Morphological Description and Clinical Implications of Myocardial Bridges: an Anatomical Study in Colombians

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Summary

Background: Myocardial bridges represent a hotly debated research topic. Myocardial bridges are considered to be a vascular heart variation due to its intermittent or enduring reducing of the arterial lumen, with a possible ischemic effect.

Objective: This study aimed at determining the incidence of myocardial bridges in the Colombian half-caste population.

Methods: 154 hearts were studied, having been extracted as fresh autopsy material. Coronary arteries were injected with synthetic resin and cleaned by extracting the pericardial fat.

Results: 92 myocardial bridges were observed in 62 hearts (40.3%). Average myocardial bridge length was 19.9 mm. Myocardial bridges varied per artery from one myocardial bridge in 42 hearts (27.3%), two myocardial bridges in 11 hearts (7.2%), three myocardial bridges in 8 hearts (5.2%) and four myocardial bridges in 1 heart (0.7%). Most myocardial bridges coincided with the anterior interventricular artery in its proximal and intermediate segments in 61 cases (39.6%) and left diagonal artery in 11 cases (7.2%). Arteries emitted just before myocardial bridges (pre-bridge branch) in 50 cases (54.3%) of the sample, with an average caliber of 1.41 mm. A third coronary artery was present in 46 cases (29.8%) of total sample. A higher frequency of myocardial bridges was found in hearts with a third coronary artery.

Conclusion: It is necessary to consider the clinical importance of the variations considering the arterial distribution and associated clinical implications. (Arq Bras Cardiol 2009;92(4):242-248)

Key words: Coronary vessels; myocardial bridging; chest pain; myocardial ischemia.

Introduction

Myocardial bridges (MB) represent a currently controversial research issue. MB have an embryological origin, and there are no gender differences regarding its incidence. A benign or a malignant interpretation of the presence of MB depends on contrasting physiopathological point of views; some arguments explain that MB generates atheromas but others as being atheromas prevention. Some authors consider MB as being normal intramural arteries and criticize their surgical management, implicitly considering them to be a risk factor[1]. MB were first reported in 1737 by Reyman as transitorily submerged myocardial arteries[2]. MB have also been shown in anatomical, physiological, biochemical and imagenological studies[3-7].

MB is generally considered to be a vascular heart variation due to their intermittent or enduring reducing of the arterial lumen, with a possible ischemic effect. Precordial ischemic pain needs an appropriate diagnosis because of the several pathologies associated with obstructive cardiomyopathy: atherosclerosis, thrombosis, hypertrophic cardiomyopathy, paroxystic AV block, segmental hypokinesia, cardiac arrhythmias, ventricular tachycardia, coronary spasm, myocardial acute infarct and/or sudden cardiac death.

Cardiac muscle ischemia appears to occur during the first 1/3 of diastole due to prolonged coronary artery lumen recovery following its systolic compression (75%). This alters coronary flow speed and reserves, especially during enhanced heart rhythm during exercise and emotional stress[8].

MB incidence variability depends on recording method, gender, ethnicity and the nature of the study; in this sense a minor 0.5-12% angiographies present MB but in cadavers they are present in 5.4%-85.7%[9-12]. MB generally originate in the left coronary artery (LCA) trunk and branches, especially in the anterior interventricular artery (AIA) (12%-63%), circumflex artery (CA) (2.8%-6.7%) and its lateral branch (13%). They are also found in diagonal arteries (DA), marginal arteries (MA) and coronary veins[13,14].

This research was aimed at determining MB incidence in the half-caste Colombian population and establishing

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MB frequency related to coronary dominance, vessels that emerge immediately before the MB of compromised arteries or pre-bridge branches (PBB), as well as MB correlation with the presence of a third coronary artery. Third coronary artery (originating in the right aortic sinus) irrigates the *conus arteriosus* and also supplies the upper and middle AIA's right ventricular territory, particularly when the AIA's middle third has MB[15-17].

Methods

The Institute of Forensic Medicine in Bucaramanga, Colombia, provided 154 hearts for the study; these were extracted as fresh autopsy material. The sample inclusion criteria consisted of being a half-caste adult male or female heart without pathology or signs of trauma.

Coronary arteries were injected with synthetic resin (80% Palatal GP 41L and 20% Styrene)[18] at 120 mm Hg of pressure. The hearts were cleaned with 15% KOH solution to extract the pericardial fat. MB number and position in the coronary arteries were determined taking sample gender into account.

