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Morphological expression of the left coronary artery: a direct anatomical study

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The left coronary artery presents wide variability in its morphological expression. The purpose of this work was to determine the variations in the left coronary artery and those of its branches in heart samples taken from a group of 154 Colombian mixed-race people. Cadaveric coronary arteries were injected with synthetic resins. Left coronary artery trunks presented 6.48 ± 2.57 mm lengths. Left coronary arteries were bifurcated in 80 hearts (52%), trifurcated in 65 hearts (42.2%) and tetrafurcated in 9 hearts (5.8%). A short circumflex branch was observed in 143 hearts (92.8%), finalising as a left marginal branch in 39 of them (25.3%). The inferior third of the posterior interventricular sulcus was the most frequently occurring segment in anterior interventricular branch finalisation (63.6%). The calibre of the left coronary artery trunk was 3.58 ± ± 0.59 mm, that of the anterior interventricular branch 2.94 ± 0.5 mm and that of the circumflex branch 2.71 ± 0.54 mm. Of the total sample 86 myocardial bridges were observed with 61 cases (70.9%) in the anterior interventricular branch, distributed amongst all segments (proximal, intermediate and distal). Average myocardial bridge length was 19.4 ± 10.7 mm, and no gender differences were observed (p = 0.20). The most frequently occurring location of the myocardial bridges, on the anterior interventricular branch (proximal and intermediate), agreed with previous studies. Left coronary artery trunk length and calibre and that of its branches were considerably smaller than those reported in other populations. (Folia Morphol 2008; 67: 135–142)

Key words: left coronary artery, anterior interventricular branch, circumflex branch, anterosuperior branch, lateral branch, myocardial bridge

INTRODUCTION

The left coronary artery presents wide variability in its morphology with regard to length, calibre and the number of branches of its trunk. The left coronary artery trunk (LCAT) divides in several ways; it bifurcates, producing the anterior interventricular branch (AIB) and the circumflex branch (CxB), trifurcates, producing AIB, CxB and a diagonal branch (DB), and tetrafurcates, producing AIB, CxB and two DBs. Such bifurcated expression has been described as being the most frequent [3–5, 45]. The obtuse face of the heart, especially of its superior and intermediate segments, can be irrigated by the DB and the anterosuperior branch (ASB) (from the superior third of the AIB) and the lateral branch (LB) coming from CxB. The left marginal branch (LMB), originating

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from the CxB, also participates in irrigation of this area of the heart. These branches present variability in the calibre and length of their subepicardial course and this is related to their presence or absence [5, 12, 39]. Variability in the length, branches and irrigated areas of the CxB and the AIB should also be considered, not just as an anatomical characteristic but also allowing different clinical events to be interpreted and the corresponding interventionist manoeuvres to be carried out. AIB and DB, and to a lesser extent LMB, can present myocardial bridges (MB), varying in length from 2 to 50 mm and 1 to 3 mm in depth. Such anatomical variations have been involved in aethiopathogenia of arrhythmia, myocardial infarction and even in sudden death [17, 30, 50]. Knowledge of such variations is important with respect to morphological variations of the left coronary artery (LCA) and its branches, in determining areas related to arterial occlusive disease, in homodynamic procedures, in handling heart trauma, for their implications for heart surgery and finally in terms of academic value [6, 26, 46].

The LCA and its branches have been described in other populations by classical dissection, injection-corrosion and radiographic techniques, some having a clinical orientation and others taking up a basic position [2, 5, 34]. In the absence of a Colombian population study, this work was aimed at determining the different morphological characteristic of the LCA and its branches in fresh cadaver material, characterising these variations in mixed-race samples and thereby making a clinical contribution towards diagnosis and handling.

MATERIAL AND METHODS

The Institute of Legal Medicine, Bucaramanga, Colombia, provided 154 hearts (125 males, 29 females) for the study; these were extracted as fresh autopsy material from cadavers. Hearts included had to meet the criteria of being from a mixed-race adult, male or female, and without pathology or signs of trauma. LCAs were injected with synthetic resin (80% Palatal GP 41L and 20% Styrene) at 120 mm Hg pressure). The hearts were cleaned with 15% KOH solution to extract pericardial fat and vessel walls [37].

