muscles; finer arborizations of the subepicardial vessels (Class A) supply the adjacent parietal wall [4].

Material and methods

For the present study ten isolated human adult hearts of both sexes, without evidence of malformations and without any ischemic history, were injected with China ink in the coronary arteries. Left papillary muscles (anterolateral, LALPM and posteromedial, LPMPM) were drawn and prepared for microscopic observation; longitudinal cuts of 20 microns and diaphanisations were preferred.

Dissections were also performed on other 20 fixed specimens from individuals without clinically known cardiac ischemic pathology, for evidencing the origin and the myocardial course of the papillary muscles main arteries. The human material was obtained and used in accordance with the local acting ethical rules.

Results

The macroscopic evidence of the papillary muscles main arteries by dissection determined the following evidence (Figures 1 and 2):

▪ in all specimens the LALPM were supplied by branches of the left coronary artery:

– the anterior interventricular artery (two specimens);

– the second diagonal branch (seven specimens, Figure 1A);

– the left (obtuse) marginal artery (11 specimens, Figure 1B).

▪ the LPMPM were supplied by the right coronary artery (14 specimens) and the left coronary artery (six specimens):

– in six specimens the supplier was the posterior interventricular artery;

– in eight specimens the source was the first left posterior ventricular artery emerged from a left retroventricular artery;

– in five specimens the LPMPM was supplied by the left (obtuse) marginal artery;

– in one specimen the supplier was a left posterior ventricular branch of the circumflex artery.

The number of individual left papillary muscles was variable, ranging from one to four on the corresponding ventricular wall; each of these muscles was provided with one or two main arteries that were invariably furnished by the same subepicardial supplier. A correlation between the number of the papillary muscles and the individual number of main arteries of these muscles could not be established (Figures 3 and 4).

The main arteries of the papillary muscles (MAPM) radiated at right or acute angles from the subepicardial vessels and traversed the ventricular wall; these arteries kept a constant caliber to enter the papillary muscles. Also, there were finer branches of the subepicardial vessels that distributed in the outer and middle thirds of the myocardium at that level; these branches emerged from the suppliers of the papillary muscles but also from the neighbor subepicardial vessels distributed in the respective ventricular wall. The microscopic study revealed that the left papillary muscles have each a dual supply: on one hand, the MAPM and, on the other hand, longitudinal networks of capillaries provided the myocardial networks of the wall attaching the papillary muscles (Figure 5).

There were evidenced in each papillary muscle multiple segmental centers of arterial branching, supplied by the MAPM (Figure 2).

From these centers, recurrent arteries coursed towards the base of the papillary muscle and collaterals were sending distally, towards the apex of the papillary muscle (Figures 2 and 3).

Successive generations of arterial branches modified their disposition in relation to the longitudinal axis of the papillary muscle; on the preparates were recognized:

▪ the MAPM adopts a longitudinal disposition (Figures 2 and 4);

▪ the primary branches of the MAPM, of 25–44 microns caliber, course obliquely or transversely; anastomotic arcades could be observed (Figure 3);

▪ the secondary branches, of average 15 microns caliber, are longitudinal and further send transversally dichotomizing arterioles of average 7 microns caliber (Figure 4);

▪ finally, the resulting capillaries, of average 3 microns caliber, course longitudinally and may also dichotomize (Figure 4).

Neighbor arterioles and, indirectly, their supplying arteries, ensured an overlapped distribution in the papillary muscle (Figure 5).

Discussions

Our results confirm that the anterolateral papillary muscles are supplied by the left coronary system as it was previously described [4] but not only by marginal branches of the circumflex artery – in 35% the supplier was the anterior interventricular artery. In our study the posteromedial papillary muscles were supplied by the right coronary system in 70%, when the right coronary artery was dominant, and by the circumflex artery in 30%.

The supply for the posteromedial papillary muscles by the right coronary system corresponds to the descriptions of Voci P *et al.* (1995), but not with those of Feinstein SB *et al.* (1988) who present the left coronary system as a frequent supplier for these muscles [3, 5]. We consider that this is a problem of coronary dominance and specimens included in the lot of study.

The number of papillary muscles is individually variable but in each case a papillary muscle is provided with two perfusion systems:

▪ one system is represented by the MPAM, provided by a single subepicardial vessel; these MAPM correspond to the Class B vessels of Esthes EH *et al.*;

▪ other system consists of well-represented capillary networks emerged from the ventricular wall that attaches that papillary muscle.

