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Original Article

Coronary Artery Dimensions as Determined by Intravascular Ultrasound in an Indian Population

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ABSTRACT

Background: Percutaneous coronary intervention (PCI) has remained one of the greatest treatment modalities of the spectrum of atherosclerotic coronary artery disease over the past few years due to its high efficacy and minimal invasiveness. The most common cause of stent failure is stenting under-expansion, which complicates PCI. Thus, it is tremendously important to perform PCI relying on the precise measurement of the size of the coronary artery obtained with the help of intracoronary imaging. There is limited data on the size of coronary arteries as measured by intravascular ultrasound (IVUS) in India and specifically in southern India. This study, conducted between January 2022 and March 2023, aimed to estimate the coronary artery dimensions, which can serve as a guide to PCI when intracoronary imaging is not available

Methods: A sample size of 165 patients with proven coronary artery disease undergoing IVUS-guided PCI during acute or chronic coronary syndrome were recruited, and coronary artery dimensions were measured in this research work. The mean arterial size and predictors of the arteries were reviewed.

Results: A total of 165 patients with 590 coronary artery segments were recruited: the mean left main (LM), external elastic membrane (EEM) diameter, and cross-sectional area (CSA) were 4.92 ± 0.41 mm and 17.83 ± 2.88 mm^2 proximal left anterior descending (LAD) artery, 3.75 ± 0.32 mm and 13.74 ± 2.45 mm^2 the mid-LAD 3.42 + 0.28 mm and 10.65 + 2.08 mm^2 the distal LAD 2.94 + 0.31 mm and 7.98 + 2.07 mm^2 the proximal left circumflex artery (LCX) 3.62 ± 0.32 mm and 11.67 ± 2.36mm^2, the distal LCX 2.91 ± 0.33 mm and 8.98 ± 2.22mm^2 the proximal right coronary artery (RCA) 4.17 ± 0.41 mm and 14.82 ± 2.78 mm^2 the mid-RCA 3.85 ± 0.36 mm and 12.94 ± 2.44 mm^2, the distal RCA 3.43 ± 0.30 mm and 11.08 ± 2.05 mm^2, respectively. The predictor of most epicardial coronary arteries is body surface area (BSA) with positive linear correlation.

Conclusions: Measurements of the coronary arteries obtained were comparable to the previous data on coronary artery size of Southeast Asia and Caucasian populations using IVUS. BSA is an independent predictor for the majority of epicardial coronary arteries with a positive linear relationship. Male gender and hypertension also positively correlate with larger coronary artery dimensions, while dyslipidemia leads to smaller coronary artery sizes. Neither diabetes nor smoking influences coronary artery size in the current study. Finally, the quantification of the size of the coronary artery will help the clinician to have a reference dimension in instances where there is no intravascular imaging available.

Key words: Dimensions of coronary arteries, South India, intravascular ultrasound, determinants of coronary artery size

INTRODUCTION

Percutaneous coronary intervention (PCI) has been one of the most significant treatment modalities of the entire spectrum of atherosclerotic coronary artery disease over the last few years, as it has a high degree of efficacy and is a minimally invasive procedure. [1] The most commonly used diagnostic tool in assessing the coronary anatomy and in guiding PCI procedures in the management of coronary artery disease is coronary angiography. Despite the relatively widespread availability of coronary angiography, it falls short because its measurements are two-dimensional, and it is just a luminogram. As a result, coronary angiography often fails to adequately visualize the vessel size, resulting in improper stent expansion, which causes the risk of stent thrombosis and restenosis. [2,3]

Nowadays, intravascular ultrasound (IVUS) has emerged as a significant supplement to angiography and aids in providing additional diagnostic data that are quickly changing established guidelines in the diagnosis and treatment of coronary artery disease. [4–6] The two major characteristics of IVUS that have been instrumental in its contribution to the treatment of coronary artery disease are the direct imaging of the vessel wall and the tomographic perspective. [4] IVUS enables precise tomographic measurement of the area of the lumen and the size, distribution, and, to some extent, composition of the plaque, whereas angiography shows only a two-dimensional silhouette of the lumen. Although IVUS has an independent value, the methodology in question must be viewed as an adjunct to angiography rather than a complete alternative. [5]

Even though angiography has been in use over the past 40 years or so as the most popular technique of defining the anatomy of coronary arteries, it has been associated with numerous challenges in terms of accuracy and repeatability, as explained in various studies. [6–9] In autopsy studies, coronary artery diseases are known to be diffuse, and there is no truly normal segment, but in angiography, the severity of the disease is determined by the measurement of the lumen diameter in the diseased segments and normal segments. Besides, early atherosclerosis may be hidden by outward remodeling of the vessel wall, which confounds angiography. Even though remodeled lesions do not necessarily limit the flow of blood, retrospective studies have shown that nonobstructive lesions are the most frequent substrate of acute coronary syndromes. [10–12]

In addition, angiogram interpretation is subject to high interobserver variability and shows little correlation with post-mortem examination owing to its visual nature of assessment. Angiography shows arteries as a two-dimensional profile of the contrast-filled vessel. The extent of luminal narrowing can be misrepresented by any arbitrary angiographic projection. The mechanical interventions can enhance luminal irregularity, which affects the quality of angiography. [13]

Intravascular imaging (IVUS) gives a better and improved picture of the size of the vessel as it penetrates at deeper levels and gives more accurate pictures and measurements of the artery size than conventional angiography. [14,15] PCI supported by intracoronary imaging has a lower target vessel failure and major adverse cardiovascular events than angiography. [15,16] The best stent size can be identified with the help of intracoronary imaging by measuring the distal reference lumen or external elastic membrane (EEM) diameter. The comparison between the minimal stent area and the reference lumen or EEM area can be used to determine adequate stent expansion. [13,15]

Despite the numerous and obvious advantages of IVUS compared to conventional angiography, most PCIs, especially in the developing world, are still guided by angiography rather than coronary imaging. [17] Several factors account for this low intracoronary imaging utilization in PCI, including but not limited to cost limitations, longer procedural time, lack of expertise in the use of imaging equipment, and higher risks of periprocedural complications. [16–19]

Since it has been established that angiography still guides the majority of PCIs, there is thus a need for more data on coronary artery dimensions to serve as guides and templates in different populations of the world. [20]

In this study, we measured the normal coronary artery dimensions in the Indian population using IVUS and attempted to propose values for normal coronary artery dimensions that can be used for stent size selection during coronary angioplasty in the same and similar population, especially when intravascular imaging is not readily available for PCI.