Left coronary artery trunk diameter and length were measured with an electronic calliper (Mitutoyo) and were classified according Reig and Petit [45] as being short (less than 6 mm), medium-sized (6 to 15 mm) or long (more than 15 mm). Internal diameters of LCA branching divisions (bifurcated, trifurcated and tetrafurcated) were measured, starting 5 mm from their origin.

Left ventricular lengths were determined according to Ortale et al. [39] between trunk division and heart apex. These ventricular lengths were divided into three equal segments to classify the length of each branch starting at the place of its origin and ending at the point of myocardial penetration. They were classified as being short if their lengths extended for less than 33.3% of the ventricular length. If the trajectories reached the second third (33.3–66.6%) of the ventricular length they were classified as being of medium-length and as long if they reached the last third (more than 66.6%) of ventricular length.

Circumflex branch trajectories were classified in agreement with Baptista et al. [6], who considered them to be short if they ended in the crux cordis or before and long if they ended in the interventricular groove or finalised as ventricular right branches. Anterior interventricular branch were classified in relation to the apex ending as being "before apex", "in the apex" or "after apex". The "after apex" type was sub-classified as ending in the inferior third of the posterior interventricular groove and in the middle third of posterior interventricular groove. Myocardial bridges were carefully observed in relation to length, depth, site and frequency. All the material was photographed.

Means and standard deviations were given for continuous variables, whilst nominal variables were described in terms of percentages. Up to 5% alpha error was accepted for the χ^2 statistical tests; Excel was used for creating the database and STATA 8.0 for statistical analysis.

RESULTS

Average LCAT length was 6.48 ± 2.57 mm (male 6.53 mm, female 6.37 mm). Different trunks lengths were observed: short in 55 samples (35.7%), medium in 95 (61.7%) and long in 4 (2.6%) (Fig. 1). The LCAT was bifurcated in 80 hearts (52%), trifurcated in 65 hearts (42.2%) and tetrafurcated in 9 hearts (5.8%) (Fig. 2, 3). Left ventricle length was 93.65 ± ± 7.59 mm. Trifurcated DB presented a 55.96 ± 21.57 mm length and 2.01 ± 0.59 mm calibre. Diagonal branch was medium-length in 34 cases (22.1%). In 81.8% of the hearts ASB was presented with a length of 50.22 ± 16.09 mm; 51.3% of these ASB were long (Table 1).

Short CxB were observed in 143 hearts (92.8%), finalising as LMB in 39 (25.3%), between LMB and

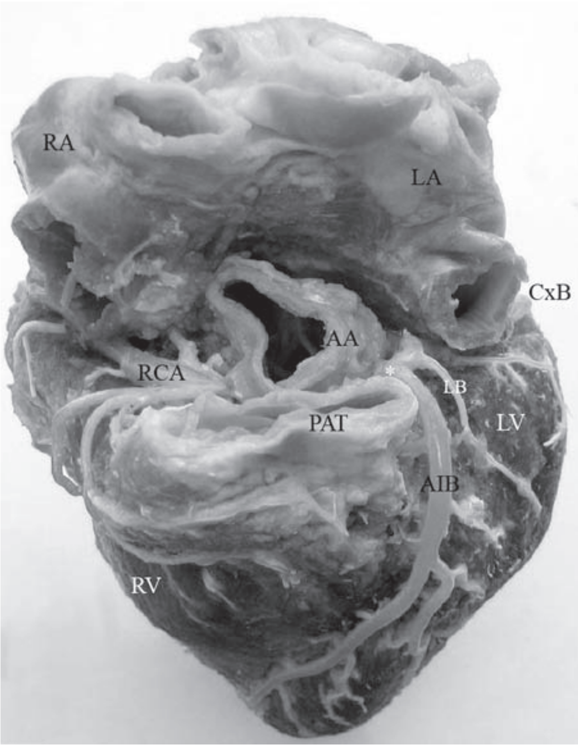

Figure 1. Sterno-costal heart surface; *short left bifurcated coronary artery trunk; RA — right atrium; LA — left atrium; AA — aortic artery; PAT — pulmonary artery trunk; RV — right ventricle; LV — left ventricle; RCA — right coronary artery; CxB — circumflex branch; AIB — anterior interventricular branch; LB — lateral branch.

