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Characterisation of myocardial bridges in pigs: a comparative anatomical analysis with the human heart

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Background: *Few studies have been conducted in pigs concerning the presence of myocardial bridges (MB) on the coronary arteries and their branches, and some of them have evaluated small samples. The objective of this study was to characterise MB in pigs of commercial breeds.*

Materials and methods: *One hundred and fifty eight hearts of pigs destined to the slaughterhouse with stunning method were studied. The coronary arteries were perfused with polyester resin (palatal 85% and styrene 15%) and then subjected to potassium hydroxide infusion to remove the subepicardial fat.*

Results: *Ninety three MB were found in 67 (42.4%) specimens, 43 (46%) of which were located on branches of the right coronary artery, 38 (41%) on branches of the left coronary artery and 12 (13%) on both vessels. The MB occurred in 26 (38.8%) females and 41 (61.2%) males, but the difference was not statistically significant (p = 0.23). Single MB were most common (70%), followed by the presence of 2 (21%) MB in different vessels. the subsinusal interventricular artery was the vascular structure with the largest number of MB (46.2%), with its middle third being the most compromised segment (79%). The mean length of the MB was 11.23 ± 5.67 mm and the thickness of the suprapontine myocardium was 1.13 ± 0.48 mm.*

Conclusions: *The frequency, localisation, and length of the MB reported in pigs are consistent with the findings of the present study, whereas in humans the MB involve mainly the anterior interventricular artery and are longer.* (Folia Morphol 2015; 74, 1: 50–55)

Key words: coronary arteries, ischaemia, myocardial bridges, pig

INTRODUCTION

The right coronary artery (RCA) emerges from the homonym aortic sinus and irrigates both the right atrium and ventricle. The RCA is divided into 3 segments of which the 2 main branches emerge: left retroventricular artery and subsinusal interventricular artery (SIA) (Fig. 1). The left coronary artery (LCA) in pigs is the main vessel that provides irrigation to the heart. The LCA irrigates most of the left ventricle and atrium, including the interventricular septum. It emerges from the left aortic sinus, runs to the left behind of the pulmonary trunk, and ends up by bifurcating into the paraconal interventricular artery (PIA) and the circumflex artery (Fig. 2) [15, 17, 31].

Myocardial bridges (MB) are superficial muscular bands that cover a short segment the subepicardial

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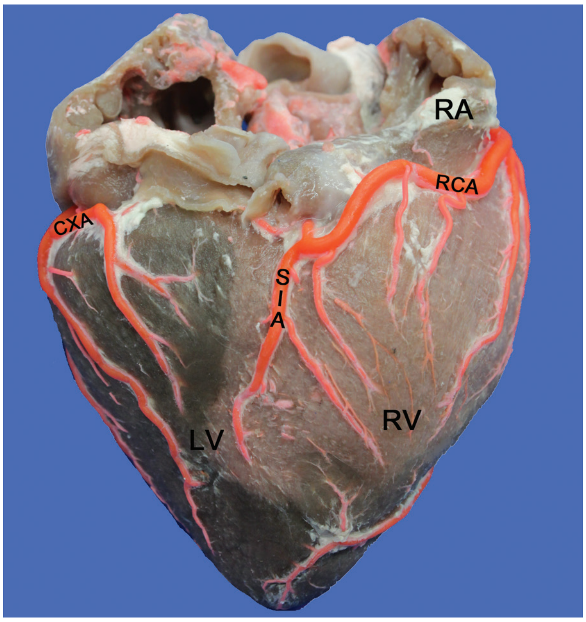

Figure 1. Right surface of the heart; SIA — subsinusal interventricular artery; RCA — right coronary artery; CXA — circumflex artery; RV — right ventricle; RA — right atrium; LV — left ventricle.

