Change in the Diameter of the Left Coronary Artery: Angiographic Study

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ABSTRACT

Background: Coronary artery diseases are among the top causes of death worldwide, and This leads to rapid advances in management. However, revisiting the basic knowledge of the coronary artery's diameter based on the developed investigation technology is essential.

Objectives: This study aimed to describe the diameter of the left main coronary artery at the opening, mid-length, and terminal parts. Also, it aimed to describe any changes in the diameter of the left coronary artery at the three points.

Methods: The study was a cross-sectional retrospective hospital-based design. A total of 356 angiograms were used (41.3% males and 58.7% females), with a mean age of 56.24±8.68 years in the study group. The study data was collected from the system records of three cardiac centers. To evaluate the change in diameter, the diameter of the left main coronary artery (LMCA) was measured at the origin (DLMCAO), mid-length left coronary artery (DLMCAM), and terminal parts (DLMCAT).

Results: The mean diameters of DLMCAO, DLMCAM, and DLMCAT were 3.8±0.72 mm, 3.8±0.48 mm, and 3.7±0.85 mm, respectively. The average diameter of the LMCA was 3.8±0.55 mm. Female participants had the highest mean age (58.3±6.95). The average diameters of LMCA at the three measurement points showed a gradual decrease among all participants, and the DLMCAO was the widest. Among all participants, there is a moderate to highly significant correlation between the DLMCAO, DLMCAM, and DLMCAT and the average diameter. A one-way ANOVA revealed no statistically significant difference between the DLMCAO, DLMCAM, and DLMCAT (P=0.37). Among males and females independently, there was a significant difference (P=0.0001).

Conclusion: The average diameter of the left coronary artery at the origin, mid-length, and terminal parts were 3.8±0.70 mm, 3.8±0.47 mm, and 3.7±0.84 mm, respectively. The average diameter of LMCA is larger than DLMCAO, DLMCAM, and DLMCAT. Females have smaller average diameters than males. The average diameters of LMCA at DLMCAO, DLMCAM, and DLMCAT show a gradual decrease. Among all participants, there was no significant difference in the measured diameters at the origin, middle, and terminal parts. However, male and female participants showed significant differences between the measured diameters, mid-length, and terminal parts.

Keywords:

Left coronary artery, diameter, change, angiographic, Sudanese.

List of abbreviations

LMCA = left (main) coronary artery

DLMCA = average diameter of the left (main) coronary artery

DLMCAO = average diameter of the left (main) coronary artery at the origin

DLMCAM = average diameter of the left (main) coronary artery at mid-length

DLMCAT = average diameter of the left (main) coronary artery at the terminal part

QCA = quantitative coronary angiography

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INTRODUCTION

Coronary artery diseases are among the top causes of death worldwide, and consequently, these lead to rapid advances in related investigations, technology, and management [1]. Such advances in investigative technology are based on technological advances and the revision of basic knowledge, including anatomy and physiology. Also, a basic understanding of the coronary arteries' morphometry is essential for perfecting related management techniques. Coronary artery angiogram is a gold standard for ischemic coronary disease investigations and revascularization determinations [2,3].

The left (main) coronary artery (LMCA) is the most affected coronary artery. Therefore, knowing its detailed morphology is essential for interpreting angiographic findings and computing the percentage of stenosis and, consequently, the management [4]. The LMCA originates from the left aortic sinus and runs between the infundibulum of the right ventricle and the left auricle to end in the coronary sulcus. Commonly, it terminates by dividing into anterior interventricular (main) and circumflex (side) branches. The LMCA has many variabilities in origin, course, length, and branching [2,3,5-7]. The LMCA is shorter and wider than the right [8]. The LMCA supplies almost all of the left side of the heart [9,10].