Justification: Knowledge of Coronary artery dimensions will aid in stent size selection during Angioplasty when/where IVUS and optical coherence tomography (OCT) equipment are not available, thereby helping to optimize Angioplasty. Currently, the availability of intravascular imaging (IVUS/OCT) is seriously limited to a few catheterization laboratories, even in the developed world.

MATERIALS AND METHODS

Study design, population, and setting

This is a retrospective cross-sectional study carried out at the cardiology department of Meditrina multispecialty and Expanded Staff Cooperative Insurance (ESCI) Specialist hospitals, both in Kollam, Kerala, South India, between January 2022 and March 2023. Out of the patients who received IVUS-guided PCI, 165 eligible patients were studied.

Definitions, inclusion, and exclusion criteria

Patients should have a confirmed diagnosis of coronary artery disease (chronic coronary syndrome [CCS]) with normal arterial segments or segments without significant stenosis to be eligible. During IVUS, atherosclerosis (<40% plaque area in the case of Left Main Coronary Artery (LMCA) and <50% in other coronary arteries) of the coronary artery to which the procedure is directed must be visualized. All left dominance systems, coronary artery anomalies, incomplete acquisition of images, the inability to obtain 180 or more degrees of the diameter, and 270 or more degrees of cross-sectional area (CSA) were excluded.

Baseline demographic data of all study participants, clinical characteristics data, electrocardiographic and echocardiographic parameters, laboratory results, and interventional procedure data were all retrieved from the medical records of patients and recorded by the lead investigator and other interventional cardiologists involved in this study. The patients were classified as CCS patients when they had symptomatic obstructive or non-obstructive atherosclerotic disease of epicardial arteries, previous acute coronary syndrome, recent revascularization, or left ventricular dysfunction. [20] Hypertension was defined as systolic blood pressure ≥140 mmHg and or diastolic blood pressure ≥90 mmHg at 2 to 3 office visits or patients taking antihypertensive drugs. [21] Dyslipidemia was also defined as total cholesterol 200 mg/dL or over, low-density lipoprotein C (LDL-C) 130 mg/dL or more, and high-density lipoprotein (HDL) 80 mg/dL or less, or patients on anti-hyperlipidemia medications. [22] T2DM was characterized by fasting blood sugar 126 mg/dL or higher, random blood sugar 200 mg/dL or higher, or HbA1c 6.5% or higher, or by patients taking an oral hyperglycemia agent. [23] Smoker was classified as currently, history of past cigarette smoking <5 years.

Ethical approval

This study protocol was cleared by the Ethics and Research Committee of Meditrina Multispecialty and ESCI hospitals, Kollam, Kerala. Written informed consent was obtained from all the patients. The study was aligned with the Declaration of Helsinki. Patients and the public were not involved in the design, conduct, reporting, or dissemination of this research.

Procedures

IVUS: A post-intravenous nitroglycerine IVUS was done using an OptiCross 40 mHz Coronary Imaging Catheter, Boston Scientific. By advancing the imaging catheter over the coronary wire, videotape recordings of the imaging were made to be analyzed later. Pullback was initiated at 15 mm distal to the lesion aorto-ostial junction with an automatic pullback speed of 0.5 mm/s. PCI was done as per the usual guidelines. One independent observer who did not know about patient details analyzed the IVUS DICOM with a Boston Scientific post-processing image viewer. The angiography was used to guide the placement of an IVUS catheter to determine each segment of the arteries. EEM, CSA, and diameter were measured in 10 to 15 mm proximal to any side branch with plaque burden less than 50% to exclude vessel remodeling. Automatic border detection was done on EEM. Measurement of diameter was done by taking the average of the longest and shortest diameters measured at the center point of the lumen using EEM. Following an automatic border detection of EEM. Manual correction was also done for the CSA measurement.

Statistical analysis

The SPSS version 26.0 (SPSS, Chicago, IL) was used to conduct all statistical tests. Numbers, percentages (%), and frequencies were used to show categorical data. The distribution of numerical data was analyzed by the student's test. In the case of normal distribution, data were presented as mean and standard deviation (mean ± standard deviation), while in the case of skewed distribution, median and interquartile range (median, interquartile range) were used to present data. Between-group comparison was done using an unpaired *t*-test in the case of normal distribution and the Mann-Whitney *U* test in the case of skewed distribution. The analysis of the predictor of coronary artery size was done through multiple linear regression and was shown as the Pearson beta coefficient. The statistical significance was *p*-value <0.05.

RESULTS

A total of one thousand and seventy-two patients had Angioplasty done within the study period at the Meditrina multispecialty and ESCI hospitals, out of which 22.5% (241 Patients) were IVUS-guided. Seventy-six patients were excluded, thus: due to incomplete visualization by IVUS, previous coronary artery bypass graft anatomy, [3] left dominance system [30], anomalous coronary arteries, [5] and stent deployed to the site of analysis. [3] Thus, research was done on 165 patients (590 coronary artery segments).