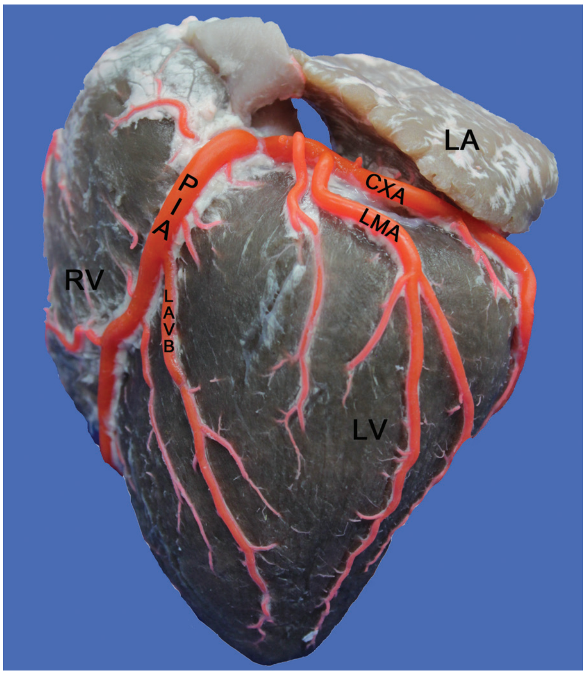

Figure 2. Obtuse edge of the heart; PIA — paraconal interventricular artery; CXA — circumflex artery; LAVB — first left anterior ventricular branch; LMA — left marginal artery; LA — left atrium; LV — left ventricle. RV — right ventricle.

course of the coronary arteries (CA) and their branches [7, 21, 22, 32]. MB can induce ischaemia in the areas localised distally to them, due to compression of the blood vessels during the systolic phase of the cardiac cycle, although only a long bridge may have a noticeable impact on the circulation [1, 9, 21, 22, 25, 32].

Studies of MB have been conducted in animals using classical dissection techniques, especially in primates and dogs and in a lower number in pigs. The presence of a single MB is the most common occurrence, followed of 2 or more bridges on different vessels. The presence of 2 MB in the same vessel is a rare occurrence [21]. The frequency of these muscle bands in pigs is 24–86% [1, 5, 21], whereas in humans they have been reported with a frequency of 23–88%, a variability that could be attributed to the diverse techniques utilized for their evaluation or to an ethnic feature of the population groups studied [2, 7, 8, 12, 24, 27, 28, 31, 33].

Concerning the site of occurrence, in pigs MB have been described especially in the middle third of the SIA [21], whereas in humans they are described more often at the level of the medium and upper thirds of the anterior interventricular artery (AIA) [3, 24, 27, 30, 31].

A high percentage of MB are asymptomatic, but their morphologic features such as length, depth, and location on one or several arterial branches, in addition to some other variables, may result in the occurrence of diverse ischaemic or arrhythmic conditions of the heart that could become the cause of sudden deaths observed among pigs [11, 14, 30].

The sparse information on MB in pigs added to the fact that the heart of this species is used for haemodynamic studies, gives relevance to the conduction of the present study developed in fresh cadaveric material with the purpose to establish a differential evaluation of this morphologic variation between the hearts of humans and pigs.

MATERIALS AND METHODS

This descriptive cross-section study assessed the presence of MB in 158 hearts of pigs of commercial breeds destined to the slaughterhouse with stunning method, with a mean age of 5 months, obtained from Frigorífico Vijagual of Bucaramanga, Colombia. The organs were subjected to an exsanguination process in a water source for 6 h. Upon repair with silk at their origin, the CA of the hearts studied were channelled through their ostium and perfused with polyester resin (palatal GP41L 80% and styrene 20%)

Table 1. Distribution of myocardial bridges (MB) in different branches of coronary arteries

Blood vessel	No. of hearts	No. of MB	Per cent
Subsinusal interventricular artery	41	43	46.2
Left ventricular branches	10	12	12.9
Left marginal branch	11	11	11.8
Left diagonal artery	8	9	9.7
First left anterior ventricular branch	8	9	9.7
Paraconal interventricular artery	6	6	6.4
Circumflex artery	1	1	1.1
Right ventricular branches	1	1	1.1
Left retroventricular branch	1	1	1.1