The mainstream of the morphometric work on the LMCA, whether cadaveric or angiographic, describes the average diameter. However, some articles have focused on the diameter of the LMCA opening [7,11-13]. The luminal diameter of the coronary arteries is influenced by functional and pathological processes that can affect the whole artery or a focal part of it[11]. A compensatory enlargement can follow these influences [12]. However, these processes can happen with or without focal narrowing or luminal irregularity; thus, the normal diameter or appearing arterial segments cannot specify that they are normal.

Furthermore, an increase in the diameter was considered an initial indicator of atherosclerosis and functional deterioration, which appeared before the development of the structural changes [13,14]. These can create problems in estimating the severity of the arterial disease through the "percent of stenosis" [11]. The percentage of stenosis is grounded on the ratio of a focal minimum to a near "normal" diameter [11]. One of the solutions to this problem is to know the normal luminal diameter of LMCA at a given point to use it as a normal reference value for the percent stenosis.

Accordingly, this study aimed to describe the diameter of the left main coronary artery at the opening, mid-length, and terminal parts. Also, it aimed to describe any changes in the diameter of the left coronary artery at the three points. However, we hypothesize that the diameter of the left coronary does not change and remains the same along the artery's course. The study's findings will establish baseline data for normal morphometry of the left main coronary artery among Sudanese. Also, the study findings will significantly increase the understanding of the diameter of the left artery along its course and if it changes.

MATERIALS AND METHODS

Study Design

The study design was a cross-sectional retrospective hospital-based [15]. The study utilizes coronary angiograms.

Sample and Setting

The sampling technique is total for all the patients who had angiograms done for elective evaluation of coronary arteries from July 2018 to August 2019 in the cardiac centers of Khartoum Hospital, Sudan Heart Center, and Al-zaytouna Specialist Hospital. The study inclusion criteria were adults who presented to any of the three cardiac centers. The exclusion criteria were age below 18 years, history of heart or congenital heart diseases or coronary artery anomalies, previous coronary diseases, stenting or bypasses, and hypersensitivity to contrast agents. The coronary angiograms were done through a standardized method [16-18]. Depending on the patient's medical status, the catheterization root was radial using 5–4 French catheters. Angiograms were performed using a digital radiographic system (TOSHIBA DFP/8000A). Different views (caudal and cranial views) were used. To evaluate change in the artery diameter, three points of measurement were used: origin (DLMCAO), mid-length (DLMCAM), and terminal (DLMCAT). The site for DLMCAO was determined to be the opening of the LMCA. The DLMCAT was determined as the point of the artery branching into the terminal branches. The artery length was measured to determine the midpoint and then used as DLMCAM. All measurements were done after calibration (using the catheter tip as reference diameter) and contrast injection. All the measurements were taken through quantitative coronary angiography (QCA) [2,17]. The measurements were consistently taken during diastole, and the part with the most dimensions in each of the three points of measurement was used. The same observer did all the measurements. All the measurements were done on the right anterior oblique or anteroposterior caudal views. The average diameters were calculated as a mean from the three measurements and used for statistical analysis.

Data Collection

The data were retrieved from the back system of cardiac centers of Khartoum Hospital, Sudan Heart Center, and Al-zaytouna Specialist Hospital centers, and the total number of retrieved angiograms was 356. The retrieved data includes coronary angiograms, age, and sex.

Ethical consideration

The study was conducted in compliance with the Helsinki Declaration and approved by the National Ribat University (IRB: ANA.P.H.D. 01.06.2020.1) and the ethical committees of the three cardiac centers. The patients were informed that their data could be used for academic research with protection to their privacy. Informed consent was obtained from all patients or their legal guardians.

Data analysis

The obtained data was tabulated in Excel and analyzed using SPSS V27 (IBM). The categorical data were reported in the form of tables and frequencies. Luminal diameters were presented in the form of mean and standard deviation. A person correlation test, one-way ANOVA, and T-test were used to assess the relationship between the variables. A P value of <0.05 was considered significant.