The myocardium attaching the papillary muscles is supplied by fine vessels (corresponding to the Class A vessels of Esthes EH *et al.*), emerged from the subepicardial vessels of that territory, either aroused from the same supplier of the MAPM, either from that supplier and a neighbor artery.

Voci P *et al.* (1995) discuss the single and double blood supply of the papillary muscles, referring to the number of subepicardial sources involved in the individual papillary muscle supply [3].

These authors performed superselective coronary graft injections and state that the LALPM have frequently (71%) double-vessel supply, while the LPMPM has a single-vessel supply in 63% of the patients. The two-perfusion systems we described correlate and justify the findings of these authors.

Delineation must be made when discussing the papillary muscles blood supply, between the intrinsic supply of that muscles and the mural supply of the insertion region of the muscles. The intrinsic blood supply of the papillary muscles is segmental in distribution, built upon the MAPM and it is reinforced by an additional capillary bed provided from the mural network. The MAPM respect a segmental distribution pattern, previously described by Esthes EH *et al.* [4].

Each arterial segment of a papillary muscle is supplied by proximal and distal sources that may be anastomosed. In turn, these arteriolar anastomoses may represent possible support for the arteriogenesis that may occur after occlusal events [6–8].

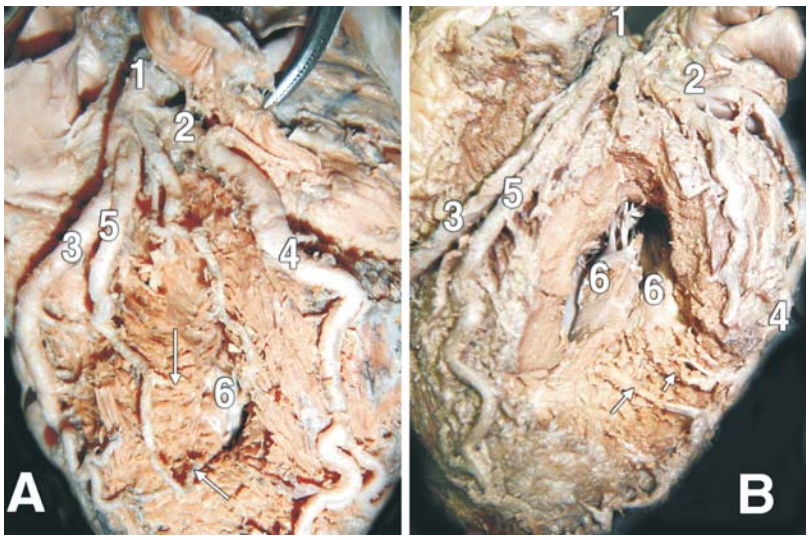

Figure 1 – ***Dissections of the main arteries of the LALPM: A) double MAPM (arrows); B) single MAPM (arrows), double LALPM (1 – left coronary a.; 2 – circumflex a.; 3 – anterior interventricular a.; 4 – left (obtuse) marginal a.; 5 – 2nd diagonal a.; 6 – LALPM)***

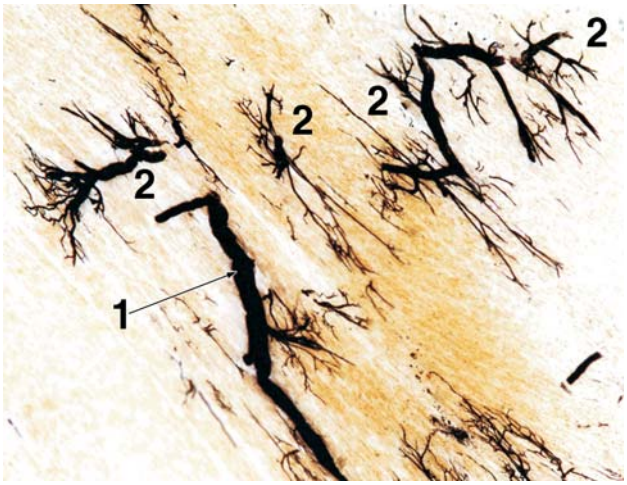

Figure 2 – ***Longitudinal cut of the LALPM. Main artery of the LALPM (1), proximal to a segmental branching area (2)***

