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Original Research Article

Anatomical variations in coronary artery origin, branching pattern, dominance and morphometry: a cadaveric study from Northeast India

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ABSTRACT

Background: The coronary arteries exhibited significant anatomical variability in its origin, branching pattern, and dominance. Accurate knowledge of these variations is essential for the interpretation of coronary angiography and the planning of percutaneous coronary intervention, coronary artery bypass grafting, and aortic root surgeries. Cadaveric studies provide detailed anatomical information that is invaluable for clinical practice.
Methods: A descriptive cross-sectional study was conducted on 30 formalin-fixed adult human cadaveric hearts in the Department of Anatomy, Regional Institute of Medical Sciences, Imphal, from July 2025 to March 2026 after Institutional Ethics Committee approval. Coronary arteries were dissected to evaluate the position of the coronary ostia relative to the sinotubular junction, branching pattern, coronary dominance, myocardial bridging, and anomalies. The length of the left coronary artery (LCA) trunk was measured using a digital Vernier caliper, and data were analyzed using IBM statistical package for the social sciences (SPSS) statistics version 26.
Results: The LCA ostium was located below the sinotubular junction in 86.7% of hearts, while the right coronary artery (RCA) ostium was below the junction in 80.0%. The LCA exhibited bifurcation in 60.0%, trifurcation in 26.7%, and tetra- and pentafurcation in 6.7% each. The sinoatrial nodal, conus, posterior interventricular, and right marginal arteries arose from the RCA in 96.7%, 86.7%, 90.0%, and 30.0% of specimens, respectively. Myocardial bridging was present in 20.0%, and a third coronary artery in 3.3%. The mean LCA trunk length was 9.34±3.39 mm. Right coronary dominance was observed in 86.7% of hearts.
Conclusions: Coronary arteries exhibited significant anatomical variability, particularly in the location of the coronary ostia and branching pattern of the LCA. These findings provide clinically relevant anatomical data that may improve the safety and accuracy of coronary imaging and surgical and interventional procedures.

Keywords: Coronary arteries, Coronary artery anomalies, Coronary dominance, Cadaver, Left coronary artery

INTRODUCTION

Cardiovascular diseases remain the leading cause of mortality worldwide, with coronary artery disease accounting for a major proportion of cardiovascular deaths. Advances in coronary angiography, coronary computed tomography angiography (CCTA), percutaneous coronary intervention (PCI), coronary artery bypass grafting (CABG), and transcatheter aortic valve implantation (TAVI) have greatly improved the diagnosis and management of coronary artery disease. The success and safety of these procedures depend on a precise understanding of coronary artery anatomy and its anatomical variations.

Normally, the right and left coronary arteries arise from the right and left aortic sinuses of the ascending aorta, respectively. The left coronary artery (LCA) typically divides into the left anterior descending (LAD) and left circumflex (LCx) arteries, although additional branches such as the ramus intermedius may be present. The right coronary artery (RCA) usually gives rise to the conus, sinoatrial nodal, right marginal, atrioventricular nodal, and posterior interventricular arteries. Considerable variation exists in the origin, branching pattern, course, and dominance of these vessels, reflecting normal developmental diversity.[1,3,4,5]

Recognition of these variations is clinically important because anomalous coronary anatomy may complicate coronary catheterization, PCI, CABG, aortic root surgery, and interpretation of coronary imaging. The location of the coronary ostia relative to the sinotubular junction influences selective coronary cannulation, whereas variations in coronary dominance determine the arterial supply of the inferior myocardium and atrioventricular node. Likewise, myocardial bridging and anomalous branching patterns may influence myocardial perfusion and procedural planning.[2,6]

Cadaveric dissection remains the reference standard for detailed evaluation of coronary artery anatomy because it allows direct visualization of arterial origin, branching pattern, and morphometry. Moreover, regional anatomical data are valuable because the prevalence of coronary artery variations differs among populations.[7]

Objective

The objective of the study was to evaluate the anatomical variations in the origin, branching pattern, dominance, and morphometry of the coronary arteries in adult human cadaveric hearts.

