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Original article

Myocardial bridges in domestic pig – morphological aspects

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Abstract

The morphology of myocardial bridges (MB) in the heart of the domestic pig remain an open issue. Despite numerous analyses of the subject, many controversies still exist. Opinions also differ when the influence of the MB on haemodynamic processes in the coronal vessel system is concerned. In the examined group of 150 domestic pig's hearts, the length of the detected MB varied from 1.8 to 39.7 mm while their thickness amounted to 0.8 – 4.7 mm. Both the longest and the thickest bridges were connected with the posterior interventricular branch. It was noticed that the MB muscle bands cross the long axis of the vessels located in the grooves mostly at almost a right angle. Three forms of perivascular space were educed using the criterion of the distance of the vessel from the surrounding muscularis externa.

Key words: myocardial bridge, pig, heart, ischemia

Introduction

Myocardial bridges (MB) are structures formed of heart muscular tissue and located over coronary vessels – arteries and veins. The origin of myocardial bridges remains uncertain and substantial discrepancies accompany the valuation of their morphological parameters (Angelini et al. 1983). Research results prove that the structures profoundly influence the run of haemodynamic processes in the coronary system. The majority of authors agree that myocardial bridges may induce ischaemia in the muscularis externa located distally from the MB through compression of blood vessels during myocardial contraction (Polacek 1961, Calcagno et al. 1994, Konduracka et al. 1997). Another concept suggests that the presence of MB significantly modifies the run of arteriosclerotic processes within the bridging vessel (Winter et al. 1998). It seems that the dynamics of these phenomena remain closely connection with the distribution and morphological diversification of myocardial bridges.

Although there are relatively many case studies on myocardial bridges in human hearts, analyses of the subject based on animal material are not that numerous. Myocardial bridges were mostly studied in the hearts of primates and dogs (Zechmeister 1965, Teofilovski-Parapid et al. 1994). The analyses were developed both in the phylogenetic aspect and also with the aim of using them in veterinary provision.

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The present study constitutes another part in a series of articles devoted to the issue of myocardial bridges. Previous studies concentrated above all on the abundance and distribution of MB in the domestic pig's heart (Kosiński et al. 2010), while the present analysis concerns issues connected with the morphological diversity of these structures.

Materials and Methods

The research was carried out on 150 domestic pig's hearts (*Sus* (*Sus*) *scrofa domestica* (Linnaeus 1758)) (Artiodactyla, Suidae), cross-breeds of Polish Landrace and Pietrain. The material, preserved in a mixture of formalin and ethanol solution, comprised of 88 male hearts and 62 female hearts. The hearts were aged between 6-9 months (due to incomplete data, detailed distinction according to age was not made). In the study organs with no macroscopic developmental anomalies were used.

The following arteries were analysed: right coronary artery (ACD), left coronary artery (ACS) and their main branches – right marginal branch (Rmd), posterior interventricular branch of the right coronary artery (Rip), anterior interventricular branch of the left coronary artery (RIA), left circumflex artery (RCX) and diagonal arteries (Rd).

Each of the examined arteries was divided into 5-milimeter segments starting from the branching of the aortic bulb to the level at which its external diameter was 1 mm. The incisions were made perpendicularly to the long axis of the artery, through the middle of each segment and on their adjacencies. In cases where MB was observed, apart from the standard cuts, additional incisions were made at every 1-2 mm. Thanks to this procedure, the starting and ending points of MB could be precisely determined. With the use of a set of magnifying glasses of variable zoom (2 – 8x) the image of the cross sections of the artery and adjacent structures was analyzed. The frequency of MB occurrence and its localization were evaluated previously (Kosiński et al. 2010). The measurements of the MB length and thickness were taken with the use of a micrometer screw and a caliper (the results were rounded to 0.1 mm). The thickness – depending on the length of the bridge – was measured every 1 – 3 mm. Images of the MB cross-sections were analyzed. Its continuity was studied as well as the architecture of the perivascular space located below. The MB were dissected to study their morphology and the direction of the muscle bands run. A selected part of the material was evaluated with the use of statistical methods.