Baseline characteristics of the study population

Figure 1 illustrates patient enrolment in the graphical form. The average age of the patients was 54.82 ± 9.29 years old. Sixty-seven percent were men. The average BSA was 1.711 ± 0.18 m^2, and the average BMI was 25.67 ± 6.0 kg/m^2. Most of them were hypertensive (62.9%), 20.9% had Type 2 diabetes mellitus (DM), 36.6% of patients had dyslipidemia, also 10.9% were smokers. The mean left ventricular mass index (LVMI) was 134.74 ± 48.35 g/m^2, with 56% identified as left ventricular hypertrophy. Descriptive information on the baseline characteristics is shown in **Table 1**.

Coronary artery sizes

From the total of 590 coronary segments analyzed, the left main (LM) was analyzed most frequently with 95 segments, followed by proximal left anterior descending (LAD) 89 segments then mid-LAD 82 segments, distal LAD 79 segments, proximal left circumflex (LCX) 42 segments, distal LCX 31 segments, proximal right coronary artery (RCA) 59 segments, mid-RCA 58 segments and distal RCA 55 segments. The average diameter of LM and CSA were 4.92 ± 0.41 mm and 17.83 ± 2.88 mm^2, proximal LAD 3.75 ± 0.32 mm and 13.74 ± 2.45 mm^2, the mid-LAD 3.42 ± 0.28 mm and 10.65 ± 2.08 mm^2, the distal LAD 2.94 ± 0.31 mm and 7.98 ± 2.07 mm^2, the proximal LCX 3.62 ± 0.32 mm and 11.67 ± 2.36 mm^2, the distal LCX 2.91 ± 0.33 mm and 8.98 ± 2.22 mm^2, the proximal RCA 4.17 ± 0.41 mm and 14.84 ± 2.78 mm^2, the mid-RCA 3.85 ± 0.36 mm and 12.94 ± 2.54 mm^2, the distal RCA 3.43 ± 0.30 mm and 11.08 ± 2.05 mm^2, respectively.

The largest vessel was LM, followed by proximal RCA, proximal LAD, mid-RCA, proximal LCX, mid-LAD, distal RCA, distal LCX, and distal LAD (**Table 2**).

Tables 3 and 4 showed a comparison of the baseline demographic variables with the mean artery size (diameter and CSA). Artery sizes were generally larger in males than in females, reaching statistical significance ($p < 0.05$) concerning mid LAD, distal LAD, proximal LCx, and distal LCX.

Coronary artery size determinants

The coronary artery dimensions were found to be smaller in patients with dyslipidemia, most predominantly in the LCX, more than the other risk factors of hypertension, DM, and smoking, which exhibited minimal influence on the dimensions of the coronary arteries in this present study. In multiple

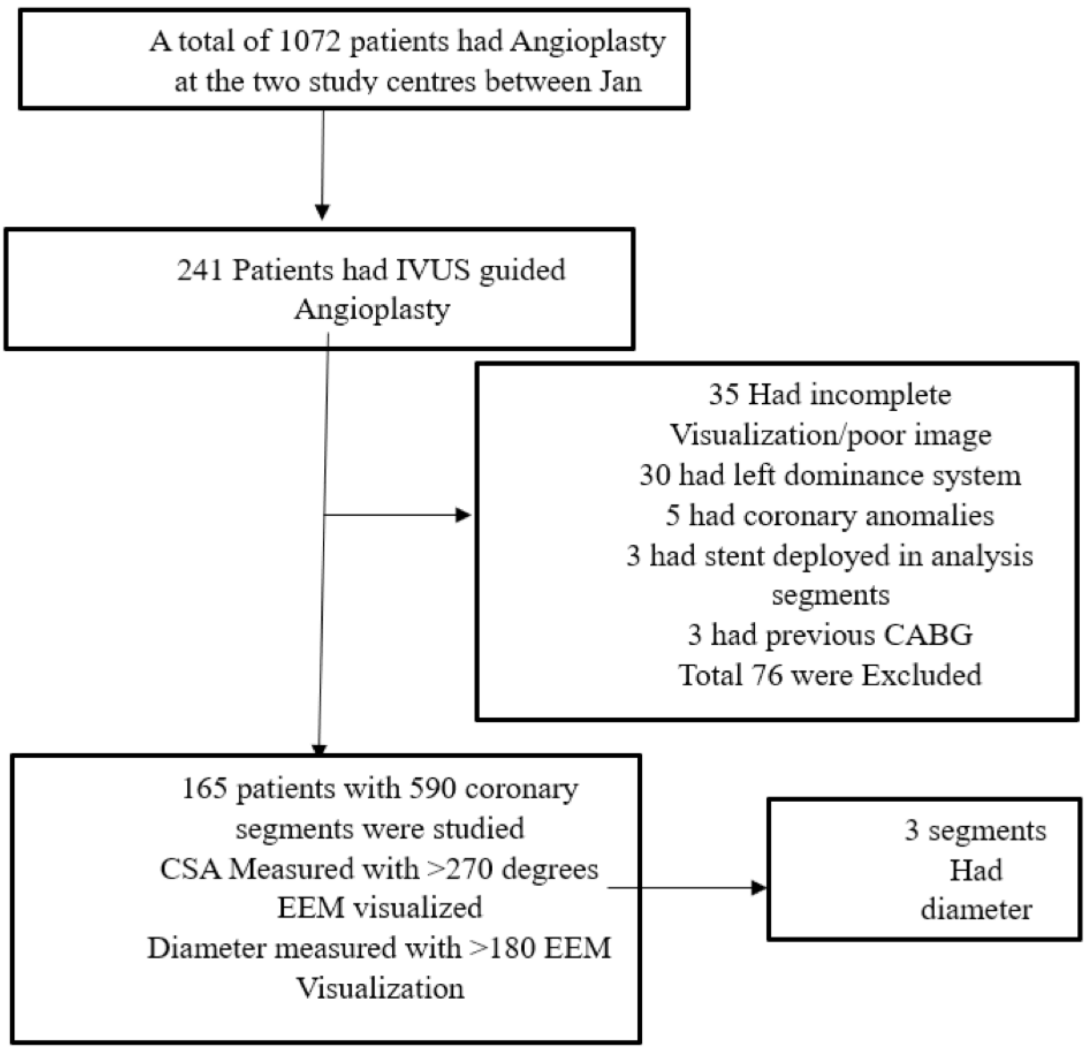

Figure 1: Patient enrollment. CABG: coronary artery bypass graft; CSA: cross-sectional area; EEM: external elastic membrane; IVUS: intravascular ultrasound.

