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Distribution of muscular bridges in the adult human heart

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Muscle bridges (MBs) are structures consisting of heart muscle tissue which pass above the coronary arteries and their branches. Although there are a relatively large number of descriptions of these MBs, researchers do not share a common view of the frequency of their occurrence, their location and their morphology, which remain the most controversial questions. The present research was carried out on 300 human hearts, adults of both sexes (161 male and 139 female), of between 21 and 76 years of age (mean age 48 years), in which no macroscopic developmental failures had been found. The hearts were preserved in formalin-ethanol solution. Selected coronary arteries were analysed. Images were examined of the perpendicular dissection of the coronary arteries and their neighbouring structures. On the basis of the analysis, the frequency of occurrence of MBs was defined as 31.3%. Muscular bridges were observed most frequently over the anterior interventricular branch of the left coronary artery (RIA) and, more rarely, over the right marginal branch of the left coronary artery (Rmd) and the circumflex branch of the left coronary artery (RCX). Using as criteria the number of muscular bridges in the heart and their location over particular coronary arteries, 4 types of configuration were established. With reference to the RIA, most MBs were located in the central part. We did not notice the same regularity with reference to other coronary arteries, nor did we observe MBs over coronary veins.
Conclusions: muscular bridges are frequently observed structures in human hearts, most often seen over the anterior interventricular branch of the left coronary artery (RIA), mainly over its central segments, and occasionally over other arteries. MBs may occur in the heart singly or in a greater number and are found over the same or different vessels.

Key words: muscular bridges, human heart, coronary arteries, morphology

INTRODUCTION

Muscle bridges (MBs) are structures consisting of heart muscle tissue which pass above the coronary arteries and their branches. Coronary arteries are usually characterised by a subepicardial localisation, but there are exceptions to this rule. It is reported that the coronary artery may penetrate the myocardium and then rise again to the surface. Although MBs are usually observed over the great coronary arteries, there are some reports confirming their existence over cardiac veins [3]. The first report to describe a MB dates from 1737 when Reymann observed that the left cardiac vein was segmentary and covered by a thin layer of myocardium [26]. The same phenomenon was described by Black in 1805 [6]. The turning point in the history of research in this

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field was the study by Geringer in 1951 [12]. This was the first thorough study and included not only notes on the morphology, but also on the anatomopathological aspect of MBs. In 1968 Polacek and Zechmeister [24] examined a dozen or so species of animals, dividing them into 3 groups (on the basis of the presence or absence of MBs): Type A, with coronary arteries lying in the myocardium (the rat and rabbit), type B with the coronary arteries characterised by a subepicardial localisation, although in some individuals MBs were present (including humans, rhesus monkeys and dogs), and Type C without MBs (horses and cows).

The first report confirming the existence of MBs in a living man was drawn up in 1960 when, during a coronarography, Portsmann and Iwig [25] confirmed the transitional occlusion of part of the anterior interventricular branch (RIA) during contraction of the heart.

Although there are a relatively large number of descriptions of these MBs, researchers do not share a common view of the frequency of their occurrence, their location and their morphology, which remain the most controversial questions. The majority of investigators agree that the presence of MBs may fundamentally modify the haemodynamics in coronary arteries. There are reports suggesting that MBs influence atherosclerotic changes and that they may cause a deficiency in the blood supply in the myocardium during the rapid working of this organ. The wide diversity on the background to the vital clinical implications of the occurrence of MBs in the literature to date has led us to undertake a detailed analysis of these structures.

MATERIAL AND METHODS

The research was carried out on 300 human hearts, adults of both sexes (161 male and 139 female), of between 21 and 76 years of age (mean age 48 years), in which no macroscopic developmental failures had been found. The hearts were preserved in formalin-ethanol solution.

An analysis was carried out of the right coronary artery (ACD), the left coronary artery (ACS) and their main branches: the right marginal branch (Rmd), the posterior interventricular branch of the right coronary artery (Rip), the anterior interventricular branch of the left coronary artery (RIA), the circumflex branch of the left coronary artery (RCX), the diagonal branch of the left coronary artery (Rd) and the left marginal branch (Rms).