Results

Measurement values of MB length varied widely, from 1.8 to 39.7 mm. Shorter structures not exceeding 20 mm were observed more frequently. It was noted that, the longest bridges were located above Rip (average length of 22.6 mm), and that was where they were usually observed. The shortest MB of 1.9 mm was also noted above the same vessel (Table 1, Figs. 1, 2). The evaluation of the thickness of myocardial bridges has indicated a range of values from 0.8 to 4.7 mm. Structures of 1 – 4 mm thickness were predominant. Both the thickest and the thinnest MB remained around the area of Rip (Figs. 3, 4). Detailed information is presented in Table 2.

Table 1. Length of myocardial bridges.

Vessel	Length (mm)		Average length (mm)
Rip	1.8 – 39.7	1.8-39.7 ♂ 2.1-32.9 ♀	22.6
RIA	3.9 – 29.3	3.9-29.3 ♂ 4.2-18.8 ♀	16.6
Rd	4.1 – 19.1	5.6-19.1 ♂ 4.1-16.1 ♀	12.1
RCX	3.1 – 9.5	3.1-9.5 ♂ 3.4 ♀	5.3
Rmd	6.2 – 9.0 ♂		7.6

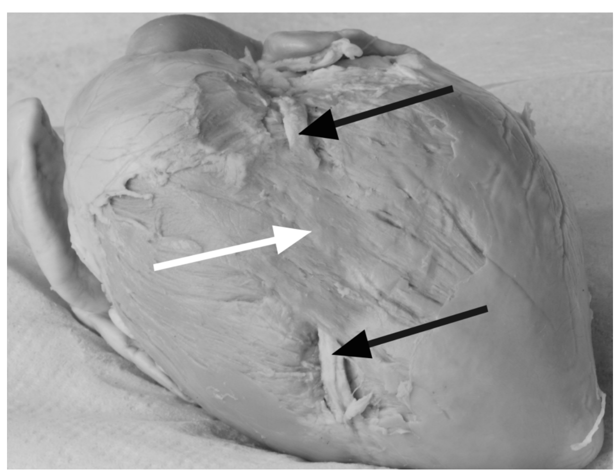

Fig. 1. Longer myocardial bridge (white arrow) above the anterior interventricular branch (black arrows), ♂.

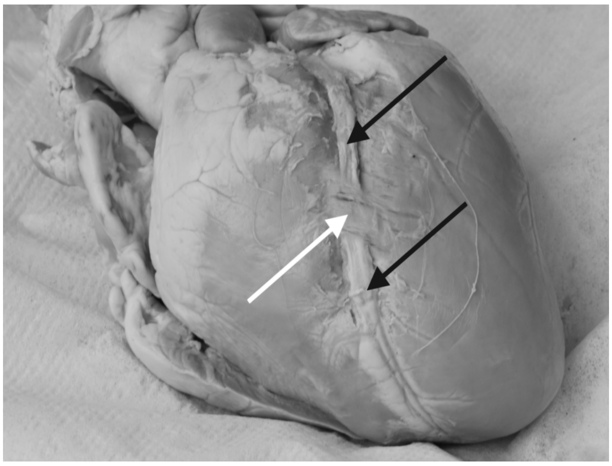

Fig. 2. Shorter myocardial bridge (white arrow) above the anterior interventricular branch (black arrows), ♂.

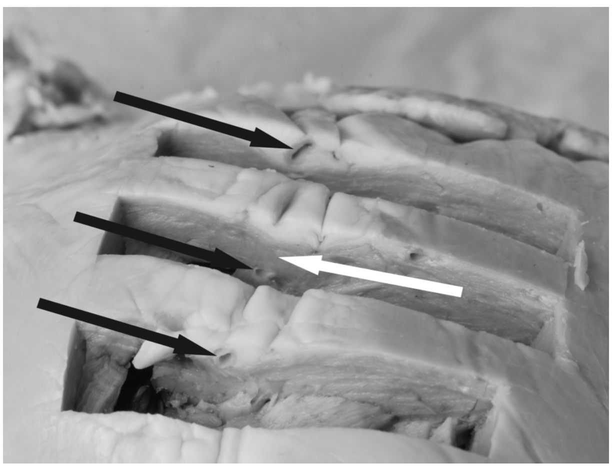

Fig. 3. Thicker myocardial bridge (white arrow) above the posterior interventricular branch (black arrows); compact form of perivascular space, ♂.