Table 1: Baseline characteristics of the patients.

Variable	*N* = 165
Age (year)	54.82 ± 9.29
Sex	
Males (*n*, %)	112 (67.8%)
Females (*n*, %)	53 (32.2%)
Body weight (kg)	65 (34.00–101.00)
Body height (cm)	162.39 ± 7.86
BSA (m^2)	1.71 ± 0.18
BMI (kg/m^2)	25.67 ± 6.02
Hypertension (*n*, %)	98 (64.1%)
T2DM (*n*, %)	32 (20.9%)
Smoking (*n*, %)	18 (10.9%)
Dyslipidemia (*n*, %)	60 (36.6%)
LVMI (*n* = 168) (g/m^2)	134.74 ± 48.35

Data presented as number (%), mean ± standard deviation, or median (interquartile range).

BMI: body mass index; BSA: body surface area; T2 DM: diabetes mellitus type 2; LVMI: left ventricular mass index.

Table 2: Mean EEM coronary artery.

Artery	LM (100)	Proximal LAD (93)	Mid-LAD (89)	Distal LAD (85)	Proximal LCX (39)
Diameter (mm)	4.92 ± 0.41	3.75 ± 0.32	3.42 ± 0.28	2.94 ± 0.27	3.91 ± 0.42
CSA (mm^2)	17.83 ± 2.88	14.34 ± 2.85	11.70 ± 2.24	8.77 ± 2.54	12.07 ± 2.53

Artery	Distal LCX (35)	Proximal RCA (66)	Mid-RCA (65)	Distal RCA (61)
Diameter (mm)	3.51 ± 0.47	4.50 ± 0.48	4.10 ± 0.38	3.81 ± 0.41
CSA (mm^2)	9.90 (5.09–14.20)	16.14 ± 3.43	13.74 ± 2.72	11.59 ± 2.46

Data presented as mean ± standard deviation, or median (interquartile range); CSA: cross-sectional area; EEM: external elastic membrane; LAD: left anterior descending; LCX: left circumflex; LM: left main; RCA: right coronary artery.

Table 3: Comparison of EEM diameter with baseline demographic by IVUS.

	EEM Diameter LM (mm)	*p*-value	EEM Diameter Proximal LAD (mm)	*p*-value	EEM Diameter Mid LAD (mm)	*p*-value	EEM Diameter Distal LAD (mm)	*p*-value
Male	5.07 ± 0.403	0.077	4.29 ± 0.388	0.105	3.91 ± 0.368	0.020*	3.43(2.86–4.30)	0.010*
Female	4.89 ± 0.496		4.13 ± 0.512		3.70 ± 0.413		3.19(2.83–3.83)	
Diabetes	5.01 ± 0.506	0.869	4.29 ± 0.440	0.623	3.85 ± 0.441	0.909	3.33(2.89–4.30)	0.888
Non-diabetes	5.03 ± 0.413		4.24 ± 0.427		3.86 ± 0.374		3.32(2.83–4.12)	
Dyslipidemia	4.83 (3.93–5.86)	0.110	4.22 ± 0.491	0.643	3.83 ± 0.429	0.633	3.23(2.84–4.30)	0.887
Non-dyslipidemia	5.11(4.00–6.28)		4.27 ± 0.392		3.87 ± 0.367		3.39(2.83–3.96)	
Hypertensive	5.09 ± 0.408	0.059	4.28 ± 0.430	0.315	3.86 ± 0.401	0.808	3.38(2.83–4.30)	0.220
Non-hypertensive	4.92 ± 0.453		4.19 ± 0.425		3.84 ± 0.372		3.22(2.86–4.02)	
Smoking	5.03 ± 0.402	0.971	4.22 ± 0.387	0.345	3.87 ± 0.381	0.716	3.38(2.86–3.93)	0.536
Non-smoking	5.03 ± 0.483		4.30 ± 0.487		3.84 ± 0.406		3.21(2.83–4.30)	

	EEM Diameter Proximal LCX (mm)	*p*-value	EEM Diameter Distal LCX (mm)	*p*-value	EEM Diameter Proximal RCA (mm)	*p*-value	EEM Diameter Mid RCA (mm)	*p*-value	EEM Diameter Distal RCA (mm)	*p*-value
Male	3.98 ± 0.400	0.032*	3.60 ± 0.423	0.022*	4.53 ± 0.453	0.305	4.18 ± 0.408	0.357	3.84 ± 0.384	0.262
Female	3.63 ± 0.384		3.15 ± 0.530		4.37 ± 0.585		4.05 ± 0.481		3.69 ± 0.506	
Diabetics	3.74 ± 0.330	0.273	3.35 ± 0.457	0.407	4.57 ± 0.435	0.566	4.28 ± 0.377	0.271	3.87 ± 0.366	0.587
Non-diabetics	3.94 ± 0.428		3.54 ± 0.480		4.48 ± 0.490		4.13 ± 0.427		3.80 ± 0.419	
Dyslipidemia	3.70 ± 0.404	0.034*	3.27 ± 0.396	0.039*	4.39 ± 0.452	0.167	4.15(2.98–4.67)	0.501	3.70 ± 0.378	0.094
Non-dyslipidemia	4.00 ± 0.395		3.63 ± 0.474		4.56 ± 0.489		4.20 ± 0.448		3.88 ± 0.417	
Hypertensives	3.93 ± 0.424	0.690	3.52 ± 0.501	0.914	4.47 ± 0.537	0.585	4.12 ± 0.459	0.369	3.78 ± 0.435	0.517
Non-hypertensives	3.87 ± 0.417		3.50 ± 0.441		4.54 ± 0.385		4.22 ± 0.354		3.85 ± 0.372	
Smoking	4.01 ± 0.352	0.072	3.61 ± 0.393	0.154	4.54 ± 0.464	0.295	4.18 ± 0.424	0.506	3.84 ± 0.414	0.449
Non-smoking	3.76 ± 0.478		3.35 ± 0.567		4.41 ± 0.506		4.11 ± 0.417		3.76 ± 0.403	

Data presented as mean ± standard deviation or median (interquartile range); *p-value < 0.05; EEM: external elastic membrane; IVUS: intravascular ultrasound; LAD: left anterior descending; LCX: left circumflex; LM: left main; RCA: right coronary artery.