RESULTS

Overall Findings

The total number of retrieved angiograms was 356 (41.3% males and 58.7% females). The age range of the study group was between 43 and 68 years, with a mean age of 55.3±8.8 years. Female participants had the highest mean age (58.3±6.95). None of the angiograms showed anomalies in the origin, course, or variation in the termination. Among all participants, the LMCA artery originated from the left aortic sinus and terminated by dividing into anterior interventricular and circumflex branches. Most of the participants were middle-aged, and females were more affected than males. The angiograms showed normal origin and

branching of the LMCA that were consistent with standard literature. The mean diameters of DLMCAO, DLMCAM, and DLMCAT were 3.8±0.72 mm, 3.8±0.48 mm, and 3.7±0.85 mm, respectively. The average diameter of the LMCA was 3.8±0.55 mm (Figure 1).

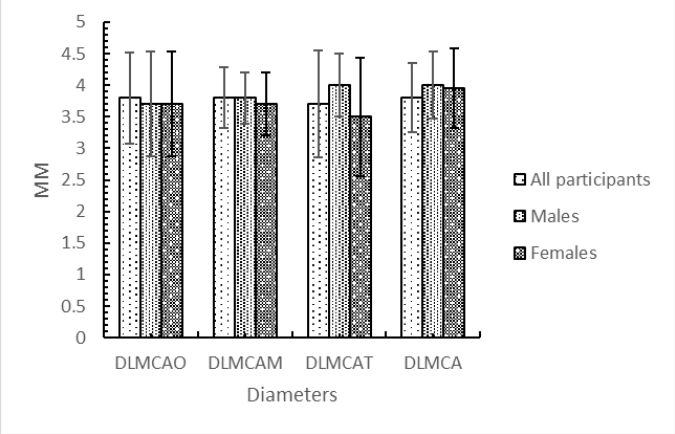

Figure 1. Shows the diameters of the left coronary artery at opening, mid-length, termination, and average diameter (n=365). DLMCAO = diameter of the left coronary artery at origin; DLMCAM = diameter of the left coronary artery at mid-length; DLMCAT = diameter of the left coronary artery at the terminal.

The average diameters of LMCA at the three measurement points showed a gradual decrease among all participants, and the DLMCAO was the widest (Figure 2). The percentage of decrease among all participants was 1.6% at mid-length and 0.3% at the terminal. Among all participants, there is a moderate to highly significant correlation between the DLMCAO, DLMCAM, and DLMCAT and the average diameter of LMCA (Table 2). There is a gradual decrease in the diameter of the LMCA.

Gender Differences

Among males, the diameter of the LMCA showed a gradual increase, and the increase percentages were 2.6% at mid-length and 5.0% at the terminal part. Among females, the diameter of the LMCA at the opening and mid-length showed no difference and decreased only at the terminal part, with a percentage decrease of 5.41%. The DLMCAT was the widest among male participants and the narrowest among females. A one-way ANOVA revealed no statistically significant difference between the DLMCAO, DLMCAM, and DLMCAT (P=0.37). Among males and females independently, there was a significant difference (P=0.0001). Among both males and females, there was a non-significant difference between DLMCAO and DLMCAM (P>0.05) and a significant difference between DLMCAM and DLMCAT (P<0.05). Such relation indicates that changes in the diameter among male and female participants may occur after the mid-length of the vessel or before bifurcation. The DLMCA was 4.0±0.53mm among male participants, and the DLMCAO was 3.7±0.83mm. In comparing males to females, females had a smaller diameter (Table 1). Meanwhile, males show a gradual increase in the diameter of LMCA; females show a decrease at DLMCAM and DLMCAT.

T-test showed a non-significant difference in diameters of LMCA at DLMCAO and DLMCAM between males and females. However, the diameter of the LMCA at DLMCAT showed a significant difference between males and females (P=0.000), with males having a wider diameter (Table 2). Females in the study group have smaller diameters than males.