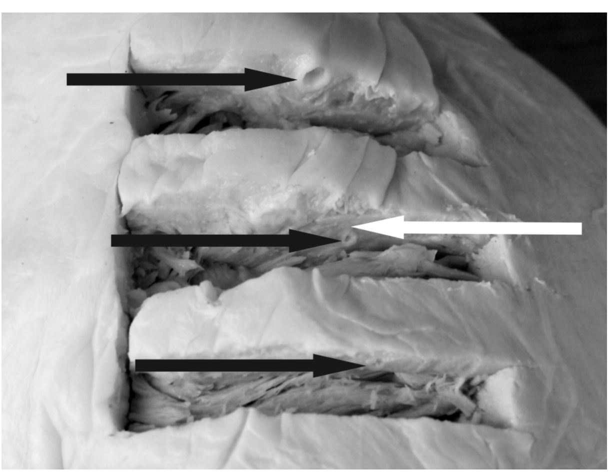

Fig. 4. Thinner myocardial bridge (white arrow) above the anterior interventricular branch (black arrows); intermediate form of perivascular space, ♀.

Table 2. Thickness of myocardial bridges.

Vessel	Thickness (mm)		Average thickness (mm)
Rip	0.8 – 4.7	0.8-4.7 ♂ 1.7-3.1 ♀	3.0
RIA	1.6 – 3.5	1.6-3.5 ♂ 1.6-2.9 ♀	2.1
Rd	1.0 – 3.1	1.8-3.1 ♂ 1.0-2.2 ♀	1.8
RCX	1.2 – 1.8	1.2-1.8 ♂ 1.4 ♀	1.4
Rmd	2.1 – 2.3 ♂		2.2

Due to significant diversity of the perivascular architecture below the bridge, three different forms were defined: loose, intermediate and compact (Fig. 5). The distance between the artery and surrounding muscularis externa was used as the criterion for classification. If the distance was bigger than the outer diameter of the vessel in at least two directions differing by ≥90°, it was classified as the loose type (Fig. 6).

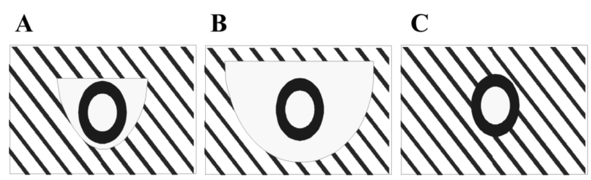

Fig. 5. Three different forms of perivascular space: A – intermediate, B – loose, C – compact.

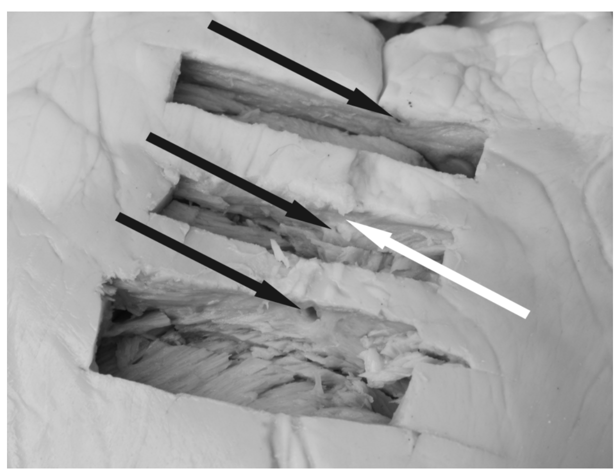

Fig. 6. Myocardial bridge (white arrow) above the posterior interventricular branch (black arrows); loose form of perivascular space, ♀.