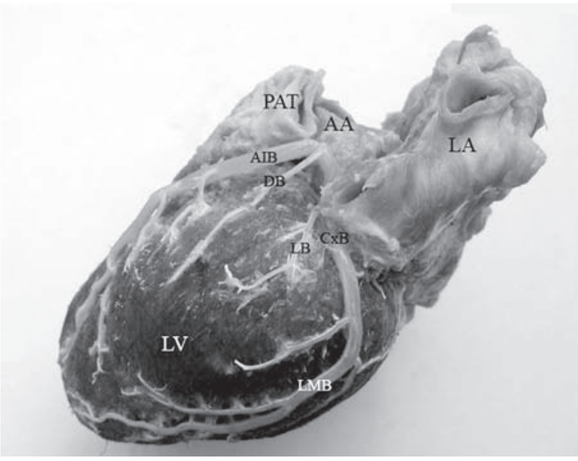

Figure 2. Obtuse heart surface of a left trifurcated coronary artery; LA — left atrium; AA — aortic artery; PAT — pulmonary artery trunk; LV — left ventricle; CxB — circumflex branch; AIB — anterior interventricular branch; LB — lateral branch; DB — diagonal branch; LMB — lateral marginal branch.

the crux cordis in 90 hearts (58.4%) and in the crux cordis in 14 of them (9.1%). Circumflex branch reached the interventricular sulcus in 8 specimens

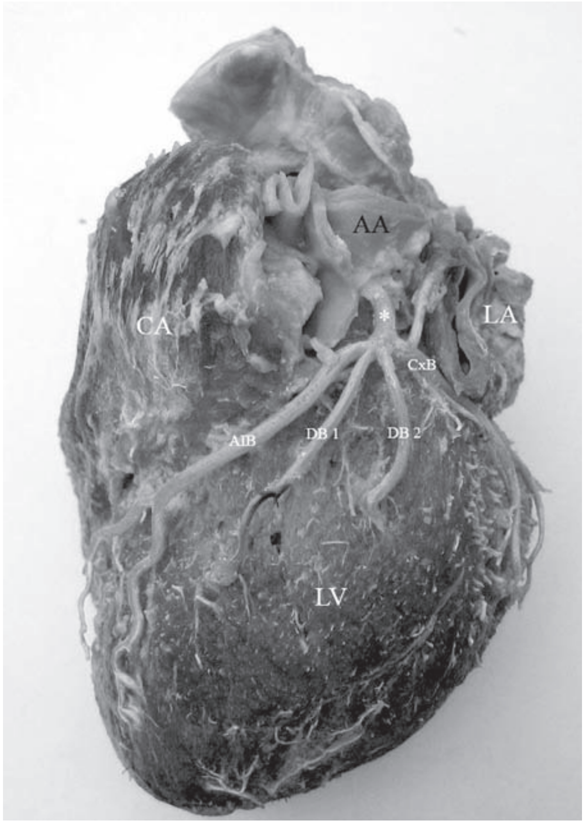

Figure 3. Obtuse heart surface; *left tetrafurcated coronary artery trunk; CA — conus arteriosus; LA — left atrium; AA — aortic artery; LV — left ventricle; AIB — anterior interventricular branch; DB 1 — first diagonal branch; DB 2 — second diagonal branch; CxB — circumflex branch.

(5.2%) and produced right posterior ventricular branches in 3 (2%).

The inferior third of the posterior interventricular sulcus was the most frequently occurring finalisation segment of the AIB (63.6%), followed by the apex (27.3%; $p = 0.005$). Of specimens with AIB finalisation in the inferior third of the posterior interventricular sulcus 61.7% were from males and 71.4% from females (Table 2).

