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Original Article

Anatomy Section

Morphometric Analysis of the Left Anterior Descending Artery using Coronary Angiograms: A Cross-sectional Study

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ABSTRACT

Introduction: Conventional Coronary Angiography (CAG) is the established procedure for the detection and quantification of coronary artery stenosis and myocardial perfusion defects. The left main coronary artery typically bifurcates into the Left Anterior Descending (LAD) and circumflex arteries. However, significant anatomical variations exist, particularly in the course and extent of the LAD artery as it supplies the cardiac apex. Understanding these morphometric variations, alongside cardiac dominance, is critical for accurate diagnostic and interventional procedures.

Aim: To investigate the morphometric characteristics of the LAD and its relationship with cardiac dominance in a patient population with normal angiograms.

Materials and Methods: The present cross-sectional study, conducted by the Anatomy and Cardiology Departments from November 2023 to May 2025 at the tertiary health Institution Dr RPGMC Tanda, Kangra, Himachal Pradesh, India, examined characteristics of the LAD artery in 381 patients aged 20-80 years with a normal coronary angiogram. Data on the LAD type, length, and diameter were collected. Data were analysed using descriptive statistics and inferential tests, including student's t-test and chi-square test, with a significance threshold of $p<0.05$.

Results: Type III was most frequent (n=365), followed by Type II (n=12) and Type I (n=4). The mean length of the LAD artery was 100.2±10.49 mm, while the mean LAD lumen diameter was 2.17±0.23 mm. There was no statistically significant difference among the three types of LAD (p=0.595). Right cardiac dominance was more prevalent (n=321), with 60 patients having left dominance.

Conclusion: Type III LAD and right cardiac dominance are the most prevalent anatomical patterns in the studied population. These findings are essential for optimising risk stratification and planning precision revascularisation procedures.

Keywords: Apex vascularity, Cardiac dominance, Cardiovascular diagnostics, Coronary morphometry, Myocardial perfusion

INTRODUCTION

Blood to the heart is supplied by the coronary arterial system, which comprises the right and left coronary arteries. The coronary arteries arise from the aorta through openings at the aortic root [1]. At the start of ascending aorta, the right coronary artery grows from the anterior sinus, while the left coronary artery evolves from the left posterior sinus. The left coronary artery generally exhibits numerous anatomical variations, variable dimensions, and segmental variations. Ostial angulation is a typical variant [2]. Each coronary artery primarily supplies its respective atrium and ventricle, but also contributes somewhat to the opposite side chambers. Variations in their anatomy can have clinical implications in cases of coronary artery disease [3]. The utmost type of division of the Left coronary artery is bifurcation, split to form the LAD artery and the left circumflex artery [4,5]. The blood to the left atrium is provided by the LAD artery, which is a part of the left ventricle and two-thirds of the septum [6]. LAD artery reaches the apex and may continue into the posterior interventricular groove to join right coronary artery branches. Understanding coronary distribution is essential for assessing total cardiac supply [7]. Variations in coronary blood supply are most commonly seen on the diaphragmatic surface of the ventricles. The origin of the posterior descending artery varies among individuals. In the most common Right Dominance (RD), the posterior descending artery arises from the right coronary artery [8]. Traditionally, the catheter angiography method was utilised for the analysis of coronary anomalies. However, the major drawback of the conventional method is that it is a two-dimensional modality that provides data for a composite three-dimensional anatomy [9]. Recent findings of Al-Omari IL et al., observed that the LAD wrapped around the apex in 53.8% of cases, while Mohan A et al., demonstrated that LAD dimensions often remain statistically similar across genders despite variations in other vessels [10,11]. There is a documented need for further morphometric studies to reconcile inconsistent data regarding gender-based vessel calibre and to establish localised anatomical baselines. The aim of the present study was to investigate the morphometric characteristics of the LAD and its relationship with cardiac dominance in a patient population with normal angiograms.

MATERIALS AND METHODS

The present cross-sectional study was conducted at Dr RPGMC Tanda, Kangra, Himachal Pradesh, India, in association with the Department of Anatomy and the Department of Cardiology from November 2023 to May 2025. Approval from the Institutional Ethical Committee vide letter no. HFW-H(DRPGMC)PRC/2023-125 dated 08/11/2023 was obtained.

Sample size calculation: Using Epi Info software version 7.2.3.1, with a 95% confidence level and 80% power, the calculated sample size was 381 individuals. The sample size is calculated based on research by Separham A et al., which reports a 54.8% incidence of RD [12]. The authors examined LAD artery type, length, and diameter in the angiogram and cardiac dominance.