The compact form was characterized by almost direct contact of the muscularis externa with the artery on its whole circumference, with a trace proportion of fatty tissue (Fig. 3). All other structures were classified as intermediate ones (Fig. 4). These were observed most frequently (37 MB), and were connected mainly with Rip (17 MB), and in fewer cases with the remaining vessels: RIA (11 MB), Rd (5 MB), Rmd and RCX (2 MB each). Less frequent, the compact form (26 MB), referred to the bridges located over Rip (14 MB), RIA (10 MB) and RCX (2 MB), whereas the least common, the loose form (18 MB), occurred in connection with RIA (9 MB), Rip (6 MB) and Rd (3 MB). The perivascular space contained mostly fatty tissue for all types of the structures.

Studies with the use of dissection techniques allowed the direction of the MB muscle band run to be evaluated. Due to the rather organized system of muscle tissue, it was possible to determine the angle at which its fibers cross the long axis of the vessel. A right or almost right angle (80º – 90º) was noticed mainly over Rip, RIA and RCX. For the remaining vessels mostly acute angles were observed (Table 3).

Table 3. Number of myocardial bridges crossing given vessel at a given angle.

	90º	80º	70º	60º	50º	40º	30º	20º
Rip	13	16	6	2	–	–	–	–
RIA	9	12	3	3	–	2	1	–
Rd	–	1	–	–	2	–	4	1
RCX	–	3	1	–	–	–	–	–
Rmd	–	–	–	–	–	1	1	–

During examination an interesting phenomenon was observed: in two cases (1Rd and 1Rmd) vessels which ran epicardially for a very short distance, penetrated deeply into the muscularis of the ventricles and did not appear again on its surface. Segments of vessels located intramusculary were found at a depth of 1 to 4 mm.

Discussion

This study constitutes a continuation of a series concerning the issue of myocardial bridges in the domestic pig heart. In the analysis the morphological parameters of the examined structures were examined as well as the architecture of the perivascular space below the bridge.

Myocardial bridges in humans were first described in the literature relatively early – in the 18th century Reyman observed segmental coating of the left coronary artery by a layer of muscle fibres (Reyman 1737). Since then the occurrence of these structures has been noticed more frequently; however, the reports remained imprecise. Geiringer's compilation from 1951 was a breakthrough in the quality of studies on myocardial bridges (Geiringer 1951). The study was very detailed and included a morphological classification of myocardial bridges as well as an analysis of the probable pathological implications of their presence. The first description of a bridge *in vivo* was presented by Porstmann and Iwig in 1960 (Porstmann and Iwig 1960). The dynamic development of diagnostic procedures enabled the bridges to be detected with the use of other techniques. Intravascular ultrasonography is exceptionally useful, since – apart from evaluation of morphological parameters – it also allows haemodynamic phenomena in the bridged vessel to be interpreted. Electrocardiographic, biochemical and radioisotopic examinations are less popular methods (Angelini et al. 1983).

Analyses on animal material are not that numerous. Early studies by Schubert are rather cursory (Schubert 1909). Relatively voluminous studies were presented by Polacek and Zechmeister in 1968 (Polacek and Zechmeister 1968). Research carried out on myocardial bridges in dog hearts were used for evaluating haemodynamic phenomena in arteries (Tangkawattana et al. 1997).

The wide range of measurements both in length and thickness of myocardial bridges in the material examined in the present study, is worth attention. Comments available in the limited literature on the subject confirm the observation. Both the shortest and the longest structures were found above Rip. Likewise, the thinnest and thickest bridges were also observed above the vessel. Here, their average length and thickness were the greatest. Bridges of the shortest average length and thickness were connected with RCX. In Berg's research of pig hearts, detected MB were shorter (3 – 19 mm) and slightly thinner (0.3 – 3 mm) (Berg 1965). Berg's analysis, however, was limited to one coronary artery. According to Aleksandrowicz, the range of lengths and thicknesses of bridges in pig hearts varies widely from: 1.4 – 52.7 mm and 0.1 – 2.6 mm respectively (Aleksandrowicz et al. 1993). The material in Aleksandrowicz's study consisted of 30 hearts. Discrepances in the results obtained may result from the examination technique (latex injection into the vessels), their range (limiting the observation to selected vessels) and the abundance of the material. Methods used in our analysis as well as an appropriate quantity in the test group guarantee an appropriate level of precision.