Each of arteries investigated was divided into divisions of 5 mm in length (from the place of departure of the artery). These parts we have called segmants. The arteries were cut perpendicularly to the long axis of the artery in the middle of each segment and on the border between segments. Using a set of magnifying glasses of magnification ranging from 2–8 ×, the transverse section of the artery and neighbouring structures were analysed. Where MBs were observed, cuts of 1-2 mm were made in addition to the standard ones. As a result of these, the exact locations of the beginning and end of the MB were defined. The frequency of occurrence and location of the MBs were calculated. Position over the artery was established according to Ishii et al. [16] by defining the number of the segment in which the front edge of the MB was located (Fig. 1).

RESULTS

The presence of muscular bridges (MB) was established in 94 hearts (31.3%) of the group studied (Fig. 2). These structures were found more frequently in the hearts of men (59 hearts — 36.6% of the male hearts studied) and relatively rarely in the hearts of women (35 hearts — 25.5% of the female hearts studied) (Fig. 3). 114 muscular bridges were observed together above 6 arteries, the anterior interventricular branch of the left coronary artery (RIA), the posterior interventricular branch of the right coronary artery (Rip), the diagonal branch of the left coronary

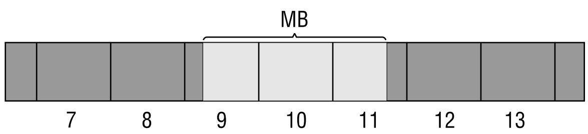

Figure 1. Location of muscular bridges (MB) over coronary artery described as the number of the segment in which the frontal edge of the MB is located.

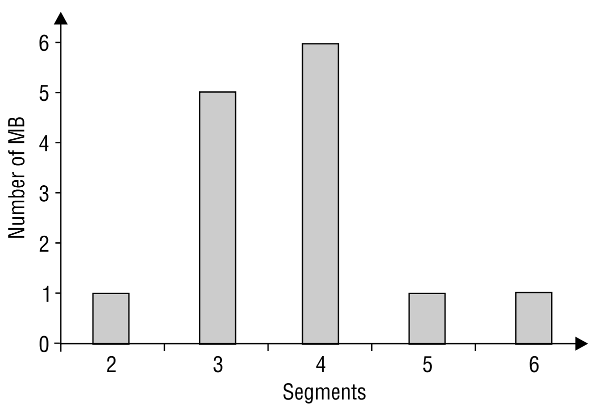

Figure 2. Number of muscular bridges with frontal edge in particular segments of the Rd.

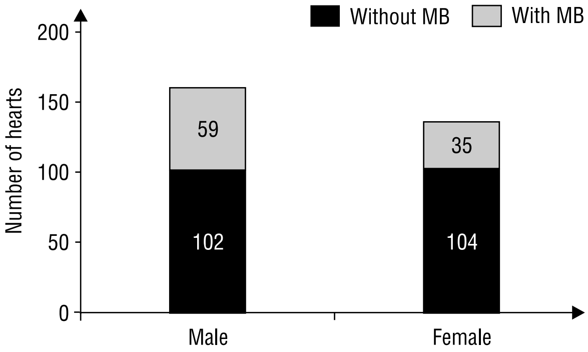

Figure 3. Number of hearts containing muscular bridges in material of male and female hearts.

artery (Rd) and the left marginal branch (Rms), right marginal branch (Rmd) and circumflex branch of the left coronary artery (RCX). The presence of muscular bridges (80 MB in 72 hearts) was found mainly over the RIA (Fig. 4) and rarely above the remaining arteries: Rd — 15 MB in 14 hearts, Rip — 11 MB in 10 hearts, Rms — 6 MB in 6 hearts, Rmd — 1 MB in 1 heart and RCX — 1 MB in 1 heart (Fig. 5). Analysis of the results in relation to the total number of MBs yielded the following: over the RIA 70.2% of the total number of MBs, over the Rd — 13.2%, over the Rip — 9.6%, over the Rms — 5.2% and over the Rmd and RCX — 0.9% each (Table 1).