Samples were measured with an electronic caliper (Mitutoyo) regarding MB length, MB wall thickness (measured as the maximum thickness at mid-point of the MB course), LCA trunk length, artery caliber at several course points just before, at mid-point and just after the MB.

MB incidence was also correlated with coronary dominance, according to Schlesinger dominance criteria[19]. MB and LCA trunk length correlation were also established. PBB were recorded just before MB artery involved. The correlation between the presence of MB and the third coronary artery was documented.

Means and standard deviations were calculated for continuous variables, whereas nominal variables were described in terms of percentages. Up to 5% alpha error was accepted for Chi(X2) square and Student-T statistical tests; Epiinfo 2002 was used to create the database and STATA 8.0 for performing the statistical analysis.

Results

The sample consisted of 154 hearts, being 125 of them from males (81.2%) and 29 from females (18.8%). Age ranged from 15 to 73 years (mean of 31.5 years).

MB were present in 62 hearts (40.3%), being 54 in males (43.2%) and 8 in females (27.6%). A higher frequency of MB in males was not statistically significant (p=0.122). Of a total of 92 MB, they varied per artery from one MB in 42 hearts (27.3%), two MB in 11 hearts (7.2%) (Figure 1 and Figure 2), three MB in 8 hearts (5.2%) and four MB in 1 heart (0.7%). Regarding MB location, most matched AIA proximal and intermediate segments in 61 cases (66.3% relative frequency, 39.6% absolute frequency) and left DA (Figure 3) in 11 cases (12% relative frequency, 7.2% absolute frequency) (Table 1).

Right coronary dominance was observed in 117 hearts (76%), balanced circulation in 25 (16.2%) and left coronary dominance in 12 (7.8%) hearts. Balanced irrigation presented higher MB incidence (56%), followed by MB in 39.3% with right irrigation dominance. There was no significant MB gender difference (female p=0.192, male p=0.295) (Table 2).

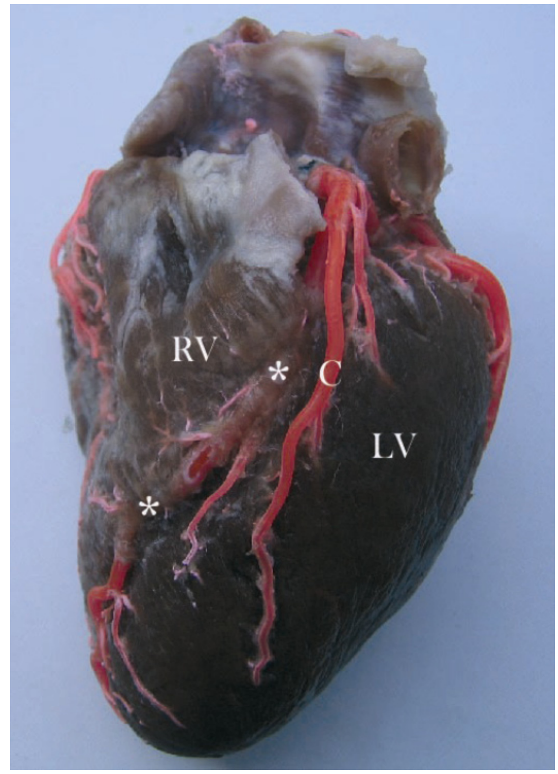

***Figure 1** - Sternocostal heart surface. Anterior interventricular artery with two myocardial bridges (*). RV - right ventricle. LV - left ventricle. C - pre-bridge branch forming left anterior ventricular artery.*

A third coronary was present in 46 cases (29.8%) of the total heart samples. A significant statistical association was found between MB and number of coronary arteries (p=0.024). The detection of three coronary arteries in hearts with MB was thus 2.34 times more common than in hearts with no MB.

Average MB length were 19.9 mm (10.83 SD), 20.09 in males (10.81 SD) and 15.2 (8.3 SD) in females. The greater length in males was not statistically significant (p=0.21). The proximal AIA and 6 intermediate segments presented the longest (52.9 mm) (Figure 4) and shortest MB (2.88 mm). MB located in the right posterior DA presented (two cases) a higher average length (33.6 mm). The only MB present in the *conus arteriosus* measured 8.9 mm (Table 3).