METHODS

This descriptive cross-sectional cadaveric study was conducted in the Department of Anatomy, Regional Institute of Medical Sciences (RIMS), Imphal, Manipur, India, from July 2025 to March 2026 after obtaining approval from the Institutional Ethics Committee (Approval No. A/206/REB/Prop(Sp)256/232/48/2025).

Thirty formalin-fixed adult human cadaveric hearts available during the study period were included. Only intact, well-preserved hearts with clearly identifiable coronary arteries and coronary ostia were examined. Hearts with gross congenital anomalies, extensive post-dissection damage, or poorly preserved coronary arteries were excluded. Information regarding age and sex of the cadavers was unavailable.

Following careful removal of epicardial fat, the coronary arteries were dissected from their origin to their terminal branches while preserving the major vessels. The ascending aorta was cleaned to identify the coronary ostia accurately.

The following parameters were evaluated: position of the right and left coronary ostia relative to the sinotubular junction (above or below the STJ); branching pattern of the left coronary artery (bifurcation, trifurcation, tetrafurcation, or pentafurcation); major branches of the right coronary artery, including the conus, sinoatrial nodal, right marginal, and posterior interventricular arteries; coronary dominance based on the origin of the posterior interventricular artery; anatomical variations such as myocardial bridging, third coronary artery, anomalous origin of coronary arteries, and variations involving the left circumflex and diagonal branches; and length of the left coronary artery trunk, measured from the centre of the left coronary ostium to its first division using a digital Vernier caliper (accuracy 0.01 mm).

Observations were recorded on a predesigned proforma and analysed using IBM statistical package for the social sciences (SPSS) statistics version 26.0. Continuous variables were expressed as mean±standard deviation, whereas categorical variables were presented as frequencies and percentages.

RESULTS

Thirty formalin-fixed adult human cadaveric hearts were examined.

Position of coronary ostia

The position of the coronary ostia relative to the sinotubular junction (STJ) is shown in Table 1. The LCA ostium was located below the STJ in 26 (86.7%) specimens and above it in 4 (13.3%). The RCA ostium was below the STJ in 24 (80.0%) specimens and above it in 6 (20.0%).

Table 1: Position of coronary ostia in relation to the sinotubular junction.

Position	LCA, N (%)	RCA, N (%)
Above STJ	4 (13.3)	6 (20.0)
Below STJ	26 (86.7)	24 (80.0)

Branching pattern of the left coronary artery

The bifurcation of the coronary artery was the most frequent pattern observed in 18 (60.0%) specimens, followed by trifurcation 8 (26.7%). Tetrafurcation and pentafurcation were each observed in 2 (6.7%) of specimens (Figure 1).

Branches of the right coronary artery

The sinoatrial nodal artery most commonly arose from the RCA in 29 (96.7%) specimens, followed by the posterior interventricular artery in 27(90.0%) specimens, conus artery in 26 (86.7%) specimens, and right marginal artery in 9 (30.0%) specimens (Figure 2).

Coronary dominance

The right coronary dominance predominated in 26 (86.7%), while left dominance and co-dominance were observed in 3 (10.0%) and 1 (3.3%) of specimens, respectively.

Figure 1: Tetrafurcation branching pattern of LCA.

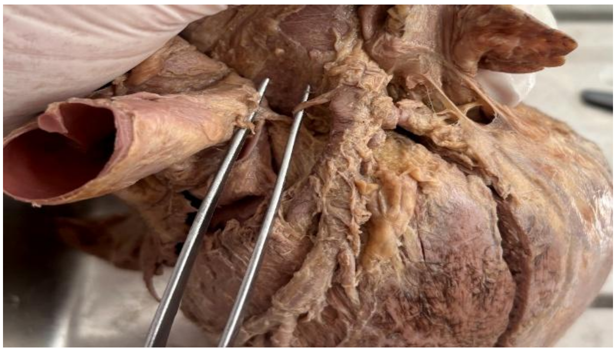

Figure 2: Conus artery arising from the right coronary artery.