On the basis of the study, 4 types of configuration of the MB position in the heart were distinguished. In Type I, which was observed by far the most frequently (75 hearts — 79.7% of hearts with MB), there was one MB in the heart. Types II (2 MBs in the heart over the same artery) and III (2 MBs in the heart over 2 different arteries) were observed only rarely (9 hearts — 9.6% hearts with MB in each type). In one case (1.1% hearts with MB) we observed 3 MBs in the heart — 2 MBs over one artery and 1 MB over another — this configuration was classified as Type IV (Fig. 6).

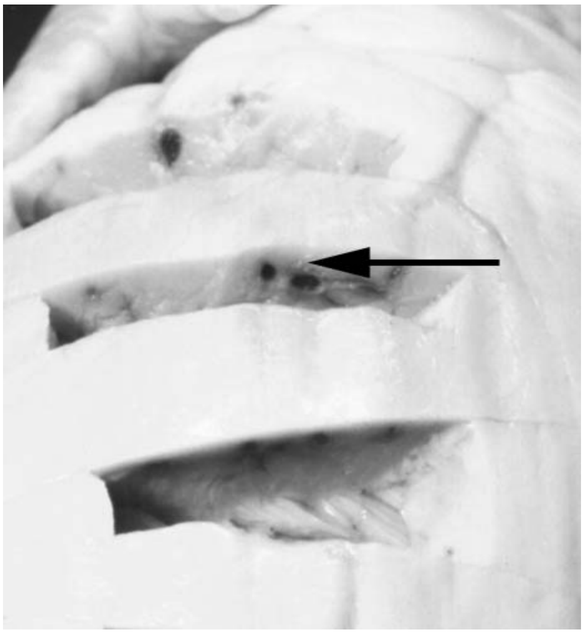

Figure 4. Typical muscular bridge over the anterior interventricular branch of the left coronary artery (RIA) (marked with arrow), M, 41 years old.

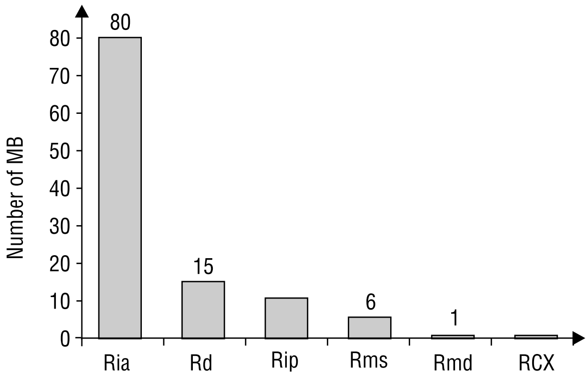

Figure 5. Number of muscular bridges over particular coronary arteries.

Table 1. Distribution of muscular bridges over particular coronary arteries (M — male, F — female)

	RIA		Rd		Rip		Rms		Rmd	RCX
Number of MB	80		15		11		6		1	1
MB	70.2%		13.2%		9.6%		5.2%		0.9%	0.9%
Number of hearts with MB	72	44 M 28 F	14	9 M 5 F	10	3 M 7 F	6	4 M 2 F	1 M	1 M
Studied material	24%		4.7%		3.3%		2%		0.3%	0.3%

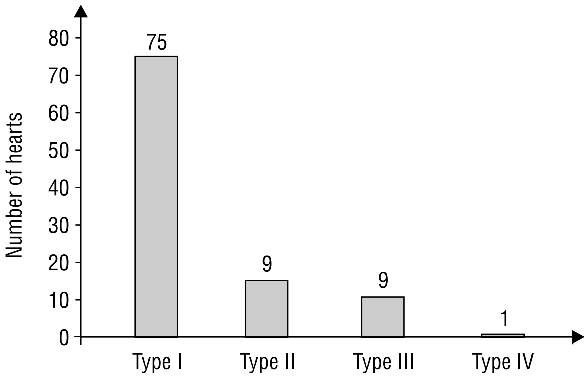

Figure 6. Number of hearts with a particular type of configuration of muscular bridges.