Average LCAT calibre was 3.58 ± 0.59 mm and for the right coronary artery (RCA) was 3.18 ± 0.52 mm. Anterior interventricular branch had a greater diameter than the CxB (2.94 ± 0.5 and 2.71 ± 0.54 mm, respectively). Left coronary artery trunk calibre was not significantly higher in males than in females ($p = 0.23$).

A total of 86 MB were observed in LCA branches in 60 hearts (39%), 52 (41.6%) being male and 8 (27.6%) female, with no statistically significant difference ($p = 0.11$); they were located in the proximal, intermediate and distal segments of the AIB in

Table 1. Anterosuperior branch (ASB), diagonal branch (DB) and lateral branch (LB) characteristics (length, calibre and longitude type)

	Length	Calibre	Short length	Medium length	Long length	Total
1 DB (trifurcated)	55.96 ± 21.57	2.01 ± 0.59	5 (3.2%)	34 (22.1%)	26 (16.9%)	65 (42.2%)
2 DB (tetrafurcated)	37.67 ± 14.87	1.54 ± 0.45	3 (2%)	5 (3.2%)	1 (0.6%)	9 (5.8%)
ASB	50.22 ± 16.09	1.69 ± 0.43	17 (11%)	30 (19.5%)	79 (51.3%)	126 (81.8%)
LB	33.35 ± 17.79	1.22 ± 0.33	59 (38.3%)	58 (37.7%)	6 (3.9%)	123 (79.9%)

Table 2. Gender differences in relation to anterior interventricular branch finalisation

	Pre-apex	Apex	IVPS inferior third	IVPS median third	Between inferior and median third of IVPS
Male	1 (0.8%)	36 (29.3%)	76 (61.7%)	6 (4.9%)	4 (3.3%)
Female	1 (3.6%)	6 (21.4%)	20 (71.4%)	–	1 (3.6%)
Total	2 (1.3%)	42 (27.3%)	96 (63.6%)	6 (4.0%)	5 (3.3%)

IVPS — interventricular posterior sulcus

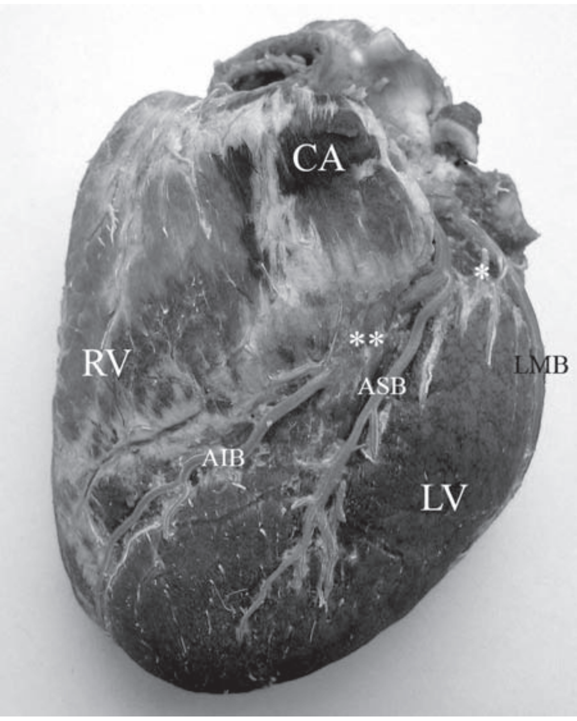

Figure 4. Sterno-costal heart surface of a left bifurcated coronary artery; **myocardial bridge; *lateral branch; CA — conus arteriosus; RV — right ventricle; LV — left ventricle; AIB — anterior interventricular branch; ASB — anterosuperior branch; LMB — left marginal branch.

61 cases (70.9% relative frequency) (Fig. 4), in the DB in 11 cases (12.8%), in the LMB in 8 cases (9.3%) and in the left ventricular branches in 6 hearts (7%).

Average MB length was 19.4 ± 10.7 mm (20.03 ± ± 10.8 mm male and 15.2 ± 8.3 mm female). The greatest length in males was not significant ($p = = 0.20$). The proximal and intermediate segments of the AIB presented the longest MB (52.9 mm) and also the shortest length (2.88 mm). The greatest average MB length presented in a DB was 29.71 mm (Table 3). Suprapontine myocardium thickness was 1.53 ± 0.72 mm (0.27–3.8 mm range).