Coronary artery variations

Coronary artery variations are summarized in Table 2. Myocardial bridging was observed in 6 (20.0%) specimens, predominantly involving the LAD (4 cases), with one case each involving the diagonal artery (Figure 3) and posterior interventricular artery. LCx arising from a diagonal branch (Figure 4), diagonal branch arising directly from LAD and a third coronary artery (Figure 5) were each identified in one specimen (3.3%). No coronary artery originated from the pulmonary artery or the non-coronary sinus (Table 2 and Figures 3-5).

Figure 3: Myocardial bridging involving diagonal artery.

Figure 4: Circumflex artery arising from diagonal artery.

Figure 5: Third coronary artery arising from anterior aortic sinus.

Table 2: Coronary artery variations.

Variation	Number	Percentage
Myocardial bridging	6	20.0
LCx arising from a diagonal branch	1	3.3
Diagonal branch arising directly from LAD	1	3.3
Third coronary artery	1	3.3
Coronary artery arising from pulmonary artery	0	0
Coronary artery arising from non-coronary sinus	0	0

Morphometry of the left coronary artery

The length of the LCA trunk ranged from 4.0 to 17.0 mm, with a mean of 9.34±3.39 mm.

DISCUSSION

Coronary artery anatomy demonstrates considerable variation in the origin, branching pattern, dominance, and course of its vessels. Recognition of these variations is essential for accurate interpretation of coronary angiography, planning of PCI, CABG, transcatheter aortic valve implantation (TAVI), and other cardiac procedures.

The present cadaveric study provides baseline anatomical data on coronary artery morphology in a Northeast Indian population.

Position of the coronary ostia

Most LCA (86.7%) and RCA (80.0%) ostia were located below the sinotubular junction (STJ). This finding agrees with previous cadaveric studies by Ravi et al, Manju et al, Bhimalli et al, Kalpana, and others, which consistently reported the coronary ostia predominantly below the STJ. Minor differences in prevalence among studies are likely attributable to ethnic diversity, sample size, and methodological variations. Knowledge of ostial location is clinically important because high or ectopic coronary origins may complicate selective coronary cannulation and aortic root procedures.[2,9-11,14]

Branching pattern of the left coronary artery

Bifurcation was the predominant branching pattern (60%), followed by trifurcation (26.7%), while tetra- and pentafurcation were uncommon. These findings are comparable to those reported by Baptista et al, Ballesteros et al, Cavalcanti et al, Ravi et al, and Kalpana (Table 3), confirming bifurcation as the usual anatomical pattern. Additional branches, such as the ramus intermedius, may influence myocardial perfusion and should be recognized during coronary angiography and surgical revascularization to ensure complete myocardial perfusion (Table 3).[2,8,10,11,13,15,18]

Table 3: Comparison of the branching pattern of the left coronary artery with previous studies.

Authors	Bifurcation (%)	Trifurcation (%)	Tetrafurcation (%)	Pentafurcation (%)
Baptista et al[8]	54.70	38.70	6.70	–
Calvacanti et al[18]	60.00	38.18	–	–
Kalpana et al[11]	47.00	40.00	11.00	1.00
Bhimalli et al[10]	56.66	33.30	8.30	1.00
Ballesteros et al[13]	70.00	36.00	5.80	–
Dharmendra et al[15]	58.06	35.48	6.45	–
Ravi et al[2]	80.00	13.30	3.30	3.30
Present study	60.00	26.70	6.70	6.70

Branches of the right coronary artery

The sinoatrial nodal artery arose from the RCA in 96.7% of specimens, a higher frequency than reported by Uemura et al, Ramanathan et al, and Bhimalli et al as shown in Table 4. The conus and posterior interventricular arteries also originated predominantly from the RCA, reflecting the high prevalence of right coronary dominance in the present study. These variations are clinically relevant because inadvertent injury to these vessels during cardiac surgery or interventional procedures may compromise myocardial perfusion or produce conduction abnormalities (Table 4).[10,23,24]

Table 4: Comparison of the origin of the SA nodal artery from the RCA.