Type I was characterised by the presence of an MB above each group of arteries studied, mainly over the RIA (55 hearts) and more seldom over the other arteries — Rd (8 hearts), Rms (6 hearts), Rip (4 hearts), Rmd (1 heart) and RCX (1 heart). In Type II we observed MBs over the RIA (7 hearts), Rd (1 heart) and Rip (1 heart). In hearts belonging to Type III 5 hearts had MBs over the RIA and Rip and 4 hearts over RIA and Rd. Type IV was represented by one heart with 2 MBs over the RIA and 1 over the Rd (Fig. 7).

The location of an MB over the artery was defined according to Ishii et al. [16] with reference to the segment on which the frontal edge of the MB was located (Fig. 1). Where a double MB was present, atten-

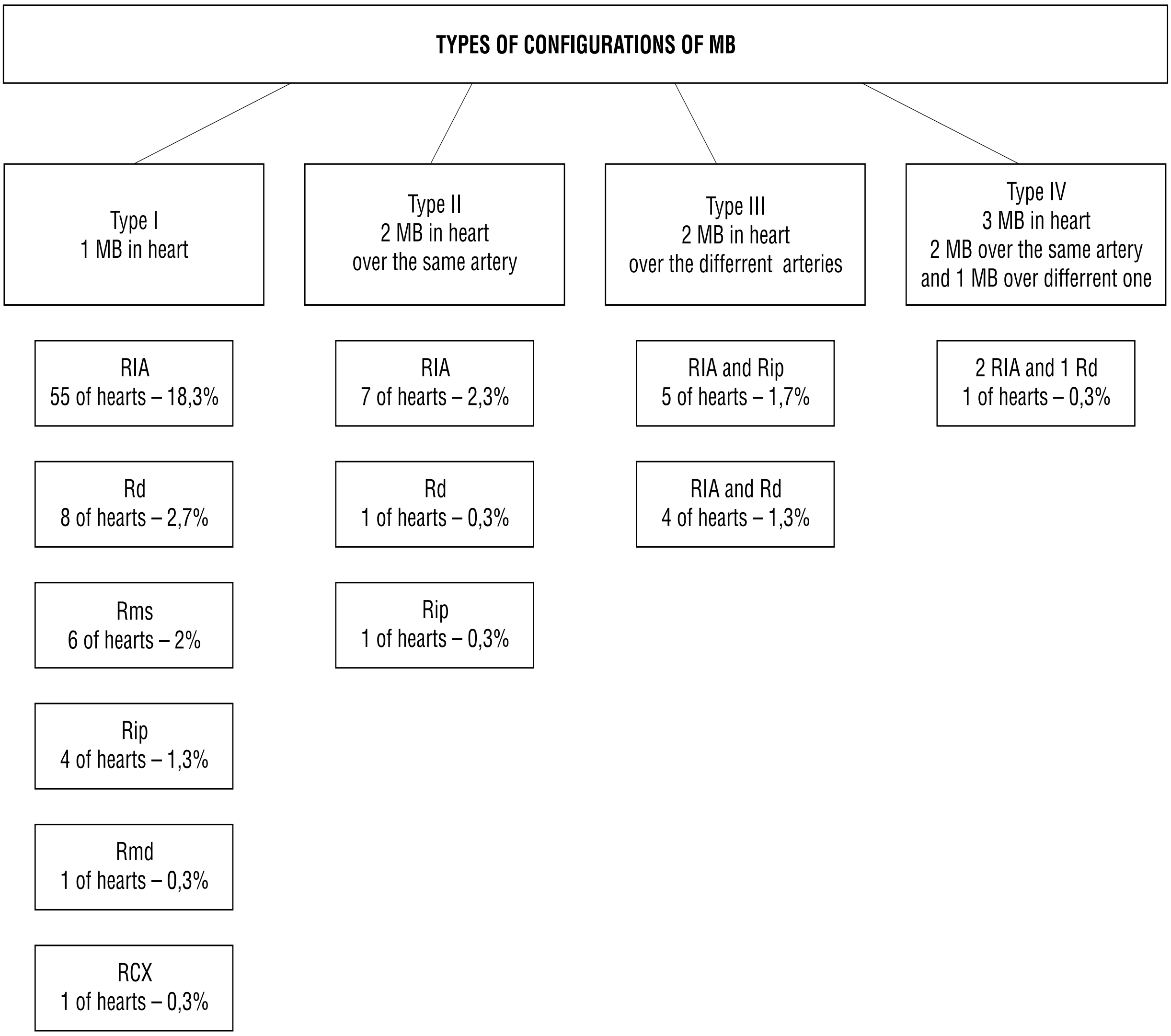

Figure 7. Configuration of muscular bridges in the group studied.

tion was focused on the location of the first. The frontal edges of the MB over the RIA were located in segments 4 to 15. One MB was located in segment number 4, 3 MBs in segment number 5, 5 MBs in segment number 6, 5 MBs in segment number 7, 12 MBs in segment number 8, 14 MBs in segment number 9, 18 MBs in segment number 10, 6 MBs in segment number 11, 3 MBs in segment number 12, 1 MB in segment number 13, 3 MBs in segment number 14 and 1 MB in segment number 15. In order