Arterial caliber changed during MB arterial course. Arterial caliber just before the MB was 2.17 mm (0.61 SD), 1.92 mm (0.55 SD) at mid-point and 1.67 mm (0.57 SD) just after MB. These measurements showed 23.05% that has a reduced artery lumen during passage under the MB (from pre-bridge to post-bridge course). Supra-bridge myocardium thickness was 1.54 mm (0.73 SD), ranging from 0.27-3.8 mm.

Average LCA trunk length was 6.18 mm. A significant statistical correlation (p=0.045) was found between LCA

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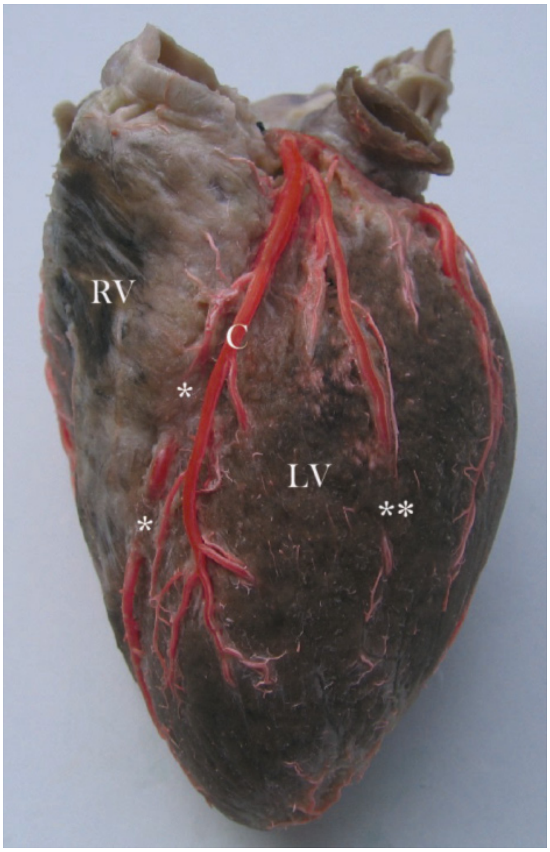

Figure 2 - Sternocostal heart surface. Anterior interventricular artery with two myocardial bridges (*). Anterior ventricular branch from the anterior interventricular artery with one myocardial bridge (**) RV - right ventricle. LV - left ventricle. C - pre-bridge branch forming left anterior ventricular artery.

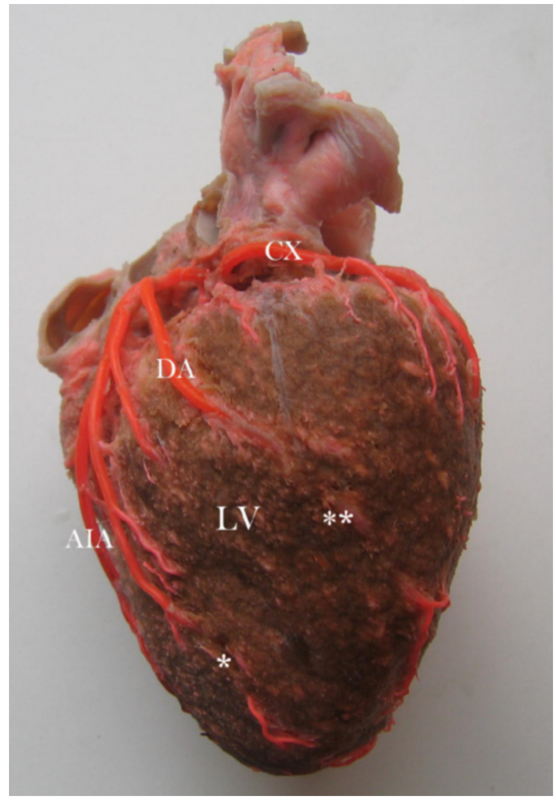

Figure 3 - Left ventricular heart surface. Diagonal artery with one myocardial bridge (**) and anterior ventricular branch from anterior interventricular artery with one myocardial bridge (*) LV - left ventricle; DA - diagonal artery; AIA - anterior interventricular artery; CX - circumflex artery.

trunk and MB length in their middle AIA portion. When LCA trunk was less than 4.37 mm (25th percentile), MB length was thus 21.49 mm and when LCA trunk was greater than or equal to 4.37 mm, MB length was 15.04 mm. Average MB length in mid-AIA portion was 14.92 mm when LCA trunk was greater than or equal to 6.81 mm (75th percentile). Such MB length were 6.56 mm greater ($p=0.059$) in LCA trunk (at 25th percentile) compared to those having 75th percentile. These data thereby suggest that the shorter the LCA trunk, the longer the corresponding MB. The multiple correlation coefficient between the LCA trunk and MB length was 0.1158.