Authors	Origin from RCA (%)
Uemura et al[23]	60.0
Ramanathan et al[24]	53.3
Bhimalli et al[10]	66.7
Present study	96.7

Coronary dominance

Right coronary dominance (86.7%) was the predominant pattern, whereas left dominance (10%) and co-dominance (3.3%) were less common. These observations are consistent with the classical description and previous anatomical studies, although the prevalence of right dominance in the present study was higher than that reported in several populations. Differences in coronary dominance among studies may reflect ethnic, geographical, and methodological variations. Since coronary dominance determines blood supply to the inferior wall of the heart and the atrioventricular node, its recognition is important during PCI, CABG, and interpretation of myocardial infarction (Table 5).[10,12,17,20,22,25]

Table 5: Comparison of coronary dominance pattern with previous studies.

Authors	Right dominance (%)	Left dominance (%)	Co-dominance (%)
James[17]	70–85	8–10	5–20*
Ortale et al[25]	62.5	12.5	25.0
Kurjia et al[22]	46.0	14.0	40.0
Loukas et al[12]	55.0	24.0	21.0
Fazliogullari et al[20]	42.0	14.0	44.0
Bhimalli et al[10]	66.7	23.3	NR
Present study	86.7	10.0	3.3

Coronary artery variations

Myocardial bridging was observed in 20% of specimens, most frequently involving the LAD, consistent with previous cadaveric and imaging studies. Although often asymptomatic, myocardial bridging has been associated with myocardial ischemia, arrhythmias, and acute coronary syndromes in selected patients. A third coronary artery was identified in one specimen (3.3%), while rare variations involving the LCx and diagonal branches were also observed.

No coronary artery originated from the pulmonary artery or the non-coronary sinus. Awareness of such uncommon variations is essential to avoid diagnostic errors and procedural complications during coronary angiography and cardiac surgery.[19,21,26-29]

Morphometry of the left coronary artery

The mean LCA trunk length was 9.34±3.39 mm, comparable to values reported by Green et al, Ballesteros et al, and Dharmendra et al. Variability in LCA length has important procedural implications because a short left main trunk may increase the risk of inadvertent selective cannulation of its terminal branches and may influence surgical and interventional planning.[13,15,16]

Clinical significance

The present findings emphasize the need for detailed knowledge of coronary artery anatomy during coronary angiography, PCI, CABG, TAVI, and aortic root surgery. Recognition of variations in coronary ostia, branching pattern, dominance, myocardial bridging, and anomalous vessels can improve procedural planning, reduce perioperative complications, and facilitate accurate interpretation of coronary imaging.[28,29]

Strengths

This study provides comprehensive cadaveric data on coronary artery anatomy in a Northeast Indian population, including coronary ostia, branching pattern, coronary dominance, myocardial bridging, coronary anomalies, and LCA morphometry. Direct dissection enabled accurate identification of anatomical variations that may not be evident on imaging, providing clinically relevant baseline data for anatomists, cardiologists, radiologists, and cardiovascular surgeons.

Limitations

The study was limited by its relatively small sample size (30 cadaveric hearts) from a single institution. Demographic details such as age, sex, cause of death, and cardiovascular history were unavailable, and the findings were not correlated with radiological or clinical data. Larger multicentre studies with imaging correlation are needed to improve generalizability.

CONCLUSION

The present cadaveric study demonstrates significant variations in the origin, branching pattern, dominance, and morphometry of the coronary arteries. Coronary ostia were predominantly located below the sinotubular junction, bifurcation was the commonest LCA branching pattern, and right coronary dominance predominated. Myocardial bridging and rare coronary anomalies were also identified. These findings provide valuable anatomical data for the Northeast Indian population and may improve the safety and accuracy of coronary angiography, percutaneous coronary intervention, coronary artery bypass grafting, and aortic root surgery.

Recommendations

Future studies with larger, multicentre populations should evaluate regional variations in coronary anatomy and correlate cadaveric findings with coronary CT angiography and conventional angiography. Further morphometric analyses, including coronary artery diameter, ostial dimensions, and distances from anatomical landmarks, would enhance their clinical applicability.

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