Figure 3 – ***Longitudinal cut of the LALPM. Anastomotic arcades, simple (1) and branched (2) between segmental arteries, in the lower half of the LALPM***

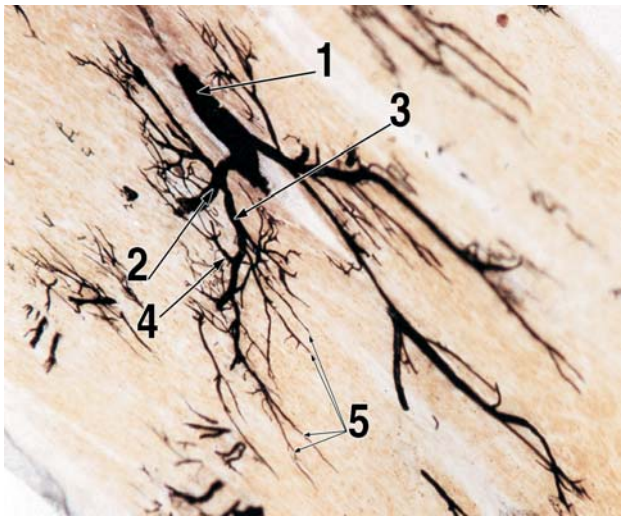

Figure 4 – ***Longitudinal cut of the LALPM. Branching pattern of the LALPM arteries: the main artery (1), longitudinally disposed, further sends primary transverse (2) and oblique branches that in turn give secondary longitudinal branches (3) continued by dichotomizing arterioles (4). Finally, capillaries result, longitudinal, directed towards the apex of the papillary muscle and recurrent (5) towards the base of that muscle***

Figure 5 – ***General microangioarchitecture of LPMPM, on longitudinal cuts, reconstruction: the base of the muscle is penetrated by two distinctive main arteries and by extensions of the capillary bed of the ventricular wall at that level***

Conclusions

The left papillary muscles are provided with distinctive and individual pathways of blood supply.

The segmental distribution pattern of the intrinsic vessels and the collateral circulation but also the papillary muscle supply from the mural capillary network represents the scaffold that ensures protection to ischemia.

Papillary muscle dysfunctions must take into account the subepicardial vessels distributed to those muscles, on one hand, and to the ventricular wall attaching that muscles, on the other hand – the subepicardial sources may differ.

References

[1] DIJKMAN M. A., HESLINGA J. W., SIPKEMA P., WESTERHOF N., *Perfusion-induced changes in cardiac contractility depend on capillary perfusion*, Am J Physiol, 1998, 274:405–410.

[2] WILLIAMS P. I., BANNISTER L. H., BERRY M. M. *et al.* (eds), *Gray's Anatomy*, 38th edition, Churchill Livingstone, New York, 1995.

[3] VOCI P., BILOTTA F., CARETTA Q. *et al.*, *Papillary muscle perfusion pattern. A hypothesis for ischemic papillary muscle dysfunction*, Circulation, 1995, 91:1714–1718.

[4] ESTHES E. H., DALTON F. M., ENTMAN M. L. *et al.*, *The anatomy and blood supply of the papillary muscles of the left ventricle*, Am Heart J, 1966, 71:356–362.

[5] FEINSTEIN S. B., LANG R. M., DICK C. *et al.*, *Contrast echocardiography during coronary arteriography in humans: perfusion and anatomic studies*, J Am Coll Cardiol, 1988, 11(1):59–65.

[6] DEINDL E., SCHAPER W., *The art of arteriogenesis*, Cell Biochem Biophys, 2005, 43(1):1–15.

[7] SCHOLZ D., SCHAPER W., *Preconditioning of arteriogenesis*, Cardiovasc Res, 2005, 65(2):513–523.

[8] HEIL M., SCHAPER W., *Pathophysiology of collateral development*, Coron Artery Dis, 2004, 15(7):373–378.

Mailing address

Mugurel Constantin Rusu, Assistant, M. D., Ph. D., Department of Anatomy and Embryology, Faculty of Dental Medicine, "Carol Davila" University of Medicine and Pharmacy, 8 Eroilor Sanitari Avenue, 050474 Bucharest, Romania; Phone +40722–363 705, E-mail: anatomon@gmail.com

Received: May 10th, 2006

Accepted: June 15th, 2006