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The impact of left main coronary artery morphology on the distribution of atherosclerotic lesions in its branches

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Background: *Atherosclerotic occlusion of a coronary vessel is the commonest cause of ischaemic heart disease. The distribution of atherosclerotic lesions is not random, with stenoses preferentially situated at branch ostia, bifurcation points, and the proximal segments of daughter vessels. The aim of this study was to determine the effect of the intrinsic anatomical properties of the left main coronary artery (LMCA) on the distribution of atherosclerotic lesions in its branches.*

Materials and methods: *A retrospective review of 170 consecutive coronary angiograms obtained from the cardiac catheterisation laboratories of private hospitals in the eThekwini Municipality area of KwaZulu-Natal, South Africa was performed. The LMCA was absent in 19/170 (11.2%). The remaining angiograms (n = 151) were divided into two groups: normal 63/151 (41.7%) and those with coronary artery disease (CAD) 88/151 (58.3%). The CAD group was sub-divided into proximal 42/88 (47.7%), mixed (proximal and distal) 26/88 (29.6%) and distal 20/88 (22.7%) sub-groups based on the location of atherosclerotic lesions in the branches of the LMCA.*

Results and Conclusions: *The mean length, diameter and angle of division of the LMCA were as follows: Total angiograms: 10.4 mm, 3.8 mm and 86.2°; normal group: 10.5 mm, 3.9 mm and 85.7°, CAD group: 10.2 mm, 3.7 mm and 86.3°; proximal sub-group: 10.9 mm, 3.7 mm and 91.6°, mixed sub-group — 9.8 mm, 3.7 mm and 85° and distal sub-group — 9.1 mm, 3.8 mm and 79.4°, respectively. The vessels with proximally located lesions were recorded to have longer lengths and wider angles of division than vessels with distal lesions. Coronary angiographic delineation of the LMCA anatomy may be predictive of a coronary arterial arrangement that may favour the progression of proximally located lesions.* (Folia Morphol 2013; 72, 3: 197–201)

Key words: left main coronary artery, left main coronary artery branches, atherosclerosis, distribution

INTRODUCTION

The arterial supply of a greater part of the myocardium is dependent on the patency of the left main coronary artery (LMCA) [10]. The LMCA is larger in calibre than the right coronary artery (RCA), and gives not only the arterial supply to a greater volume of myocardium, including almost all of the left ventricle and atrium [13] but also a significant proportion of

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the right ventricle [9]. The exception in right coronary arterial dominance lies in the fact that a posterior region of the left ventricle [13] is partly supplied by the RCA. On reaching the atrioventricular groove, the LMCA usually divides into two (the left anterior descending artery [LAD] and left circumflex artery [LCx]) or more branches. The LAD is commonly described as the continuation of the LMCA [13], and is also referred to as the anterior interventricular artery in anatomical textbooks.

The distribution of atherosclerotic lesions is not always random, but stenoses tend to be situated preferentially at branch ostia, bifurcation points, and the proximal segments of the resulting daughter vessels [2, 8]. Caro [3] noted that the proximal lateral walls of the daughter branches are sites of low flow and low shear stress (Fig. 1). Studies have shown that, in these sites, the flow pattern of blood is reduced, with an increase in the generation of atherosclerotic lesions [6, 12]. The location of atherosclerotic lesions in the proximal segment of a coronary vessel is a significant predictor of the development of myocardial infarction [1].

Gazetopoulos et al. [4] suggested that the development of atherosclerosis in the branches of the LMCA is associated with the modification of local mechanical and haemodynamic factors by the changes in the length of the LMCA. Atherosclerotic lesions develop frequently at outer walls of vessel branch points (Fig. 1) and inner walls of curved arterial segments [2]. In these sites, there is the occurrence of flow separation, flow reversal and turbulence with associated low shear stress [5]. The aim of this study was to determine the effect of the intrinsic anatomical properties of the LMCA on the distribution of atherosclerotic lesions in its branches.