to facilitate the investigative analysis, the RIA was divided into the following 3 segments termed "tierces" [14]: Tierce I from segment 4 to 7, Tierce II from segment 8 to 11 and Tierce III from segments 12 to 15.

The results obtained show that most MBs begin in the central segments of the artery, from 8 to 11, Tierce II (Fig. 8). Because of the relatively small number of MBs over other coronary arteries, we abandoned the division into tierces. The distribution of MBs over the Rd was as follows: 1 MB in segment number 2, 5 MBs in segment number 3, 6 MBs in segment number 4, and 1 MB each in 5 and 6 (Fig. 2). The frontal edge of the MBs in Rip were located as follows: 2 MBs in segment number 18, 1 MB in segment number 19, 3 MBs in segment number 20, 1 MB in segment number 21, 2 MBs in segment number 24 and 1 MB in segment number 28 (Fig. 9). To increase the precision of the investigation, we numbered the segments from decrease studied artery from ACD. Over the Rms we observed one MB in segment number 3, 3 MBs in segment number 4 and 2 MBs in segment number 5 (Fig. 10). The single MBs over the RCX and Rmd were located in segments number 3 and 2 respectively.

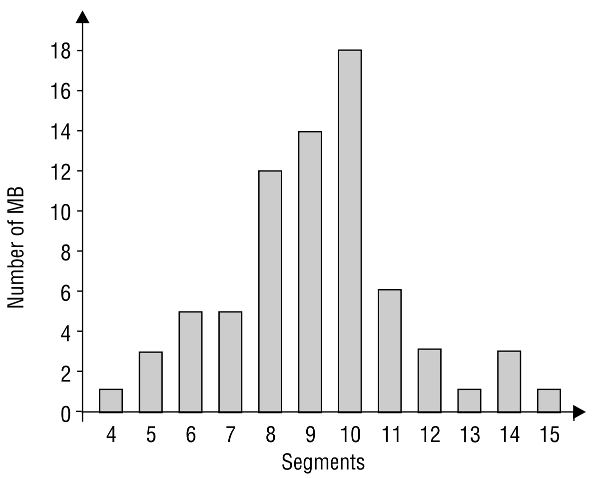

Figure 8. Number of muscular bridges with frontal edge in particular segments of the RIA.