Table 4: Comparison of EEM CSA with baseline demographic by IVUS.

	EEM CSA LM (mm^2)	*p*-value	EEM CSA Proximal LAD (mm^2)	*p*-value	EEM CSA Mid LAD (mm^2)	*p*-value	EEM CSA Distal LAD (mm^2)	*p*-value
Male	20.27 ± 3.352	0.086	14.64 ± 2.550	0.053	12.04 ± 2.150	**0.013***	9.27(6.61–14.99)	**0.011***
Female	18.84 ± 3.758		13.09(9.43–24.55)		10.71 ± 2.230		8.28 ± 1.553	
Diabetics	19.82 ± 3.950	0.862	14.72 ± 2.930	0.494	11.79 ± 2.477	0.832	8.98(6.73–14.99)	0.653
Non-diabetics	19.97 ± 3.382		14.23 ± 2.847		11.67 ± 2.176		8.64(6.23–13.20)	
Dyslipidemia	19.12 ± 3.771	0.079	14.19 ± 3.327	0.693	11.58 ± 2.537	0.704	8.26(6.27–14.99)	0.993
Non- dyslipidemia	20.40 ± 3.250		14.43 ± 2.568		11.77 ± 2.058		9.02 ± 1.579	
Hypertensives	20.36 ± 3.358	0.107	14.57 ± 2.785	0.269	14.57 ± 2.785	0.704	9.24 ± 1.788	0.143
Non-hypertensives	19.19 ± 3.619		13.87 ± 2.806		13.87 ± 2.806		8.11(6.61–12.71)	
Smoking	19.95 ± 3.382	0.960	14.14 ± 2.515	0.431	11.72 ± 2.063	0.883	9.05 ± 1.390	0.557
Non-smoking	19.91 ± 3.702		14.67 ± 3.333		11.65 ± 2.508		8.09(6.23–14.99)	

	EEM CSA Proximal LCX (mm^2)	*p*-value	EEM CSA Distal LCX (mm^2)	*p*-value	EEM CSA Proximal RCA (mm^2)	*p*-value	EEM CSA Mid RCA (mm^2)	*p*-value	EEM CSA Distal RCA (mm^2)	*p*-value
Male	12.50 ± 2.516	**0.034***	10.35 ± 2.421	**0.039***	9.13 ± 3.177	0.290	13.89 ± 2.701	0.339	11.75 ± 2.349	0.271
Female	10.40 ± 1.901		8.00 ± 2.947		10.33 ± 2.274		13.02 ± 2.844		10.84 ± 2.918	
Diabetics	11.13 ± 1.698	0.324	8.95 ± 2.478	0.404	16.57 ± 3.042	0.632	14.51 ± 2.554	0.283	12.12 ± 2.190	0.434
Non-diabetics	12.24 ± 2.637		10.04 ± 2.702		16.04 ± 3.528		13.57 ± 2.752		11.47 ± 2.520	
Dyslipidemia	10.89 ± 2.341	0.051	8.42 ± 2.048	**0.026***	15.34 ± 2.977	0.141	13.77(7.16–16.70)	0.497	10.99 ± 2.252	0.127
Non-dyslipidemia	12.60 ± 2.472		10.55 ± 2.681		16.62 ± 3.626		14.04 ± 2.995		11.98 ± 2.539	
Hypertensives	12.18 ± 2.589	0.703	9.97 ± 2.826	0.791	15.93 ± 3.841	0.568	13.51 ± 2.921	0.413	11.36 ± 2.559	0.401
Non-hypertensives	11.85 ± 2.498		9.71 ± 2.435		16.43 ± 2.770		14.08 ± 2.408		11.91 ± 2.321	
Smoking	12.62 ± 2.202	0.087	10.33 ± 2.274	0.169	16.50 ± 3.427	0.231	13.94 ± 2.796	0.405	11.81 ± 2.499	0.331
Non-smoking	11.19 ± 2.842		7.77(5.09–13.72)		15.42 ± 3.395		13.34 ± 2.589		11.16 ± 2.382	

Data presented as mean ± standard deviation or median (interquartile range); *p-value < 0.05; CSA: cross-sectional area; EEM: external elastic membrane; IVUS: intravascular ultrasound; LAD: left anterior descending; LCX: left circumflex; LM: left main; RCA: right coronary artery.

linear regression, the BSA was found to be an independent predictor of most artery sizes, except for the LCX, which showed a positive linear correlation. Age was a beneficial non-dependent predictor of artery diameter (β = 0.008 [95% CI, 0.001–0.014] and p = 0.017) and CSA of distal LAD (β = 0.041 [95% CI, 0.008–0.074] and p = 0.017). Female gender was an adverse autonomous predictor of the artery diameter of the distal LCX (β = −0.453 [95% CI, −0.835 to −0.071] and p = 0.022) and the CSA of proximal LCX (β = −2.101 [95% CI, −4.039 to −1.163] and p 0.034). Hypertension was a positive independent predictor for the artery diameter of LM (β = 0.172 [95% CI, 0.006–0.337] and p = 0.043). Dyslipidemia was a detrimental independent predictor of the artery diameter of proximal LCX (ß = 0.292 [95% CI, 0.563–0.021] and p 0.036) and CSA of distal LCX (ß = 2.128 [95% CI, 3.984–0.272] and p = 0.026). Independent variables that emerged as significant predictors of vessel size are shown in **Tables 5 and 6**.