It was observed that compromised MB vessels emitted PBB just before MB in 50 cases (54.3%), with an average caliber of 1.41 mm (0.55 SD). This characteristic was more frequent in the AIA (60.7%) (Figure 5).

Table 1 - **Myocardial bridge artery location**

Myocardial bridge artery location	n	%(£)	%(Ω)
Proximal AIA	61	66.30	39.6
Left DA	11	11.96	7.2
Left MA	8	8.70	5.2
AIA ventricular branch	6	6.52	3.9
PIA	3	3.26	1.9
RPDA	2	2.17	1.3
CALB	1	1.09	0.6
Total	92	100	59.7

AIA - anterior interventricular artery; PIA - posterior interventricular artery; DA - diagonal artery; MA - marginal artery; RPDA - right posterior diagonal artery; CALB - conus arteriosus left branch.

Discussion

A wide-range incidence of MB was observed, depending on the assessment method used; angiographic and anatomic results were therefore different. By contrast, the angiographical method returned very low prevalence. We think that this happens due to intra-myocardical course under thin supra-bridge segments cannot produce evident coronary stenosis during ventricular systole and during early diastole that are different to thick supra-bridge segments. Stenosis could only be registered during angiography during evident MB

Table 2 - MB side, gender and coronary arterial dominance

Coronary dominance	MB absent n (%)	MB present n (%)	Total n (%)
Right	71(60.7)	46(39.3)	117(76.)
Male	53(58.2)	38(41.8)	91(100)
Female	18(72)	7(28)	25(100)
Left	9(75)	3 (25)	12(7.8)
Male	7(70)	3(30)	10(100)
Female	2(100)	0(0)	2(100)
Balanced	11(44)	14(56)	25(16.2)
Male	10(43.5)	13(56.5)	23(100)
Female	1(50)	1(50)	2(100)
Total	92(59.7)	62 (40.3)	154(100)

MB - myocardial bridge.

Table 3 - MB length

Artery	MB	Average	SD	Min	Max
AIA proxim.	21	16.56	6.16	7.93	25.78
AIA interm.	26	16.53	8.17	6.83	31.5
AIA prox-interm	11	28.17	13.54	2.88	52.86
AIA distal	1	24.23		24.23	24.23
AIA ventr. branch	6	16.17	8.30	6.7	30.41
PIA	3	14.57	1.19	13.35	15.74
DA	10	29.71	14.55	8.9	51.34
RPDA	2	33.56	8.28	27.7	39.41
Left MA	7	16.01	10.10	9.16	37.96
CALB	1	8.91		8.91	8.91

MB - myocardial bridge; AIA - anterior interventricular artery; PIA - posterior interventricular artery; DA - diagonal artery; MA - marginal artery; RPDA - right posterior diagonal artery; CALB - conus arteriosus left branch.

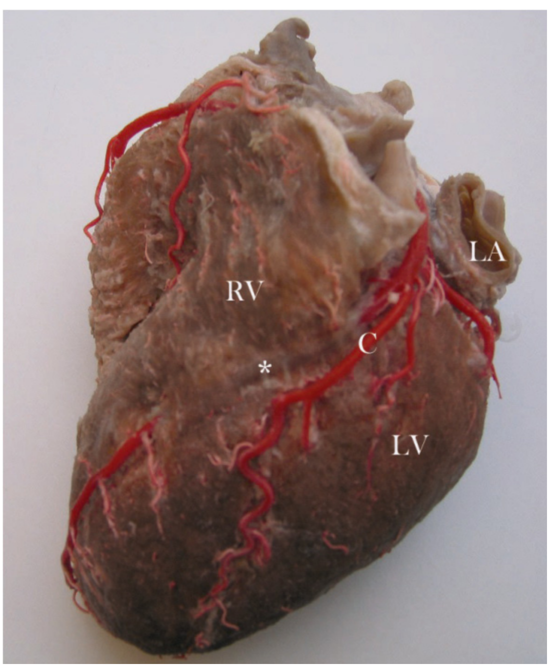

Figure 4 - Sternocostal heart surface. Anterior interventricular artery with the longest myocardial bridge (*). RV - right ventricle; LV - left ventricle; C - pre-bridge branch forming left anterior ventricular artery; LA - sectioned left auricle.