DISCUSSION

The LCAT length recorded in our study was considerably smaller than that reported in other populations (10 to 15 mm) [8, 35, 39, 45]. Fox et al. [14] have reported the shortest length to date (5.5 mm), 73% of their samples measuring less than 6 mm. Such data does not agree with other results indicating a short trunk frequency ranging from 7–15% [31, 35, 45]. Only four hearts (2.6%) had LCAT length greater than 15 mm in our series, fewer than reported by Green et al. [19] (26%), MacAlpine [35] (14%) and Reig and Petit [45] (18.9%). Short trunks are considered risk factors for suitable coronary perfusion during aortic valve replacement [14, 19, 45];

Table 3. Myocardial bridge (MB) length in left coronary artery

Artery	MB	Average	±	Min. [mm]	Max. [mm]
AIB proximal	22	16.56	6.16	7.93	25.78
AIB intermedial	26	16.53	8.17	6.83	31.50
AIB proximal-intermedial	12	28.17	13.54	2.88	52.86
AIB distal	1	24.23		24.23	24.23
AIB ventricular branch	6	16.17	8.30	6.70	30.41
Diagonal branch	11	29.71	14.55	8.90	51.34
Left marginal branch	8	16.01	10.10	9.16	37.96

AIB — anterior interventricular branch

the catheter may be inserted into one of the terminal branches in this situation, thereby producing an ischaemic area, which can lead to arrhythmia, myocardial heart attack or both. A short LCAT has also been considered as a risk factor in developing coronary atherosclerosis [16]; such an anatomical variant could therefore be considered a pathogenic substratum for the high incidence of coronary illness amongst the Colombian population.

Previous studies have reported wide variation in LCAT branching and have found a greater prevalence of bifurcated expression. Our results (57.8% of this type) coincided with previous reports indicating 40–70% [5, 31, 39, 45], although this was greater than that reported by Fox et al. [14]. The trifurcated division (with the addition of a DB) observed in this work (36.4%) was in an intermediate range in relation to previous reports giving a frequency of 9–55% [5, 12, 31, 41], although Grande et al. [18] reported trifurcation in 82.5% of their cases. Such a wide range can be explained by the different approaches used for defining the DB. For some authors, the DB is the artery located in the angle formed by the AIB and CxB [5, 45]; other authors use a broader approach and consider that the DB originates in the vertex of the angle formed by the terminal branches of the LCA or in the initial millimetres of the AIB or CxB [3, 23]. The frequency of LCAT tetrafurcation in our study was 5.8%, similar to that reported by previous authors (5–7%). Diagonal and lateral branch penetrating to the myocardium at the level of the intermediate third of the ventricular surface predominated in our study, in agreement with Baptista et al. [5] and DePaula [11], while Ortale et al. [39] and Banchi [4] have reported the prevalence of a short DB. Diagonal branch length variations have special importance in heart surgery because their external portion is frequently used for an autogenous bypass implant [1, 5]. The presence of collateral irrigation in the obtuse face of the heart, with CxB or AIB diagonals or collaterals, could respond to vascular compensation for a greater territorial demand in irrigation because of deficiency in the larger arteries.

The incidence of the short CxB found in this work (92.85%) was similar to that reported by Mouchet [36], but higher than that described by Banchi (70%), James (81%), Baptista (86.4%) and Kalpana (83%) [4, 6, 23, 26]. Reig et al. [47] have reported a low incidence (53%). The frequency of the long CxB in our work (7.2%) was lower than that reported in previous studies, which range from 13 to 23% [6, 8, 10, 26, 51]. The high frequency of the short CxB correlated with the low incidence of left coronary dominance observed in this work.

Short CxB terminated as marginal branches in our work (25.3%), agreeing with previous studies describing 13–21% [6, 8, 11, 26]. It has been observed in many cases that the marginal branches, besides irrigating segments of the obtuse face of the heart through collateral branches positioned in horizontal or oblique trajectories, participated in doing so with the posterior branches of the left ventricle (right coronary artery), such an association irrigating the intermediate and lateral segments of the posterior face of the left ventricle.