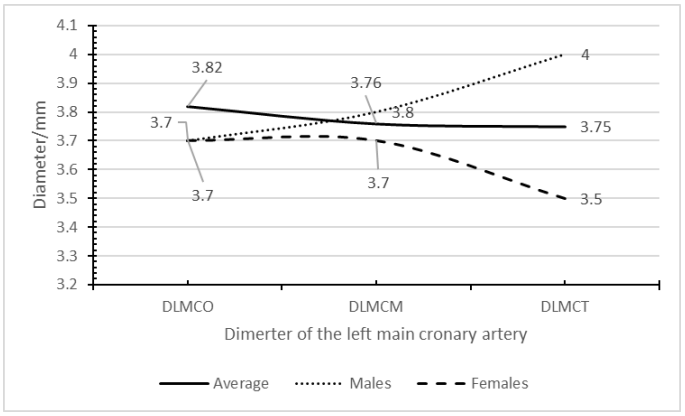

Figure 2. Shows the changes in diameters of the left coronary artery at the origin, mid-length, and terminal parts (n=365). DLMCAO = diameter of the left coronary artery at origin; DLMCAM = diameter of the left coronary artery at mid-length; DLMCAT = diameter of the left coronary artery at the terminal.

Table 1. shows the correlations of the diameters of the left coronary artery at the origin, mid-length, and terminal parts and the average diameter (n=365).

Correlations					
		DLMCO	DLMCM	DLMCT	DLMCA
DLMCO	Pearson Correlation	1	0.462**	0.230**	0.819**
	Sig. (2-tailed)	-	0.000	0.000	0.000
	N	356	356	356	356
DLMCM	Pearson Correlation	0.462**	1	0.812**	0.590**
	Sig. (2-tailed)	0.000	-	0.000	0.000
	N	359	359	359	359
DLMCT	Pearson Correlation	0.230**	.812**	1	0.370**
	Sig. (2-tailed)	0.000	.000	-	0.000
	N	356	356	356	356
DLMCA	Pearson Correlation	0.819**	0.590**	0.370**	1
	Sig. (2-tailed)	0.000	0.000	0.000	-
	N	356	356	356	356

**. Correlation is significant at the 0.01 level (2-tailed).

DLMCA= average diameter of the left coronary artery; DLMCAO = diameter of the left coronary artery at origin; DLMCAM= diameter of the left coronary artery at midlength; DLMCAT= diameter of the left coronary artery at the terminal; DLMCA= average diameter of the left coronary artery; measurements are in mm.

DISCUSSION

The mean age of participants was 56.2±8.7 years. Female participants had the highest mean age (58.3±6.95) and represented the majority (58.7%) of the participants.

The current study describes the changes in the diameter of LMCA along its course among 356 participants. Change in the diameter was assessed through measurements taken from coronary angiograms. The LMCA diameters were measured in origin, mid-length, and terminal parts. DLMCT had the least average diameter. The DLMCO and DLMCM had a mean diameter of 3.82±0.71 and 3.76±0.48, respectively. The DLMCO had the widest average diameter. The significant positive

Table 2. Shows the T-test for the difference in the diameters of the left coronary artery between males and females (n=365).

t-test for Equality of Means						
		t	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
DLMCAO	Equal variances not assumed	-1.771	0.08	-0.14026	-0.29627	0.01575
DLMCAM	Equal variances not assumed	1.152	0.25	0.05455	-0.03855	0.14764
DLMCAT	Equal variances not assumed	6.270	0.000*	0.46883	0.32178	0.61588
DLMCA	Equal variances not assumed	0.667	0.51	0.04026	-0.07848	0.15900

**. Correlation is significant at the 0.01 level (2-tailed).

Levene's Test for Equality of Variances (0.05) in all groups. So, a T-test for equal variances that was not assumed was used. DLMCAO = diameter of the left coronary artery at origin; DLMCAM= diameter of the left coronary artery at midlength; DLMCAT= diameter of the left coronary artery at the terminal; DLMCA= average diameter of the left coronary artery.