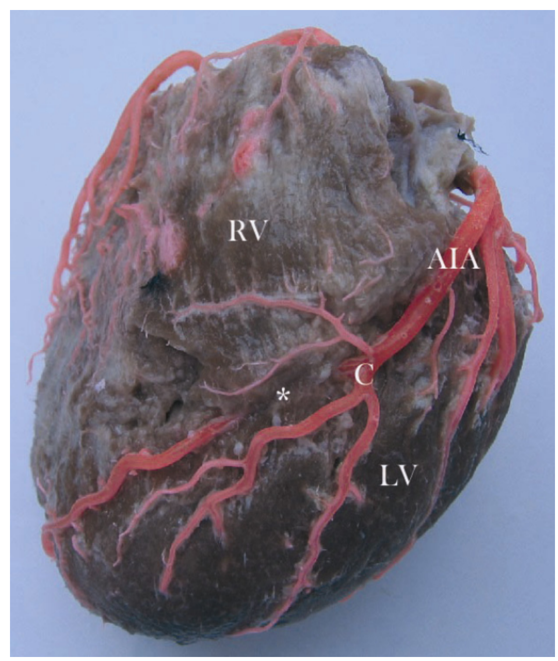

Figure 5 - Sternocostal heart surface. Anterior interventricular artery with one myocardial bridge (*). RV - right ventricle; LV - left ventricle; AIA - anterior interventricular artery; C - pre-bridge branch common trunk forming left anterior ventricular arteries.

compression (milking). Angiographic incidence ranged from 0.5% to 12%[20-24].

Our anatomical MB incidence results (40.3%) partly coincided with other studies' major and minor incidence findings. Polacek[10], found a major incidence of 87.5%, Bezerra et al[25], 78%, Ferreira et al[26], 58% and Von Ludinghausen 57%[27]. Sahni and Jit[9] found a minor incidence of 34.5%, Loukas et al[28] 34.5%, Reig et al[29], 25% and Bohm et al[30], 23%. We believe that such differences are due to sample sizes, ethnicity and other authors' interpretation of complex differences amongst MB and intramural arterial segments (grooves)[9].

Regarding gender differences, our results revealed a male predominance with no significant statistical difference, in agreement with previous reports[9,26,30-32]. Polacek[10] attained the same results, but with significant difference in a study of a Czechoslovakian population. Concerning MB location, proximal AIA and intermediate segments are the most frequent sites[33]. Angiographic studies have shown AIA frequency ranging from 0.4% to 3.5%[24,34] and anatomical studies range from 12%-60%[10,29,30,35-38]; our findings (39.6%) were in the middle of such range. Different reports have pointed out that the MB presence in the diagonal and left marginal arteries are secondary MB locations. There is a consensus regarding rarer MB locations in the circumflex and right coronary branches, such as the posterior interventricular. MB were not found in circumflex artery and the frequency in the posterior interventricular artery was 1.9%. Table 4 shows our results and other authors' findings.

A higher single MB frequency (27.3%) was found in this study, rather than two or more MB (13.1%). The single MB frequency (17-60%) is in agreement with Kosinski and Grzybiak[38], Reig et al[29], Bezerra et al, Sahni and Jit[9] and Loukas et al[28]. Our results are in agreement with the literature regarding one MB; two or three MB have been reported at a lower frequency (5%-40%). However, Becerra et al[25], have obtained 38% for one MB and 40% for two or more[26]. Our results are in agreement with Kosinzky and Grzybiak[38], Sahni and Jit[9], and Loukas et al[28], who have shown a 4% incidence of two MB in AIA.

Great MB length variability has been reported, with dimensions ranging from a few millimeters to 50 millimeters[11,29,39]. Our results reported MB length as being within a mid-range of previous reports. Higher averages (i.e. 31, 26, and 25 mm) have been reported by Loukas et al[28], Rozemberg et al[39], and Lima et al[11], respectively, whereas lower averages (13, 17, and 16 mm) have been reported by Reig et al[29], Kantarcy et al[24], Kosinsky e Grzybiak[38], respectively. Kosinsky and Grzybiak[38], did not find gender differences in MB length, as observed in our results.