The heart apex has traditionally been singled out as the place where AIB conclude with greatest frequency; however, other reports, including the present one, have described termination in this segment in only 6–33% of cases [23, 26, 49], the interventricular posterior sulcus being the most frequent place for finalisation (42–80%), once it has supplied the apex with numerous collaterals. Anterior interventricular branch finalisation before the apex has been described as having an 8% frequency [21, 26, 49] compared to 1.3% in our work, although James [23] has reported a slightly higher rate (17%).

A compensatory phenomenon has been observed in the irrigation of the heart's posterior-inferior segments because of a short posterior interventricular branch due to the distal segment of the AIB overcoming the apex and irrigating neighbouring territory on the diaphragmatic side. Such anatomical expression must be considered when evaluating a myocardium heart attack located in the inferior segment of the posterior wall of the heart, since arterial obstruction could compromise the distal portion of the AIB instead of the posterior interventricular branch, as is usually assumed.

It is worth stressing that the internal diameter of the LCAT and its branches found in this work was smaller than that reported previously [8, 13, 24, 25, 33, 42, 53]. The average LCAT diameter was 3.58 mm, contrasting with other works that report measurements of 4–5 mm; the calibre of the CxB has been reported as ranging from 3.2–4 mm and of the AIB as 3.1–4 mm [8, 24, 33, 52]. The LCA had a larger calibre than the RCA, in agreement with Ortale et al. [38], although his measurements were external. The same was seen with the AIB compared to CxB; such findings agreed with angiographic and post-mortem internal measurements [15, 28, 40, 52]. Bearing in mind that the heart's weight proportionally corresponds to 0.45–0.5% of an individual's total weight [20], we speculated that the lower measurements found in the coronary arteries evaluated here would represent a characteristic of the mixed-race Colombian population studied. Although in this work the average weight and height of the described population were not measured, it is noteworthy that the Colombian population is of less than the average weight and height of Caucasian populations.

The most frequently occurring location of MB is the AIB proximal and intermediate segments. Anatomical studies have shown a 12–60% AIB frequency [7, 29, 34, 43, 48, 50]; however, our findings revealed an intermediate frequency (39.6%). Other authors have pointed to a secondary MB localisation in the DB and LMB. There has been agreement in regarding as unusual MB localisation in the CxB and in branches of the RCA, such as the posterior interventricular artery.

Our results revealed no statistically significant gender difference for MB frequency, thereby agreeing with previous reports [9, 22, 50]. Great variability has been reported regarding MB length, which can range from a few millimetres to 50 mm [32, 44, 48]. This submerged portion of the coronary arteries can have great implications in the irrigation and the physiopathology of ischaemic disease. Our MB length was in an intermediate range in relation to previous reports [32, 34, 48]. Myocardial branch lengths have been reported as ranging from 25 to 31 mm and shorter ones (12.5 to 17 mm) have been reported by other authors [27, 29, 44]. Kosinski et al. [29] did not find any significant gender differences regarding MB length and our results agreed with this.

In our work MB depth was 1.53 mm, although a greater depth has been described, ranging from 1.8 to 3 mm [27, 29, 48]. A lesser MB depth (1.2 mm) has been reported by Loukas et al. [34] and Reig et al. [44] (0.9 mm). Myocardial branch length, depth and number are variables which may affect the nature of different ischaemic or arrhythmic pathological expressions of the heart. It must be understood that the presence of several long and deep MB can be the anatomical basis that facilitates the origin of clinical events such as angina, arrhythmias or even sudden death, which originate from situations of high demand on heart function, such as stress or exercise.

The high degree of variability of the coronary arteries and their branches must be carefully observed and studied from anatomical, pathophysiological, diagnostic and therapeutic viewpoints. Ethnicity is an interesting topic that must be carefully taken into account, especially in relation to the calibre of the coronary arteries. It appears that a relationship exists between body dimensions and this characteristic of the heart, although this suspicion must to be studied and validated in future works.

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