Table 3. Shows the average diameters of the left coronary artery at opening, mid-length, termination, and average according to literature and current study (n=365).

Study	Gender	Methodology	Diameter				
			DLMCAO	DLMCAM	DLMCAT	DLMCA	Nationality
Current study	♂/♀	QCA	3.8±0.72	3.8±0.48	3.7±0.85	3.8±0.55	Sudanese
	♂		3.7±0.83	3.8±0.41	4.0±0.5	4.0±0.53	
	♀		3.7±0.83	3.7±0.50	3.5±0.94	3.95±0.63	
Goel, Liladhar Vora et al	♂/♀	IVUS	-	-	-	4.33 ± 0.32	India
		QCA	-	-	-	3.89 ± 0.25	
Raut, Patil et al.	♂	QCA	-	-	-	2.34±0.28	India
	♀		-	-	-	2.33±0.27	
Kulkarni and Paranjpe	♂/♀	Cadaveric	2.8 ± 1.0	-	-	-	India
Luckrajh et al.	♂/♀	Cadaveric	3.87	-	-	-	S. African
Nasr and El Tahlawi	♂	Cadaveric	4.46±0.68	-	-	-	Egyptian
	♀		4.38±0.74	-	-	-	
Ballesteros and Ramirez	♂/♀	Cadaveric	-	-	-	3.58 ± 0.59	Colombian
Zhou et al.	♂/♀	Angiograms				2.87±0.37	Chinese
Zindrou et al.	♂	QCA	-	-	-	4.5 ±0.9	Caucasian
						4.6± 0.9	S. Asians
Alhassen, Abdalla et al.	♂/♀	QCA	-	-	-	3.96±0.549	Sudanese
Manpoong et al.	♂/♀	CTA	-	-	-	4.38±0.58	India
Muneeb et al.	♂/♀	QCA	4.14 ±0.56	4.03±0.65	4.16±0.74	-	Pakistan
Turamanlar et al.	♂	QCA	-	-	-	4.59±0.8	Turkish
	♀		-	-	-	4.35±0.6	
Rezigalla	♂/♀	QCA	-	-	3.75±0.85	-	Sudanese

DLMCAO = diameter of the left coronary artery at origin; DLMCAM= diameter of the left coronary artery at mid-length; DLMCAT= diameter of the left coronary artery at the terminal; DLMCA= average diameter of the left coronary artery; IVUS=Intravascular Ultrasound, QCA = Quantitative Coronary Analysis, QCA =quantitative coronary angiography, ♂=Males, ♀=Females. S= South.

correlation between the three measured diameters indicates that a change in the diameter in the proximal part of the vessel is associated with a similar in the terminal part and possibly the subsequent parent and side branches. The diameter at the origin was less than reported by Muneeb et al., Luckrajh et al., and Nasr et al. and more than reported by Kulkarni et al.[19-22] (Table 3).

The average diameter of LMCA in the current study was 3.8±0.55 mm, which is less than reported by Goel et al., Zindrou et al., Alhassen et al., and Manpoong et al. [2,23-25]. Meanwhile, it was more than reported by Ballesteros et al., Raut et al., and Zhou et al. [26-28] (Table 3). Differences in the measured diameters across literature can be related to two main factors: the study methodology and the study group. In the study methodology, cadaveric materials are subjected to fixatives and mainly formalin-fixed. Fixatives are reported to cause tissue shrinking and possible constriction [29-31]. The effect of fixative can alter the vessel's diameter. Also, in cadaveric materials, the thickness of the vessel wall is measured as part of the total vessel diameter [32]. The thickness of the coronary artery wall was reported to range from 0.55 to 1.0 mm (0.75±0.17) in normal subjects [32]. Meanwhile, Angiogrfic methodology measures the luminal diameter, excluding the arterial wall thickness. These methods accurately measure the luminal diameter and determine the requested stent size. The study group is the second factor contributing to the differences in coronary diameter. The study group is governed by two determinates: the group's ethnicity and the domination of females among participants. Some ethnic groups had small coronary artery diameters [33,34]. Females were reported to have a small arterial diameter, and the domination of females in the study group or participants can lead to a small average [28,33,35]. In females, the small diameter of coronary arteries and the difference from males is not significantly related to weight, height, body surface index, body mass index, and left ventricular mass [35]. In addition, other authors reported a significant correlation between genetic factors, age, gender, heart weight, ethnicity, and environmental factors[34].