Table 2. Location of myocardial bridges on the subsinusal interventricular artery (SIA) and paraconal interventricular artery (PIA)

	SIA		PIA	
	Sample	Per cent	Sample	Per cent
Upper third	1	2	1	17
Middle third	34	79	1	17
Lower third	5	12	4	66
Middle and lower third	3	7		
Total	43	100	6	100

impregnated with mineral red. Then the hearts were subjected to a partial corrosion process with 15% potassium hydroxide (KOH) to remove the subepicardial fat located inside the interventricular and atrioventricular sulci. The presence of MB was assessed along with the level of their location on each one of the CA and their branches, both in males and females. MB were classified as type I if a single MB was found in the heart, type II for 2 MB on the same vessel, and type III for 2 or 3 MB on different vessels [21]. Similarly, the myocardial band was resected with a scalpel to determine its length and thickness with a digital calliper (Mitutoyo®).

Statistical analysis

The data were recorded both in a physical matrix and in a digital medium using an Excel table. All pieces were photographed to support the observations reported. Continuous variables were analysed using a t test, whereas the discrete variables were analysed using Pearson's χ^2 test and the Fisher's exact test. The results were evaluated using the statistics "Epi – Info 3.5.4" program. The significance level used for this research was ($p < 0.05$).

RESULTS

The 158 hearts evaluated had an average weight of 360 ± 61.21 g, obtained from pigs of 90 kg body weight. The presence of MB was found in 67 (42.4%) specimens, in 43 (46%) of which this morphologic expression was located on branches of the RCA, in 38 (41%) on branches of the LCA, and in 12 (13%) cases MB occurred simultaneously on both arteries. Similarly, MB occurred in 26 (38.8%) females and in 41 (61.2%) males, but this difference was not statistically significant ($p = 0.23$).

Were found 93 MB in the samples evaluated, with the vascular structure most frequently affected being the SIA with 43 MB in 41 hearts (46.2%). This anatomic feature was similarly observed in some other branches of the CA (Table 1).

Of the MB cases occurring in the SIA, the most frequently compromised segment of this vessel was its middle third (34 cases; 79%), unlike the MB observed in the PIA, which were mostly located in its lower third (4 cases; 66%) (Table 2). The mean length of the MB was 11.23 ± 5.67 mm, with this dimension being slightly smaller in the branches of the RCA (10.73 ± 5.19 mm) as compared with the branches

Table 3. Length and thickness of myocardial bridges in different branches of the coronary arteries

Blood vessel	Range [mm]	Mean length [mm]	Mean thickness [mm]
Subsinusal interventricular artery	3.06–6.45	10.68	1.13
Paraconal interventricular artery	5.14–21.32	11.75	1.37
Left diagonal artery	7.78–14.27	10.98	1.03
Left marginal branch	6.19–22.8	12.53	1.38
Left anterior ventricular branch	4.03–23.84	13.11	1.19
Left ventricular branches	3.22–16.16	10.80	0.71