MATERIALS AND METHODS

A retrospective review of 170 consecutive coronary angiograms obtained from the cardiac catheterisation laboratories of private hospitals in the eThekwini Municipality in KwaZulu-Natal, South Africa was performed. The coronary angiograms with absent LMCA were excluded from the analysis of the morphometric parameters of the LMCA. The remaining angiograms were divided into two groups: normal and coronary artery disease (CAD) based on the absence (Fig. 2) or presence (Fig. 3) of atherosclerotic lesions in the branches of the LMCA. The CAD group was further divided into proximal, mixed and distal sub-groups (Fig. 4) based on the location of atherosclerotic lesions

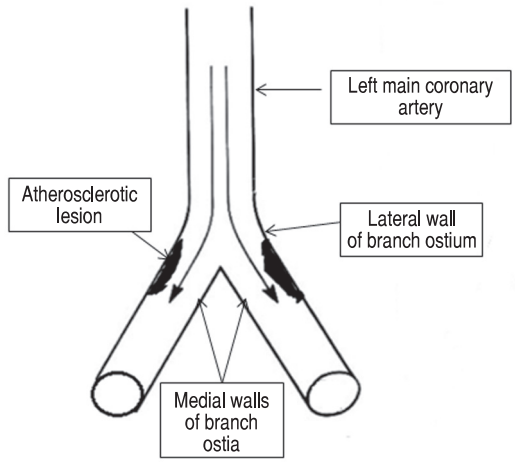

Figure 1. Schematic diagram showing the location on atherosclerotic lesion in the proximal lateral wall of the left main coronary artery.

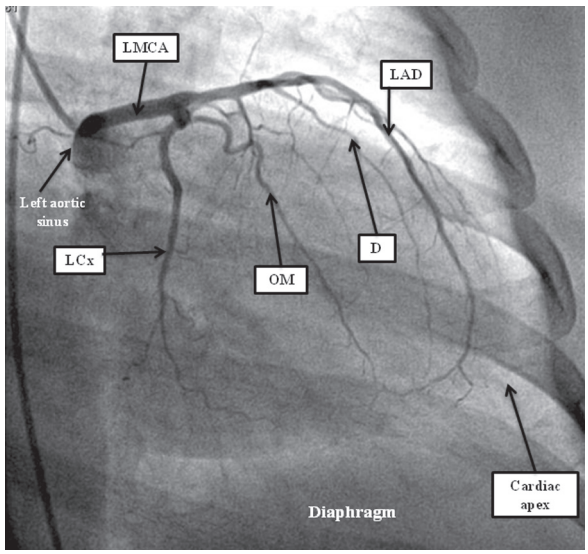

Figure 2. Normal coronary angiogram in the left anterior oblique projection (caudal view) showing left main coronary artery (LMCA) and its branches; D — diagonal branch of left anterior descending artery; LAD — left anterior descending artery; LCx — left circumflex artery; OM — obtuse marginal artery.

in the LMCA branches. In the mixed sub-group, the atherosclerotic lesions were located in both the proximal and the distal segments of the LMCA branches. In order to evaluate the effect of LMCA morphology on the proximal or distal location of atherosclerotic lesions, the morphometric parameters of the proximal and the distal subgroups were subjected to statistical analysis. The mixed subgroup was excluded because it contained atherosclerotic lesions in both the proximal and distal segments.

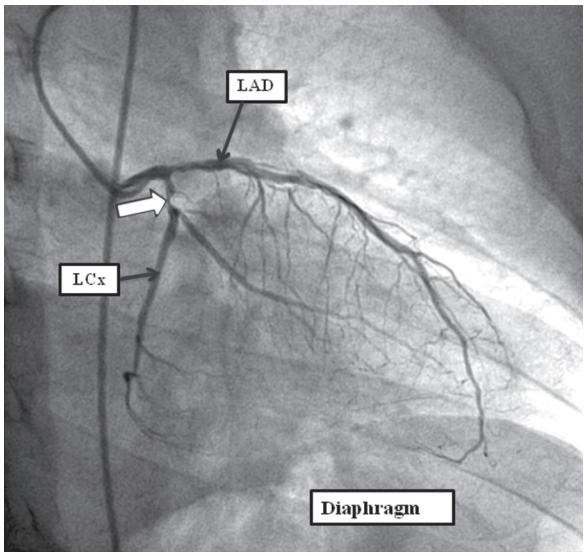

Figure 3. Coronary angiogram in the right anterior oblique projection showing presence of atherosclerotic lesion (open arrow) in the left circumflex artery (LCx); LAD — left anterior descending artery.