DISCUSSION

This study reported the dimensions of coronary arteries in a southern Indian population as measured by intravascular imaging. The diameters were determined to be 4.49 to 5.15 cm, 3.83 to 4.67 cm, 3.83 to 4.25 cm, 2.85 to 3.79 cm, 3.49 to 4.33 cm, 3.04 to 3.98 cm, 4.02 to 4.98 cm, 3.74 to 4.58 cm, 3.40 to 4.22 cm for the LM, proximal LAD artery, mid LAD, distal LAD, proximal left circumflex (LCx), distal LCx, proximal RCA, mid RCA, and distal RCA, respectively. The CSAs for the various arteries were as documented in **Table 1**. Results from the current study, compared to previous studies in Asians and Caucasians, suggest that southern Indians' coronary artery dimensions were similar to those of Caucasians' artery sizes but larger than those of other Asian cohorts. [24–26] These differences have been attributed to the contribution of body surface area (BSA), which, when discounted for, coronary artery dimensions are mostly similar in Asian and Caucasian populations. [25,27]

Genetics, age, gender, BSA, LVMI, and environmental factors are generally shown to influence coronary artery sizes. [24–26] Some previous studies have tried to compare coronary dimensions from different populations of North India, Caucasians, and South-East Asia, with variable similarities and differences in the values obtained. Results from this study, particularly LM, proximal LAD, and proximal LCx dimensions, were similar to data from other Indian cohorts and larger than those for other Southeast Asian populations. However, data obtained by Kim et al. showed that some South Asians' coronary artery sizes were larger than those of Indians. [24–28] These relatively variable results could be attributed to relative differences in the inclusion criteria used. Whereas one Indian study included coronary artery segments with <20% atheroma, another Indian study included plaque burden ±30%, and yet another study from Southeast Asia. Included diseased LM with a total plaque burden 40% to 70%. [26,28] In our study, we included the coronary artery segment with <50% plaque burden.

Table 5: Statistical significance of variables as predictors for EEM diameter (mm).

Artery	*p*-value								
	LM	Proximal LAD	Mid LAD	Distal LAD	Proximal LCX	Distal LCX	Proximal RCA	Mid RCA	Distal RCA
Age	0.756	0.565	0.290	**0.017***	0.511	0.768	0.534	0.508	0.420
Gender	0.955	0.302	0.255	0.125	0.504	**0.022***	0.505	0.565	0.939
BMI	0.890	0.589	0.811	0.706	0.495	0.560	0.651	0.129	0.977
BSA	**0.002***	**0.004***	**0.011***	**0.001***	0.739	0.689	**0.004***	**0.003***	**0.019***
DMT2	0.380	0.736	0.873	0.995	0.252	0.412	0.954	0.463	0.734
HT	**0.043***	0.295	0.980	0.551	0.352	0.916	0.655	0.466	0.690
Dyslipidemia	0.473	0.561	0.706	0.784	**0.036***	0.158	0.33	0.515	0.155
Smoking	0.791	0.239	0.834	0.448	0.253	0.459	0.753	0.618	0.927

BMI: body mass index; BSA: body surface area; EEM: external elastic membrane; DMT2: diabetes mellitus type 2; HT: hypertension; IVUS: intravascular ultrasound; LAD: left anterior descending; LCX: left circumflex; LM: left main; RCA: right coronary artery; **p*-value < 0.05.

Table 6: Statistical significance of variables as predictors for EEM CSA (mm^2).

Artery	*p*-value								
	LM	Proximal LAD	Mid LAD	Distal LAD	Proximal LCX	Distal LCX	Proximal RCA	Mid RCA	Distal RCA
Age	0.567	0.596	0.163	**0.017***	0.423	0.736	0.781	0.681	0.627
Gender	0.929	0.473	0.177	0.104	**0.034***	0.252	0.338	0.559	0.875
BMI	0.885	0.580	0.888	0.716	0.577	0.551	0.528	0.136	0.847
BSA	**0.000***	**0.004***	**0.011***	**0.001***	0.900	0.746	**0.002***	**0.005***	**0.017***
T2DM	0.449	0.583	0.874	0.686	0.344	0.395	0.852	0.446	0.588
HT	0,071	0.321	0.935	0.498	0.358	0.790	0.730	0.589	0.646
Dyslipidemia	0.378	0.606	0.700	0.668	0.075	**0.026***	0.266	0.438	0.199
Smoking	0.825	0.182	0.618	0.293	0.280	0.669	0.678	0.750	0.932

BMI: body mass index; BSA: body surface area; CSA: cross-sectional area; EEM: external elastic membrane; T2DM: diabetes mellitus type 2; HT: hypertension; IVUS: intravascular ultrasound; LAD: left anterior descending; LCX: left circumflex; LM: left main; RCA: right coronary artery; **p*-value < 0.0.

BSA has been consistently shown to exhibit a positive correlation with coronary dimensions in many studies. [24,26,28] A previous study from India found a linear relationship between BSA and LM coronary artery size. Our current study also showed that BSA is a positive independent predictor of dimensions in the majority of epicardial coronary arteries, especially LM, LAD, and RCA. This study may not have been sufficiently powered to establish BSA as a positive predictor for the LCX artery.

Data obtained by Sheifer and colleagues in their work showed that after correcting for BSA, females had smaller coronary dimensions compared to males. They propound that hormonal variations, especially differences in estrogen levels, may control vascular tone and size. [29] Similarly, Kim et al. showed that the LM artery dimensions in females were smaller than in males, even after adjusting for BSA, although BSA had a greater influence than sex. [24] However, data from the work of Reddy and colleagues found no significant difference in artery size between genders after adjusting for BSA. [26] In the current study, females had statistically significantly smaller coronary artery dimensions compared to males, particularly most pronounced with the LCX artery.