Inclusion criteria: Patients who have been recommended for CAG and found to have normal angiograms.

Exclusion criteria:

- Patients who have recently experienced or are currently having an acute myocardial infarction;
- Patients whose age is below 20 years or above 80 years;

- Patients with a history of renal diseases, cardiomyopathies, or previous myocardial infarction.

There are three major anatomical types of the LAD artery, which are characterised as given below [11-13].

Type I is where the LAD finishes earlier, reaching the apex.

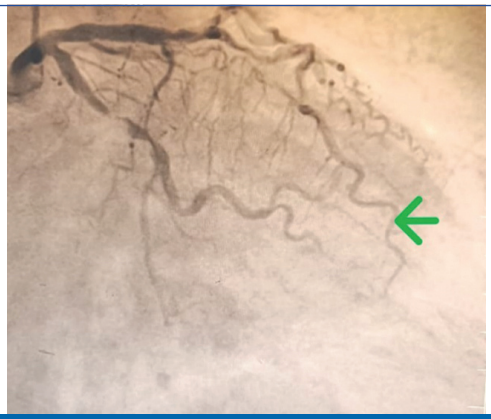
Type II is where the LAD extends up to the apex.

Type III is when the LAD wraps around the apex.

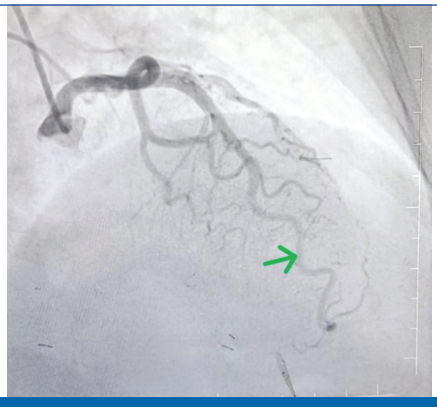
Study Procedure

For the purposes of lesion localisation, the LAD artery was divided into three segments based on established anatomical landmarks: the proximal LAD, extending from the bifurcation of the left main coronary artery to the origin of the first major septal perforator; the mid LAD, extending from the first septal perforator to the origin of the first major diagonal branch, and the distal LAD, defined as the remaining vessel distal to the first diagonal branch [14].

Cardiac dominance refers to the artery responsible for supplying the posterior interventricular septum. The RD, the most common type, occurs when the posterior descending artery originates from the right coronary artery. In left dominance, this artery arises from the left circumflex artery [7,8]. Cardiologists doing the procedure confirm the normal CAG pattern. After image acquisition on the Philips allura xper FD20 angiographic machine, the LAD was categorised as Type I, II, or III [Table/Fig-1,2], and LAD dimensions were assessed using a digital calliper. Coronary dimensions of the LAD artery were determined using quantitative coronary analysis software. To convert pixels to absolute units (mm), the system was calibrated using the known outer diameter of the contrast-filled diagnostic catheter. Lumen diameter and length were measured in the working view (primarily LAO Cranial) that showed the vessel at its maximum length with minimal foreshortening or vessel overlap [Table/Fig-3] [15]. To ensure the accuracy and reproducibility of the vascular measurements, all angiographic assessments were performed by 2-3 experienced interventional cardiologists, each with over five years of experience, who were blinded to the clinical data. To minimise intra-observer variability, each parameter (LAD diameter and length) was measured two times by the same observer, and the mean value was recorded.



[Table/Fig-1]: Angiogram of Type II LAD, which extend upto the apex.



[Table/Fig-2]: Angiogram of Type III LAD (arrow) which wraps around the cardiac apex.

[Table/Fig-3]: Angiographic image of LAD artery measurement.

STATISTICAL ANALYSIS

Data was analysed using Epi-Info software 7.2.6. Descriptive statistics, such as mean, range, frequency, percentage, and standard deviation, were used. Inferential statistics, including the chi-square test and independent t-test, were used to compare variables. Statistical significance was determined using a p-value <0.05.

RESULTS

A total of 381 subjects were analysed. Type III LAD was the most common variant, accounting for 365 cases (95.8%) of the total, while Type II LAD was present in 12 cases (3.28%) and Type I LAD in four cases (1.05%) [Table/Fig-4]. The mean length of the LAD artery was 100.2±10.49 mm, while the mean LAD lumen diameter was 2.17±0.23 mm [Table/Fig-5].

Gender	Type of LAD
Male (n=232)	I-3, II-3, III-226
Female (n=149)	I-1, II-9, III-139

[Table/Fig-4]: Gender based distribution of LAD type (N=381).