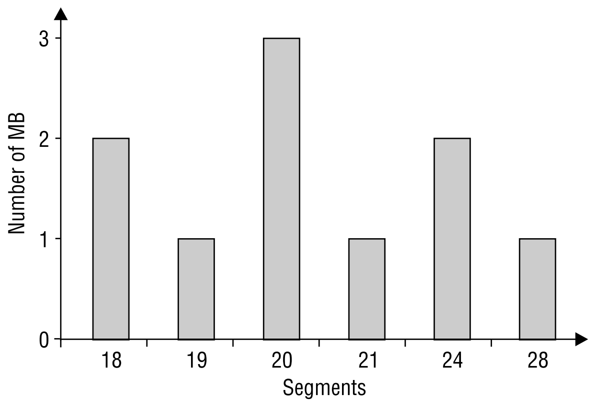

Figure 9. Number of muscular bridges with frontal edge in particular segments of the Rip.

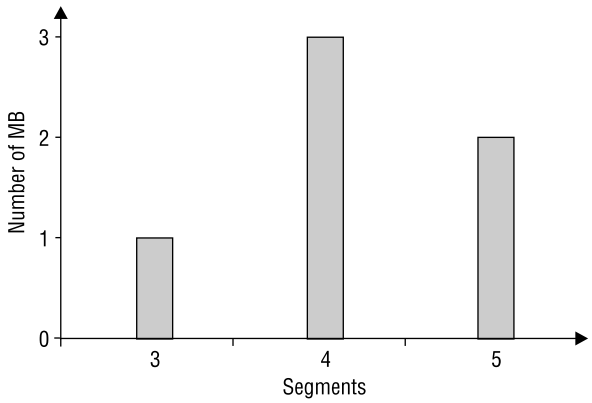

Figure 10. Number of muscular bridges with frontal edge in particular segments of the Rms.

DISCUSSION

Muscular bridges are relatively often observed during anatomical investigations [3, 4, 10, 12, 20, 28] but somewhat seldom during coronarography [2, 5, 11, 13, 14, 17, 23, 25, 27]. Morphological analyses show the highest degree of sensitivity; *in vivo* assessment is not usually so precise. Angiographic techniques enable MBs to be visualised *in vivo* but unfortunately these procedures are dependent on many indefinable factors.

The manifestation of a muscular bridge in coronarography depends on the thickness, lengths and orientation of the muscular fibres and the presence of other tissues in muscular bridge structure. The blood pressure in the artery, the pressure applied and the occurrence of atherosclerotic changes are also of importance [8, 19]. There are reports in the literature describing the camouflaging effect of advanced sclerotic processes on the presence of myocardial bridges [22]. Although the phenomenon of the MB has become an object of many investigative projects, the conclusions resulting from the observations are in agreement. The first description of an MB dates from the eighteenth century [26]. Since then repeated references to the segmentary intramuscular course of coronary arteries have appeared in literature. The frequency of MBs in anatomopathological investigation remains a matter of controversy. According to data in the literature MBs are present in approximately 5% to 86% of hearts [3]! Geringer, one of first to do so, made a precise analysis of MBs, both by macro and microscopic methods; unfortunately, however, his observations were limited exclusively to the RIA [12]. He established the presence of MBs in 23 hearts in a group of 100 (23%). Other authors analysing other the great coronary arteries have obtained varied results. Edwards et al. [9] observed them only in 15 out of 276 in the group of hearts studied (4.7%), and Ferreira et al. [10] in 50 out of 90 hearts (55.6%). Lee and Wu [20] established the presence of MBs in 58% of hearts examined in a study group of 108 and Lüdinghausen [21] in 57%. According to Polack [24], the high degree of variation is a result of insufficient precision in the anatomopathological investigations. He analysed 10 hearts precisely. In these he observed MBs over the RIA only in 6% during routine anatomopathological examination but found MBs in 60% of hearts during precise analysis. Our investigation performed on a material of 300 adult hearts resulted in the frequency of MBs being computed as 31.3%. The number of hearts examined by us is high in comparison with the numbers detailed in the literature. Our analysis was carried out on images of cross sections of arteries and perivascular spaces obtained by cutting every 2.5 mm. The small distance between cuts and the use of magnifying glasses would seem to guarantee sufficient precision in the detection of MBs. The research performed by Ishi [15, 16] and Lee and Wu [20] involved cuts at every 5 mm. Injecting gel into the coronary arteries does not ensure a higher degree of precision in the investigation [4].