Hypertension was found to be a leading indicator of LM EEM diameter (*p*-value, 0.034). Reddy et al. revealed that hypertension was an influential factor in EEM CSA of LAD, and a positive correlation existed between the two. This is similar to data obtained from a past study that compared the LM CSA. [27]

In the study by Kozakoza et al., on the comparison of the LM CSA of hypertensive subjects and those with athlete heart using transesophageal echocardiography it was found that in hypertensive heart disease the LM CSA was positively correlated to the LV mass ($r = 0.40$, $p < 0.01$) and inversely with the systolic blood pressure ($r = -0.48$, $p < 0.01$). It is so since physiologic concentric Left Ventricular Hypertrophy (LVH) will augment the coronary flow reserve (CFR), thereby increasing LM luminal diameter. However, in uncontrolled hypertension, the CFR was reduced due to artery remodeling and poor endothelial function. [30]

In this study, 64% of patients had well-controlled blood pressure with a mean LVMI of 134.74 ± 48.35 g/m^2. Out of these, 48% were concentric LVH. That is why the patients with the hypertensive disease had a higher LM EEM diameter.

Researchers that have examined the correlation between coronary dimension and age have found no correlation between the two and have mostly produced inconsistent results most of the time. [29,31] According to Reddy et al., age was an independent predictor of LM and proximal LAD. [26] In our current research, age is an independent, significant predictor of distal LAD size with a small positive correlation.

A previous study that used autopsy data as a source indicated that the age factor had a minor predictive ability for EEM CSA, indicating that older patients had bigger coronary arteries. This could be because of age-related changes attributable to dilation of the coronary transverse and longitudinal dimensions. [32]

The research by Paul et al. propounded that patients with higher body mass index (BMI) had smaller coronary artery sizes. [31] They proposed that the higher the BMI, the more adipose tissue deposits in the heart, resulting in a smaller coronary artery size. [31] Data from the current research showed that BMI was not a significant predictor for coronary artery size; however, patients with dyslipidemia had smaller coronary dimensions, especially for the EEM diameter of proximal LCX and CSA of distal LCX, which may be due to positive remodeling. However, more data is needed to establish this relationship.

The current data showed an insignificant contribution of diabetes and smoking as independent correlators of coronary artery dimensions, similar to the findings from the research of Punamiya and colleagues, whose data also showed negligible predictive capacities of Diabetes and smoking, though they are well-known atherosclerosis risk factors. [28]

The current research is one of the few in an Indian population that used IVUS guidance to measure the coronary artery dimensions of all epicardial coronary arteries. Most previous data for coronary artery measurements were obtained using coronary angiography, with its attendant limitations in artery size estimation. Thus, the coronary artery size data obtained in the current research were relatively larger than those obtained from the few previous studies.

Study strengths and limitations

One of the strengths of this study is that it is relatively among the few that have attempted to determine coronary artery dimensions in a South Indian population. Secondly, it was conducted in two cardiac centers with a relatively large number of coronary artery segments involved (590 artery segments).

However, a major limitation is that it was not conducted in completely normal coronary arteries, though a major inclusion criterion is the presence of a significant plaque-free arterial segment to allow for IVUS measurement. Secondly, only one imaging modality (IVUS) was used for measurement. OCT was not used, but it is proposed as a methodology for further study.

CONCLUSIONS

The average coronary artery diameters of these South Indian cohorts were similar to the data obtained from past research, which used IVUS guidance to measure the coronary artery size of other Indian and Caucasian populations. BSA emerged as an independent predictor of most epicardial coronary arteries with a linear positive relationship. Male gender and hypertension exhibited a positive correlation with coronary artery dimensions, whereas dyslipidemia exhibited a negative correlation. Data from this study showed a negligible contribution of diabetes and smoking as predictors of coronary artery size. Finally, the knowledge of coronary artery size will help the clinician to have a reference dimension for intervention, especially when there is no intravascular imaging available.

AUTHORS' CONTRIBUTION

Each author has made a substantial contribution to the present work in one or more areas, including conception, study design, conduct, data collection, analysis, and interpretation.

All authors have given final approval of the version to be published, agreed on the journal to which the article has been submitted, and agree to be accountable for all aspects of the work.

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CONFLICT OF INTEREST

None.