Parameter	Males (n=232)	Females (n=149)	Total (N=381)	p-value
LAD length (mm)	100.10±9.9	100.38±11.2	100.2±10.49	0.81
LAD lumen diameter (mm)	2.17±0.2	2.14±0.2	2.17±0.23	0.27

[Table/Fig-5]: Gender-based analysis of LAD dimensions; Independent t-test.

There was no statistically significant difference among the three types of LAD (p=0.595) [Table/Fig-6].

The results revealed that right cardiac dominance was the most prevalent, observed in 321 patients (84.3%), while left cardiac dominance was noted in 60 patients (15.7%). Analysis based on

Parameters	Type I	Type II	Type III	p-value
Mean length (mm)	99.32±13.22	97.86±9.93	100.88±10.50	0.595
Mean diameter (mm)	1.97±0.26	2.24±0.29	2.17±0.23	0.129

[Table/Fig-6]: Measurements of LAD in relation to Type of LAD; One-way analysis of variance test.

Parameters	Right dominance (RD)	Left dominance	p-value
Average LAD length (mm)	100.90±10.5	100.05±10.3	0.579
Average LAD lumen diameter (mm)	2.17±0.23	2.18±0.22	0.277

[Table/Fig-7]: Measurements of LAD in relation to cardiac dominance; Independent t-test.

Study	Population	Population size studied	Patients' age range	LAD type	Diameter	Length
Mohan A et al., 2023 [11]	South India	453 (257 males and 196 females)	20- >70 years	-	3.46±0.55 mm (Females) 3.54±0.48 (males)	-
Separham A et al., 2019 [12]	Iran	247 (97 males and 150 females)	27-79 years	Type III= 153 Type II= 75 Type I= 19		
Present study	North India	381 (232 males and 149 females)	20-80 years	Type III= 365 Type II= 12 Type I= 4	2.17±0.23 mm	100.10±9.9 (males) and 100.38±11.2 (females)

[Table/Fig-8]: Comparison of the present study with previous literature [11,12].

coronary dominance revealed no statistically significant differences in LAD length and lumen diameter [Table/Fig-7].

DISCUSSION

The current study provides a comprehensive analysis of anatomical variations in the LAD artery among patients undergoing routine CAG. In contrast to the 2019 study by Separham A et al., which identified a significant link between coronary dominance and LAD anatomical types ($p<0.001$), the present findings indicate no significant difference in the average length or lumen diameter of the LAD between right-dominant and left-dominant individuals ($p=0.579$; $p=0.277$) [12].

The present study revealed that Type III LAD was the most common variant. Studies of Ilia R et al., and Kobayashi N et al., have shown that Type III LAD is a significant independent predictor of major cardiac events in patients with anterior wall myocardial infarction undergoing primary percutaneous coronary interventions [16,17].

Ilia R et al., reported longer LADs in females and with worse outcomes [18]. In contrast, our study found no gender-based differences in LAD. The angiographic study conducted in north-east India by Manpoong CP et al., reported a mean LAD length and diameter of 109.46 ± 14.49 mm and 2.62 ± 0.5 mm; our findings were consistent with these results [19].

Ozturk E et al., analysed 356 coronary CT angiograms and reported a right dominant pattern in 87.1% of cases, with left dominance and balanced circulation occurring in 9.5% and 3.4%, respectively [20]. Similarly, a large-scale retrospective analysis of 500 coronary angiograms by Singh S et al., demonstrated that the RCA and LCA were dominant in 77.2% (386/500) and 9.8% (49/500) of cases, respectively, whereas co-dominance occurred in 13% (65/500) of the sample examined. The comparison with the previous studies has also been cited in [Table/Fig-8] [11,12,21].

Future research should transition toward large-scale multicentre trials across diverse ethnic cohorts to establish regional anatomical norms. It is recommended that future studies integrate functional flow assessments alongside anatomical mapping to clarify the physiological impact of Type III LAD variations.

Limitation(s)

First, the single-centre design may limit the generalisability of the present findings to broader, more diverse populations. Second, the assessment was restricted to anatomical parameters via CAG; the absence of functional assessments, such as fractional flow reserve or high-resolution imaging like intravascular ultrasound, means the physiological significance and detailed wall morphology were not evaluated. Finally, although the study included patients with visually normal coronary angiograms, the authors cannot entirely exclude the potential impact of latent co-morbidities.

CONCLUSION(S)

Type III LAD was the most common anatomical variation. Right cardiac dominance was significantly more common than left dominance. Accurate imaging of LAD dimensions and configuration is crucial for therapeutic interventions.

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