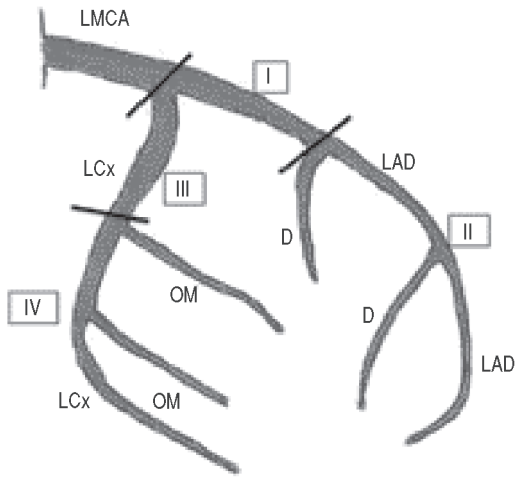

Figure 4. Schematic diagram showing the division of the left main coronary artery (LMCA) and branches into segments; D — diagonal branch of left anterior descending artery; LAD — left anterior descending artery; LCx — left circumflex artery; OM — obtuse marginal artery; Black lines — demarcation point between segments: proximal (I and III), distal (II and IV) or mixed (I, II, III and IV) sub-groups.

The LMCA length was measured in each of the angiograms from its orifice (visualised by spillback of contrast medium into the aorta during selective injection) to its division into the LAD and LCx arteries. The LMCA diameter was measured internally at the mid-LMCA length. Measurements were made in the right anterior oblique (RAO) projection that shows the LMCA and its point of branching clearly. Correction for magnification was done by auto-calibration of the projected size of the Judkins® catheter to its actual size after contrast filling. The projected radiological angle between the origins of the LAD and LCx arteries (division angle) was also measured in the left anterior oblique (LAO) caudal view ('spider' view) projection that shows the division of LMCA into its branches clearly. The measurements were taken 3 times by the same observe and the average of these values was recorded. The morphometric values of the LMCA in angiograms with proximally located lesions were compared with those with distal atherosclerotic lesions using Student's paired t test. All analyses were performed by a single observer and used the Statistical Package for the Social Sciences (SPSS); a p value ≤ 0.05 was considered significant. Ethical clearance (Ethics no BE 103/11) was obtained from the relevant institutional committee.

RESULTS

The LMCA was absent in 19/170 (11.2%) of cases. The remaining angiograms (n = 151) were divided into two groups: normal 63/151 (41.7%) and CAD 88/151 (58.3%). The CAD group was further divided into proximal 42/88 (47.7%), mixed 26/88 (29.6%) and distal 20/88 (22.7%) sub-groups.

Length of the left main coronary artery

The mean lengths of the LMCA in the proximal, mixed and distal sub-groups were: 10.9 ± 4.4 mm (range 5.1–22.4 mm); 9.8 ± 3.6 mm (range 5.3–16.6 mm) and 9.1 ± 2.8 mm (range 4.2–17.2 mm), respectively. There was no statistically significant difference between the proximal and distal sub-groups (p = 0.53) (Table 1).

Diameter of the left main coronary artery

The mean diameter of the LMCA in the proximal, mixed and distal sub-groups were 3.7 ± 0.6 mm (range 2.3–4.9 mm), 3.7 ± 0.9 mm (range 2.1–5.2 mm) and 3.8 ± 0.8 mm (range 2.6–5.1 mm), respectively. There was also no significant difference between the proximal and distal sub-groups (p= 0.584) (Table 1).