Despite the non-significant difference between the three measured diameters, the average of LMCA at DLMCAO, DLMCAM, and DLMCAT showed a gradual decrease among all participants. The percentage of decrease was 1.6% at DLMCAM and 0.27% at DLMCAT. The current finding of gradual decrease is supported by the previous work of Muneeb et al. (2023) on the right coronary artery and all, Dodge et al., Sandgren et al., Talalwah et al., and Getachew et al. on radial and femoral arteries [11,19,36-38]. They described that the diameter gradually decreased from the origin to the terminal part. Contrary to the current findings, Muneeb et al. (2023) didn't report the same on the left coronary artery [19]. The decrease in the artery diameter leads to increased blood flow velocity as the blood flow velocity is inversely associated with the vascular cross-sectional area [39]. Such a decrease in the vessel diameter maintains adequate blood perfusion to the distal parts due to increased blood velocity. Meanwhile, it was reported that the diameter of LMCA is inversely correlated with the severity of coronary heart disease as assessed by the Gensini score or vessel score [40].

In the current findings, the T-test showed a non-significant difference in the diameter at DLMCAO and DLMCAM; it was significant at the DLMCAT. Among male participants, the arterial diameter increased towards the terminal part. The percentage increase from DLMCAO to DLMCAM was 2.6%, and from DLMCAM to DLMCAT was 5.7%. Among females, the arterial diameter showed a gradual decrease in diameter, in accordance with the total participants, which was not consistent for males. The percentage of decrease in females was 5.7% from DLMCAM to DLMCAT, while the mean diameter from DLMCAO to DLMCAM remained without significant change. The difference in the body features or genetics between males and females cannot explain the increase or decrease in the arterial diameter towards the terminal part.

Managing coronary heart disease through a stent or balloon depends on solid knowledge about the vessel diameter, the operator's experience with the stent, and the characteristic features of the lesion [41,42]. The current findings showed that the average diameter of LMCA is larger than that of DLMCAO, DLMCAM, and DLMCAT. Thus, using a stent should be subject to the lesion site rather than the average diameter of the artery.

CONCLUSION

The diameter of the left coronary artery at the origin, mid-length, and terminal parts were 3.8±0.70 mm, 3.8±0.47 mm, and 3.7±0.84 mm, respectively. The average diameter of LMCA is larger than DLMCAO, DLMCAM, and DLMCAT. Females have smaller average diameters than males. Among all participants, there was no significant difference in the measured diameters at the origin, middle, and terminal parts, which accepts the study hypothesis. However, male and female participants showed significant differences between the measured diameters, mid-length, and terminal parts.

Study limitation.

- Few sample size.
- Limited literature.
- Using a single population.

Study strength

- The study is multicenter.
- The study provides a reference value for the diameter of the left coronary artery at the origin, mid-length, and terminal parts.
- The study described changes in the diameter of the left coronary artery along the artery length.

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Authors Contributions

All authors contributed to the study's conception and design. Muntaser Mohammed Alhassen, Assad Ali Rezigalla, Masoud I. E. Adam, Tahir Osman Ali performed material preparation, data collection, and analysis. The first draft of the manuscript was written by Muntaser Mohammed Alhassen, Assad Ali Rezigalla, and Tahir Osman Ali, and Magaji Garba Taura contributed to the analysis, interpretation and critical revision of the manuscript. All authors read and approved the final manuscript.

Potential Conflict of Interest: None

Competing Interest: None

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