Supra-bridge myocardial thickness has been reported as being between 0.3 to 3.8 mm. Mean MB thickness in our study was 1.54 mm. This represents a mid-point amongst the results reported by other authors (3, 2.5, 1.8, 1.2, and 0.9 mm)[24,28,29,38,39].

MB length, thickness and number are variables that must be considered in the cardiac pathophysiology of different diseases; however, it is equally likely that MB does not produce any effects. It is understandable that a coronary artery with one or several MB might produce signs and symptoms such as angina or arrhythmias in situations requiring high cardiac demand (exercise and stress) and even sudden death, especially if such MB are large and deep. The anatomical characteristics of coronary arteries thus play a relevant protagonist role in the outcome of such situations.

Although it has not been reported in the literature, we found a high incidence of PBB (54%) in the AIA with considerable caliber (mean of 1.4 mm) compared to usual branches from the respective AIA. We consider that this PBB irrigation could act as compensation mechanism (angiogenesis) to irrigate neighboring territory, which might have suffered ischemia without such PBB and thus explain asymptomatic presentation in the presence of MB in some patients. Although this hypothesis is difficult to prove using conventional macroscopic morphological evaluation, perhaps the next step is to prove it through proteomics and genomics that characterize the morphogenesis protein involved in this vascular compensation model.

These PBB could behave as collaterals based on the general agreement that defines collateral vessels as emerging from another territory and irrigating an arterial territorial obstruction. These PBB actually could be generated currently by a MB. Rosenberg and Nepomnyashchikh[39] have stated that the hemodynamics of coronary arteries with MB change due to obstructed flow and turbulence, producing collateral arterial compensation, which (according to the authors), prevent MB atheroma production40,41. It will be interesting to observe the presence of PBB and their biometrics in angiographic studies in the pediatric population.

Coronary hemodynamics in the presence of MB appears to be the neuralgic point regarding effects on myocardial irrigation capacity and also on cardiomyopathy due to the poor irrigation and possibly in its angiogenic development pattern. In this study an inverse relationship was found between LCA trunk length and MB in the AIA length. We think that temporary obstruction of arterial flow under the MB segment during systole affects development of LCA trunk length by

Table 4 - **Percentage of MB location by different authors**

Authors	AIA	Left DA	Left MA	AIA Vent Bran	PIA	CXA	RCA
Polacek 1961	60	22	-	-	-	-	-
Decourt 1980	30	-	-	-	-	2.8	2
Bezerra 1987							
Reig 1986	22.2	-	8.3	-	2.7	-	-
Sahni 1991	22	3	10	-	6	-	-
Baptista 1992	35.4	3.6	7.3	-	6.1	-	-
Kosinski 2001	33	5	3	-	4	-	-
Rosenberg 2004	18.9	-	-	-	-	6.7	2.2
Loukas 2006	17.5	7	2.5	13	-	-	7.5
Present study	39.6	7.2	5.2	3.9	1.9	-	-

AIA - anterior interventricular artery; DA - diagonal artery; MA - marginal artery; PIA - posterior interventricular artery; CXA - circumflex artery; RCA - right coronary artery.

reperfusion. This is consistent with LCA trunk stress during systolic turbulence against arterial walls. However, multiple correlation coefficient between LCA trunk and MB length (0.1158) showed a mild correspondence.

We also observed that a third coronary artery in AIA with MB is 2.34 times more frequent. This third coronary artery added to the AIA PBB compensation mechanism might work together to balance decreased coronary blood flow. The MB arterial stenosis was 23.5% in our study, almost concurring with that by Lima et al[11], (28.2%). Although there is a controversy regarding coronary dominance and MB, our results revealed balanced coronary irrigation in most observed MB. This is in agreement with Reig et al[29]; we found no statistically significant difference between balanced coronary irrigation and right or left dominance[29]. MB in left coronary dominance has been reported by Loukas et al[28], Penthe et al[37], Matonoha and Zechmeister[42], and Polacek[10], although the last two groups found statistically significant differences. Differently from our results, Loukas et al[28], affirmed that the MB presence is directly related to coronary artery dominance. The presence of MB in angiographic studies and the type of coronary irrigation may be taken into account for future studies.

MB remain a fascinating issue, leading to many hypotheses and some speculation. The presence of MB must certainly be carefully observed and studied from anatomical, pathophysiological, diagnostic and therapeutic viewpoints.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

This study is associated with post-graduation program.

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