REFERENCES

1. Ozan MD, Francesca L, Enrico P, Alessandra L. Contrast-induced nephropathy after percutaneous coronary intervention for chronic total occlusion versus non-occlusive coronary artery disease. Am J Cardiol. 2018;122:1837-1842.
2. Mintz GS, Matsumura M, Ali Z, Maehara A. Clinical utility of intravascular imaging: Past, present, and future. Cardiovasc Imaging. 2022;15:1799-1820.
3. Goel PK, Vora PL, Sahu AK, Khanna R. Left main coronary artery diameter–a correlation between intravascular ultrasound and quantitative coronary angiography. Indian Heart J. 2021;73:660-663.
4. Tobis JM, Mallery J, Mahon D, Lehmann K, Zalesky P, Griffith J, et al. Intravascular ultrasound imaging of human coronary arteries in vivo. Analysis of tissue characterizations with comparison to in vitro histological specimens. Circulation. 1991;83:913-926.
5. Nissen SE, Gurley JC, Grines CL, Booth DC, McClure R, Berk M, et al. Intravascular ultrasound assessment of lumen size and wall morphology in normal subjects and patients with coronary artery disease. Circulation. 1991;84:1087-1099.
6. Arnett EN, Isner JM, Redwood CR, Kent KM, Baker WP, Ackerstein H, et al. Coronary artery narrowing in coronary heart disease: Comparison of cineangiographic and necropsy findings. Ann Intern Med. 1979;91:350-356.
7. Grodin CM, Dydra I, Pastgernac A, Campeau L, Bourassa MG, Lespérance J. Discrepancies between cineangiographic and postmortem findings in patients with coronary artery disease and recent myocardial revascularization. Circulation. 1974;49:703-709.
8. Isner JM, Kishel J, Kent KM. Accuracy of angiographic determination of left main coronary arterial narrowing. Circulation. 1981;63:1056-1061.
9. Vlodaver Z, Frech R, van Tassel RA, Edwards JE. Correlation of the antemortem coronary arteriogram and the postmortem specimen. Circulation. 1973;47:162-168.
10. Zir LM, Miller SW, Dinsmore RE, Gilbert JP, Harthorne JW. Interobserver variability in coronary angiography. Circulation. 1976;53:627-632.
11. Galbraith JE, Murphy ML, Desoyza N. Coronary angiogram interpretation. Interobserver variability. JAMA. 1981;240:2053-2059.
12. Waller BF. “Crackers, breakers, stretchers, drillers, scrapers, shavers, burners, welders, and melters”: The future treatment of atherosclerotic coronary artery disease? A clinical morphologic assessment. J Am Coll Cardiol. 1989;13:969-987.
13. Mintz GS, Matsumura M, Ali Z, Maehara A. Clinical utility of intravascular imaging: Past, present, and future. Cardiovasc Imaging. 2022;15:1799-1820.
14. Goel PK, Vora PL, Sahu AK, Khanna R. Left main coronary artery diameter–a correlation between intravascular ultrasound and quantitative coronary angiography. Indian Heart J. 2021;73:660-663.
15. Räber L, Mintz GS, Koskinas KC, Johnson TW, Holm NR, Onuma Y et al. Clinical use of intracoronary imaging. Part 1: Guidance and optimization of coronary interventions. An expert consensus document of the European Association of Percutaneous Cardiovascular Interventions. Eur Heart J. 2018;39:3281-3300.
16. Lee JM, Choi KH, Bin SY, Lee J-Y, Lee S-J, Lee SY, et al. Intravascular imaging– guided or angiography-guided complex PCI. N Engl J Med. 2023;388:1668-1679.
17. Bergmark BA, Osborn EA, Ali ZA, Gupta A, Kolli KK, Prillinger JB et al. Association between intracoronary imaging during PCI and clinical outcomes in a real-world US Medicare population. J Soc Cardiovasc Angiogr Interv. 2023;2:100556.
18. Smilowitz NR, Mohananey D, Razzouk L, Weisz G, Slater JN. Impact and trends of intravascular imaging in diagnostic coronary angiography and percutaneous coronary intervention in inpatients in the United States. Catheter Cardiovasc Interv. 2023;92:E410-E415.
19. Low AF, Wongpraparut N, Chunhamaneewat N, Jeamanukoolkit A, Jhung LT, Zhen-Vin L, et al. Clinical use of optical coherence tomography during percutaneous coronary intervention and coronary procedures in Southeast Asia: A survey-based expert consensus summary. AsiaIntervention. 2023;9:25.
20. Knuuti J, Wijns W, Saraste A, Capodanno D, Barbato E, Funck-Brentano C, et al. 2019 ESC Guidelines for the diagnosis and management of chronic coronary syndromes. Eur Heart J. 2020;41:407-477.
21. Unger T, Borghi C, Charchar F, Khan NA, Poulter NR, Prabhakaran D, et al. 2020 International Society of Hypertension global hypertension practice guidelines. Hypertension. 2020;75:1334-1357.
22. National Cholesterol Education Program (US). Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). International Medical Publications; 2002.
23. Cosentino F, Grant PJ, Aboyans V, Bailey CJ, Ceriello A, Delgado V et al. 2019 ESC Guidelines on diabetes, pre-diabetes, and cardiovascular diseases. Eur Heart J. 2020;41:255-323.
24. Kim S, Apple S, Mintz GS, McMillan T, Caños DA, Maehara A, et al. The importance of gender on coronary artery size: In-vivo assessment by intravascular ultrasound. Clin Cardiol. 2004;27:291-294.
25. Skowronski J, Cho I, Mintz GS, Wolny R, Opolski MP, Cha MJ, et al. Inter-ethnic differences in normal coronary anatomy between Caucasian (Polish) and Asian (Korean) populations. Eur J Radiol. 2020;130:109185.
26. Reddy S, Kumar S, Kashyap JR, Rao R, Kadiyala V, Reddy H, et al. Coronary artery size in North Indian population–intravascular ultrasound-based study. Indian Heart J. 2019;71:412-417.

27. İbrahim K, Dönmez Y, Yildirim A, Ömer G, Acele A, Demirtaş A et al. Coronary artery dimensions, anatomic findings, and distributions of Southern Turkey. Dokuz Eylül Üniv Tıp Fak Derg. 2020;34:1-8.
28. Punamiya K, Jha T, Punamiya V, Pradham J. IVUS determination of normal left main stem artery size and plaque burden, and correlation with body surface area in an Indian population. AsiaIntervention. 2022;8:116-122.
29. Sheifer SE, Canos MR, Weinfurt KP, Arora UK, Mendelsohn FO, Gersh BJ, et al. Sex differences in coronary artery size assessed by intravascular ultrasound. Am Heart J. 2024;139:649-652.
30. Kozakova M, Paterni M, Bartolomucci F, Morizzo C, Rossi G, Galetta F, et al. Epicardial coronary artery size in hypertensive and physiologic left ventricular hypertrophy. Am J Hypertens. 2007;20:279-284.
31. Paul AD, Ashraf SM, Ezhilan J, Vijayakumar S, Kapadiya A. A milestone in prediction of the coronary artery dimensions from the multiple linear regression equation. Indian Heart J. 2019;71:328-333.
32. Roberts CS, Roberts WC. Cross-sectional area of the proximal portions of the three major epicardial coronary arteries in 98 necropsy patients with different coronary events: relationship to heart weight, age and sex. Circulation. 1980;62:953-959.