Angle of division of left main coronary artery

The mean angle of division of the LMCA were 91.6 ± 22.6º (range 46.5–148.6º), 85.0 ± 25.9º (range 43.3–125.4º) and 79.4 ± 31.2º (range 27–153.8º) in

Table 1. Mean length, diameter and angle of division of the left coronary artery between proximal and distal sub-groups

Location	Sample size (n)	Mean [mm]	SD	Min–max [mm]	P
Mean length					
Proximal	42	10.9	4.4	5.1–22.4	0.53
Distal	20	9.1	2.8	4.2–17.2	
Mixed	26	9.8	3.6	5.3–16.6	
Mean diameter					
Proximal	42	3.7	0.6	2.3–4.9	0.584
Distal	20	3.8	0.8	2.6–5.1	
Mixed	26	3.7	0.9	2.1–5.2	
Mean angle of division					
Proximal	42	91.6	22.6	46.5–148.6	0.139
Distal	20	79.4	31.2	27–153.8	
Mixed	26	85.0	25.9	43.3–125.4	

SD — standard deviation

the proximal, mixed and distal sub-groups, respectively. There was also no statistically significant difference between the proximal and distal sub-groups ($p = 0.139$) (Table 1).

DISCUSSION

The morphology of anatomical structures and distribution of the coronary arteries is determined by heredity [4]. Since the rate of development of an atherosclerotic lesion in the branches of the LMCA may be influenced by the length of the LMCA, this may therefore be considered a hereditary factor predisposing to atherosclerosis [4]. In fluid mechanics, the length of a conduit is shown to have effect on the difference in the pressure at the ends of the conduit.

In blood haemodynamics, according to Poiseuille's Law, "the length (L) of a pipe through which a Newtonian fluid flows is directly proportional to the pressure drop (ΔP) in the pipe and inversely related to the volume flow (Q) along it" [6].

$$\Delta P = \frac{8\mu LQ}{\pi r^4}$$

(ΔP is the pressure drop; L — the length of pipe; μ — the dynamic visscosity; Q — the volumetric flow rate; r — the radius; π — the mathematical constant).

Blood acts like a Newtonian fluid within the physiological range in vessels greater than 0.1 cm internal diameter [11]. The above equation demonstrates that the longer the LMCA, the greater the pressure drop in the vessel before it branches. A low pressure at the branching point is associated with low shear stress. This may lead to an increase in the development of atherosclerotic lesions in the proximal segment of the daughter branches. A short LMCA has the opposite effect and causes a decreased pressure drop, increased flow, and hence high wall shear at the division point of the vessel. This may be protective against atherosclerotic lesion formation.

The finding of this study illustrates that a longer LMCA length may predispose its terminal branches (the LAD and LCx arteries) to having a more proximal atherosclerotic lesion. This corroborates earlier studies on the effect of vessel morphology and haemodynamic changes on the development of atherosclerosis [2, 3, 5, 8, 12]. However, the results of the present study differed from the findings of the only reported similar study of Saltissi et al. [11] that associated shorter LMCA with the development of atherosclerotic lesions in the proximal segment of its branches.

Malcolm and Roach [7] in an experimental investigation, evaluated the significance of the angle of division of a vessel in altering haemodynamics with its effect on the development of atherosclerotic lesions in its branches. They showed that shear stress was substantially reduced on the lateral wall of daughter branches with an increase in atherogenesis by asymmetry or irregularity of the division; imbalances of the relative flows down the daughter branches and an increased angle of division.

In the present study, the mean angle of division of the LMCA was wider in the group with proximal

disease (91.6 ± 22.6º) than in the group with distal disease (79.4 ± 31.2º). Although, this did not reach significance at the 5 per cent level, it indicated however that the wider the angle of division of the LMCA, the more proximally located the atherosclerotic lesions is in its branches (Table 1). These results confirmed the finding of Saltissi et al. [11], which also recorded a wider angle of division for the proximal group (85 vs. 76º)

Saltissi et al. [11] concluded that the proximal location of atherosclerotic lesions in the branches of the LMCA is associated with shorter length and wider angle of division of the LMCA. However, the result of the present investigation differed from their finding by showing that vessels with proximally located lesions have longer lengths and wider angles of division than vessels with distal lesions.

CONCLUSIONS

The anatomy of the LMCA may have an important function in the pathogenesis and distribution of atherosclerotic lesions. Furthermore, the rate of progression of proximally located lesions may be strongly influenced by the anatomical features of the LMCA and its branches. Coronary angiographic delineation of the LMCA anatomy may be predictive of a coronary arterial arrangement that may favour the progression of proximally located lesions. A larger prospective study may be useful in determining a definitive morphological relationship.

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