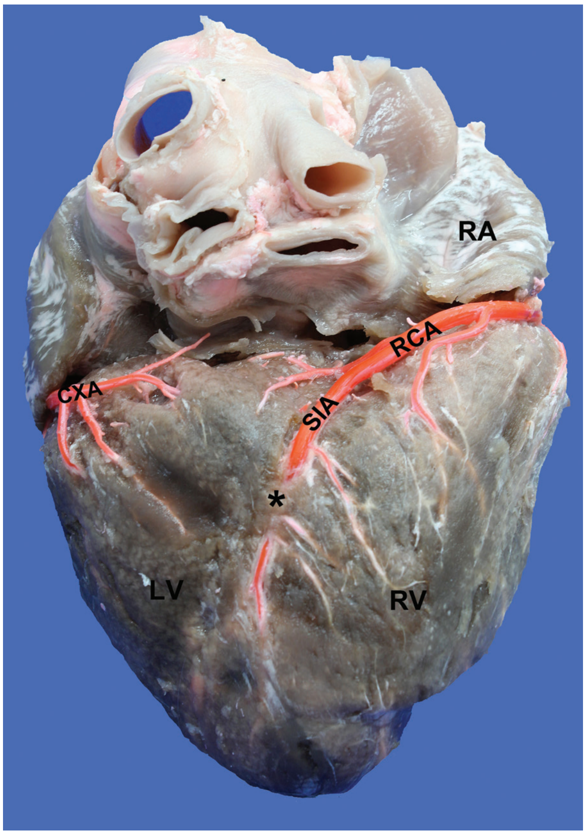

Figure 3. Right surface of the heart; SIA — subsinusal interventricular artery with one myocardial bridge (*); RCA — right coronary artery; CXA — circumflex artery; RV — right ventricle RA — right atrium. LV — left ventricle.

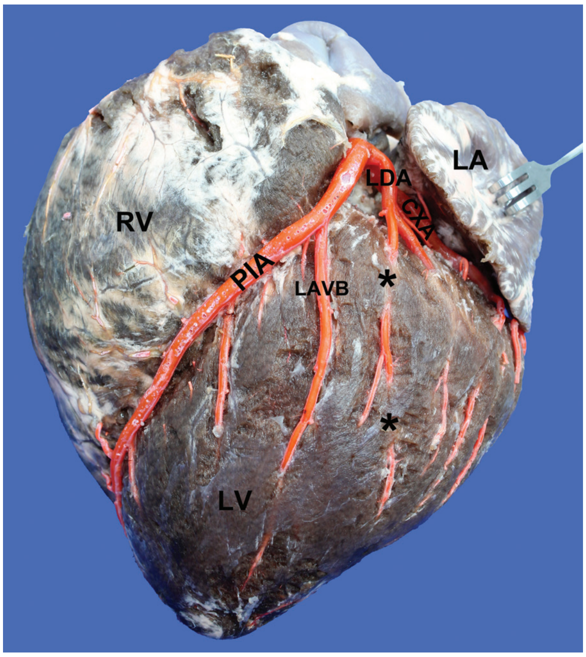

Figure 4. Obtuse edge of the heart; LDA — left diagonal artery with two myocardial bridges (*); PIA — paraconal interventricular artery; CXA — circumflex artery; LAVB — first left anterior ventricular branch; LA — left atrium; LV — left ventricle; RV — right ventricle.

of the LCA (11.69 ± 6.09 mm). The thickness of the suprapontine myocardial band was 1.13 ± 0.48 mm, similar in the different branches of the CA (Table 3).

Forty seven types I MB (50.5%) were found (Fig. 3); 12 type II MB in 6 (13%) samples (Fig. 4) and 34 (36.5%) type III MB (Fig. 5).

DISCUSSION

Few studies have been conducted on the presence and clinical implications of MB in pigs. The findings of MB in the present study (42.4%) are located in the middle of the 24–86% range reported in prior studies for this morphologic expression [1, 5, 21]. The frequency of MB in humans, as with pigs, has been reported along a wide range of 23–88% [2, 7, 8, 12, 24, 27, 28, 31, 33].

MB in pigs have been found more frequently in the middle third of the SIA (36–45%), a finding consistent with the observations of this study [1, 21]. In contrast, the vessel more frequently affected by MB in humans is the AIA at the level of its proximal and middle segments within a range of 12–60% [2, 8, 10, 13, 26, 27, 28].

The length of the MB in pigs has been reported in a wide range of 1.4–52.7 mm, with suprapontine bands