The results of a comparison of our recent observation with our earlier report [18] proved somewhat surprising. In this study we detected fewer muscle bridges over the RIA than in our previous paper, but the frequency of appearance of these structures over the Rd, Rip, Rms and Rmd was similar. With reference to the RIA, we obtained similar data to that resulting from Geringer's analysis [12]. As we used an almost identical procedure to that previously adopted, we see the make-up of the group studied as the reason for the difference in the results. Despite our efforts we did not always have full information about the causes of death of persons whose hearts were included in the study. It is probable that a higher percentage of muscle bridges would have appeared in a group of hearts taken from persons who had died for cardiological reasons. This, along with other factors, may have led to such highly divergent results [3]. The large number of hearts studied has brought other details to our notice. We have detected up to 3 myocardial bridges in one heart, and noticed a muscular bridge over the RCX.

In the light of previous studies, MBs are most often associated with the RIA, mainly the central part of this [3, 4, 10]. These results are consistent with our observation. The searching for the nature of this coexistence should probably focus on analysis of the processes connected with the development of the coronary vessels during foetal life. The formation of a superficial arterial system begins between 5 and 6 weeks after fertilisation and before the development of the myocardium has been completed [1]. It is likely that the coincidence of these processes is a prerequisite for a MB arising [12]. The earlier development of the artery leads to a greater probability of some fibres of the myocardium forming a MB over it. Initially arteries occur in grooves along the places with a maximum concentration of connective tissue. The RIA stands apart as the first [1] and MBs are observed most frequently over this artery.

Data in the literature concerning the occurrence of MBs over other coronary arteries are not consistent. Chen et al. **[???]** and Zapędowski [30] specify the left marginal branch as being the second most frequent over which an MB occurs, while Polacek et al. [24] cite the right coronary artery. Baptista and DiDio, Chen et al. and Edwards et al did not demonstrate the presence of a MB over the circumflex branch of the left coronary artery (RCX) [4, 9]. In the group of hearts examined by us, we were able to demonstrate the presence of MBs not only over the RIA but also over the Rd and Rip and more seldom over the Rmd and RCX. Although Geringer did not observe double and triple MBs [12], the analyses of the majority of investigators and our own observation confirms that these can potentially occur (over one or more coronary arteries). Ferreira et al ascertained the existence of triple MBs related to different arteries in 5 hearts [9] and Baptista and DiDio found double MBs in 6 hearts, but related only to the RIA [4]. Voelker et al observed 3 MBs in one heart over the RIA, Rd and Rms during angiography [29]. Unfortunately, we have found no detailed data in the available literature about the configuration of MBs over particular arteries. We did not find MBs over coronary veins; data from some literature, however, describes this phenomenon [3]. Nor did we find a rare variant previously described by Geringer, the division of the RIA into 2 arteries of similar size, the first being covered by an MB [12]. This case would provide a very good model for the examination of the influence of a MB on the dynamics of atherosclerosis.

The question of MBs is remains an open one. There is discussion about whether MBs should be classified as pathological or a variant of the norm. Their presence is innate. Investigations of the hearts of foetuses have shown that MBs occurred in the prenatal period of life and may coexist with some developmental anomalies.

The occurrence of important clinical events as a consequence of MBs is inducing investigators to conduct research on the ultrastructural level. Detailed morphological analysis of myocardial bridges will be the subject of our future reports.

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