In the available literature we found no study concerning the orientation of myocardial bridges in the domestic pig heart. Results obtained in our study are concurrent with those shown in the work of Babtista and DiDio conducted on human heart material (Baptista and DiDio 1992). In their research, the angle of intersection of the long axis of the vessel through the fibers of the bridge ranged between 1 to 90 degrees.

In most cases, a perpendicular orientation of the MB was observed over the vessels located in grooves (RIA, Rip and RCX).

Studies on the organization of the perivascular space below the bridge allowed three forms to be distinguished: compact, intermediate and loose. The distance between the artery and the surrounding muscularis externa was used as the criterion for classification. In the available literature we found no such analyses concerning pigs hearts. There exist, however, a few descriptions of the issue in reference to human, dog, goat and sheep hearts. In studies by Ozbag and Kervancioglu the distance between the MB tissue and the bridged vessel was measured, as well as between the vessel and the myocardium located below (Ozbag and Kervancioglu 2004). Results obtained referring to the vertical orientation proved to be very accurate and determined the location of the artery in the perivascular space on the basis of one direction. Taking into account the mechanics of the myocardial bridge influence, the two-dimensional analysis of the relations in this area is especially valuable. The literature provides many examples of the clinical implications of myocardial bridges in humans. The structures often substantially modify the run of haemodynamic processes in the blood vessel. Unfortunately, the most evident results of this influence are incidents of ischemic character. There are numerous descriptions of cardiac arrhythmias, infarctions or sudden cardiac death in patients in whom the only possible cause of death must have been the bridge (Bestetti et al. 1991, Konduracka 1994, Bashour et al. 1997). It seems that the phenomena are qualified by a coincidence of various processes. It is known that the flow of blood in coronary arteries takes place during the diastole. Although the bridge evokes a compression during the systole, the compression usually lasts until the protodiastolic phase. The flow of blood filling the vessel is severely impeded at the coarctation and thus a ischemia may occur in the area of muscularis externa located distally to the bridge. During fast cardiac rhythms the delay of MB relaxation stretches even more onto the shortening phase of diastole, which increases the deficiency of blood supply. This mechanism is the most common cause of infarction and sudden cardiac death, also in young patients in whom other pathologies were not diagnosed. Bestetti et al. presented a case of the death of a 38-year-old-man during exertion – except for a large bridge and pulmonary edema the post-mortem did not reveal any other anomalies (Bestetti et al. 1991). On the other hand, the compression of a blood vessel causes a damage to its *intima*, which further leads to the initiation of arteriosclerotic lesions and an endemic decline in the production of the endothelial-derived relaxing factor EDRF (Kuhn et al. 1991). These phenomena result in artery occlusion (Winter et al. 1998). Since there are anatomical resemblances between the human and pig heart and a comparable model of coronary blood distribution, one should suspect that these processes run similarly (Sahni et al. 2008).

The intensity and dynamics of the described processes are qualified by the morphological profile of the bridge and the perivascular space. Many authors highlight the immediate relation between the distribution of muscle fibers, the thickness of the bridge and the effect it evokes (Angelini et al. 1983, Ferreira et al. 1991). Longer and thicker structures will generate greater compression. Moreover, the relation of haemodynamic consequences and the orientation of MB muscle fibers is also very probable. One should suspect that their perpendicular run causes a higher level of compression. The organization of the perivascular space seems to play a role too. The three observed forms differ one from another in the distance of the bridge muscle to the wall of the artery and the content of fat tissue. It is likely that together with the increase in these parameters the phenomenon of buffering the compression of the vessel becomes more evident (Angelini et al. 1983). Consequently, the presence of even a massive MB co-existing with loose architecture of the perivascular space will not necessarily manifest itself haemodynamically. One may predict a reverse relation: a very small bridge in coincidence with compact form will become evident in more cases.

The problem of myocardial bridges remains an open issue. A natural development of our studies is a planned microscopic evaluation of these structures in the domestic pig heart.

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