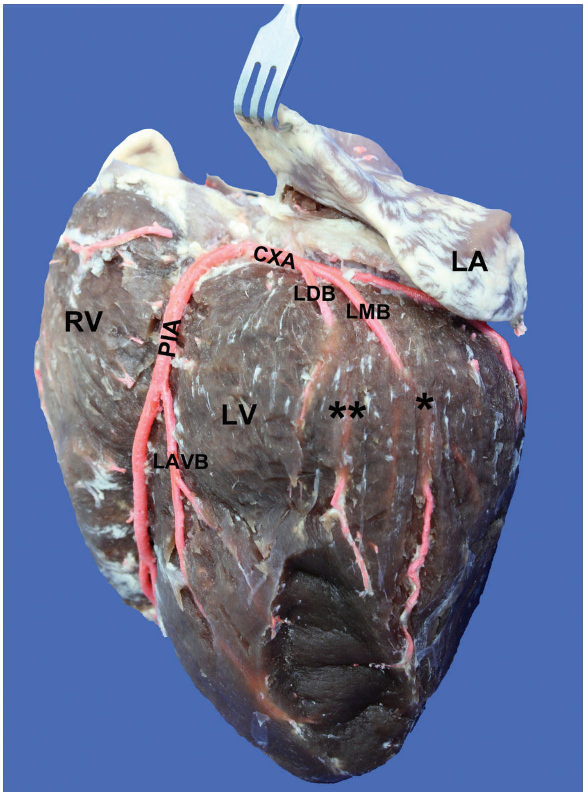

Figure 5. Obtuse edge of the heart; LDB — left diagonal branch with one myocardial branch (**) and LMB — left marginal branch with one myocardial bridge (*); CXA — circumflex artery; PIA — paraconal interventricular artery; LAVB — first left anterior ventricular branch; LA — left atrium; LV — left ventricle; RV — right ventricle.

not exceeding 20 mm being found more frequently [1, 22], similar to what was observed in our study, which found that only 8.6% exceeded this length. MB found in human hearts have been reported to be longer than those found in pigs, between a few millimetres and 50 mm, with an average range of 18–25 mm [2, 16, 23, 24, 28, 29]. Reports on the thickness of MB in pigs have not included means, but ranges (0.8–4.7 mm) [1, 22], thus making difficult to qualify our finding (1.13 mm) as similar or dissimilar to the findings of the studies described. Upon comparison of the thickness of the MB in humans, the majority of the studies reveal mean thicknesses in the range of 1.2–2.5 mm [16, 20, 24, 28, 30]. Several reports confirm the influence of MB in the aetiology and pathogeny of ischaemic episodes of the heart [4, 19, 22]. However, it is important to indicate that the majority of MB are asymptomatic because due to their length and thickness they are not able to create a sufficient compression of the involved vessels, and also compensation mechanisms could occur, such as the occurrence of collateral branches that emerge in the prepontine segment and contribute to the irrigation of adjacent territories. Similarly, when added to the relatively adverse anatomic substrate, factors such as the atheromatosis could trigger clinical events such as angina, arrhythmias, myocardial infarction or even sudden death before stressful and exertion situations [6, 11, 14, 18, 30]. Likewise, if atheromatous factors are added to the presence of MB of considerable length and depth, the resultant decreased lumen could trigger clinical events such as angina, arrhythmias, myocardial infarction or even sudden death, that are evident under stressful and exertion situations [6, 11, 14, 18, 30].

The frequency of single MB observed in the present study (50.5%), is considerably lower to what has been reported by Kosiński et al. [21] (85.9%), whereas the incidence of multiple MB affecting several vessels was significantly higher (36.5%) to what had been indicated in the above study (5.6%). Kosiński et al. [21] reported that the frequency of 2 MB in a same vessel was 8.5%, whereas this trait was found in the present study in 13%. Single MB have been reported in human hearts within a range of 17–60%, and 2 or more MB in different vessels within a range of 5–40% [2, 7, 24, 28, 31]. The differences of these findings can be explained by the size of the samples and the genetic makeup determined by the variable number of crossings of commercial pigs evaluated.

CONCLUSIONS

The overall frequency of MB in the present study was located within an intermediate range as compared with the reports in the literature about pigs and humans.

Consistent with prior studies in pigs, MB were found more frequently in the middle third of the SIA, whereas in humans these myocardial bands are more frequent in the proximal and middle thirds of the AIA.

Both length and thickness of the MB in this and in prior studies in pigs are smaller than those reported in human hearts.

The knowledge of MB in pigs is useful for the design of haemodynamic procedures using this particular animal species.

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