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Research Article

Gross Anatomical Study of Coronary Artery Dominance in Human Hearts

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Abstract: ***Introduction:*** Coronary artery dominance is a core fundamental index of cardiac anatomy. It directly determines the blood supply characteristics and patterns of the heart's posterior interventricular septum and atrioventricular node. It carries important clinical value for surgical revascularization, interventional cardiology practice, pathological interpretation of forensic autopsies, diagnosis and treatment of ischemic heart disease, and prognostic assessment of coronary artery bypass grafting, and can provide key references for cardiologists, cardiac surgeons, and anatomists. This study is a cross-sectional observational study conducted at a tertiary care center in Pune, India, with a study period spanning from January 2024 to April 2025. A total of 30 formalin-fixed human cadaveric heart samples were included in the study. Classification of dominance was based on the posterior interventricular artery (PIVA), and data were analyzed using descriptive statistics and the chi-square test. The results showed that right coronary dominance accounted for 70%, left coronary dominance for 16.67%, and balanced (codominant) coronary circulation for 13.33%. Additionally, 20% of the samples presented with coronary artery ostial variations. The conclusions on the distribution of coronary artery dominance drawn from this study align with the findings of previous similar studies published both globally and within India. It is recommended that future research expand the sample size and conduct further exploration combined with imaging techniques.

Keywords: Coronary artery dominance; Right dominant; Left dominant; Posterior interventricular artery; Cardiac anatomy; Coronary variations; Cadaveric study; Pune; India

INTRODUCTION

As the core organ of the cardiovascular system, the heart's normal function relies on support from a dedicated blood supply network. The coronary arteries are the core structures that deliver blood to the myocardium. The academic community uses the concept of coronary dominance to define the classification characteristics of coronary blood supply 1[3]. The core criterion for determining this concept is the origin of the posterior interventricular artery (PIVA, also called the posterior descending artery, PDA). The major coronary arteries involved include the right coronary artery (RCA) and the left coronary artery (LCA, which encompasses the left anterior descending artery (LAD) and the left circumflex artery (LCX)). This classification is divided into three specific types: the right-dominant type, in which the PIVA originates from the right coronary artery; the left-dominant type, in which the PIVA originates from the left circumflex artery; and the balanced type, which receives shared blood supply from both sides.

The clinical relevance of coronary artery dominance cannot be overstated. It is the core foundation supporting the anatomical blood supply of the heart, linked to the blood supply logic of the atrioventricular node (AV) and the right coronary artery (RCA), and it plays a critical role in electrocardiogram (ECG) diagnosis, percutaneous coronary intervention (PCI), and coronary artery bypass grafting (CABG). This established value is supported by references [4,5], while reference [6] further confirms the differences in disease incidence and interventional procedure needs between populations with right-dominant and left-dominant coronary circulation. Far from being an irrelevant anatomical curiosity, it is a core parameter that directly impacts clinical diagnosis and treatment decision-making.

Previous anatomical studies[7,8,9,10] have thoroughly documented morphological variations of the coronary arteries, and the distribution of coronary artery dominance types among populations from different regions and ethnic groups has been widely reported: globally, the right-dominant type, the most prevalent form, accounts for 70%–90% of cases, the co-dominant type accounts for 10%–20%, and the left-dominant type accounts for 5%–15%. However, significant heterogeneity exists across these studies due to differences in research methods, sample sizes, study populations, and definitional criteria. Relevant local research focused on the Indian population remains scarce. Overall, existing findings from India align with international trends, with variations only in the occurrence frequency of the balanced type in a few regional subgroups. Currently, the vast majority of cardiac surgeries in India are concentrated in high-volume tertiary Class A centers, so accurate baseline anatomical data of the local Indian population carries value for both scientific research and clinical surgical practice.

According to existing research[11], gross cadaveric dissection remains the gold standard for obtaining direct, accurate morphological data on coronary arteries. Compared with the three limitations of coronary CT angiography and conventional catheter coronary angiography namely restricted imaging timing, motion interference, and reconstruction artifacts[12,13] this dissection method has clear advantages. This study used 30 formalin-fixed human heart specimens collected between January 2024 and April 2025 from the Department of Anatomy of a tertiary medical institution in Pune, Maharashtra, India. It aims to systematically document the gross anatomical patterns of coronary artery dominance types, supplement local anatomical validation data, and build a reference framework for clinical application.

2. OBJECTIVE

This study is a gross anatomical study of coronary arteries in human cadaveric hearts, conducted at a tertiary medical center in Pune, India. The study samples are human cadaveric hearts collected between January 2024 and April 2025. Its primary core objective is to clarify the classification characteristics of the three coronary dominance types: right-dominant, left-dominant, and balanced. The study also has three additional research objectives: to observe coronary artery caliber and the origin and branching patterns of the posterior interventricular artery, to screen for all types of coronary artery ostial abnormalities, and to analyze the correlations between coronary dominance type and gross cardiac morphology, donor age, and donor sex.

This study sets three categories of research objectives arranged by logical priority: the first is a secondary objective, which aims to compare the findings of this study with publicly available autopsy and imaging research data from countries across the world and within India, to anchor the academic context of this study's results; the second is an application objective, which serves four categories of practitioners in central India to support the development of anatomy teaching syllabi for local medical colleges; the last is a supplementary objective, which aims to identify morphological variations with potential clinical significance that cannot be detected by imaging alone.

MATERIALS AND METHODS

This cross-sectional observational autopsy study was conducted at the Department of Anatomy of a tertiary teaching hospital in Pune, Maharashtra, India, spanning the period from January 2024 to April 2025. A total of 30 formalin-fixed adult cadaveric hearts were included in the study; all specimens were sourced from the institution's body donation program and forensic autopsies from a collaborating mortuary. This study obtained ethical approval (reference number IEC/2023/AN/047). Consent for the use of all specimens was secured, either from the donors themselves prior to death or from their immediate next of kin. The study strictly complied with India's Transplantation of Human Organs Act, 1994 (amended 2011) and all anatomy acts applicable in the state of Maharashtra. When harvesting the hearts, the proximal segment of the aorta and the trunk of the main pulmonary artery were retained to support subsequent analysis.

The heart specimens used in this study were first fixed in 10% neutral buffered formalin for at least 72 hours before any subsequent dissection procedures were carried out: the entire process of gross dissection was completed under sufficient lighting using standard anatomical instruments. Excess epicardial fat was first removed to fully expose the coronary vessels, and the anatomical courses of the right coronary artery (RCA), left main coronary artery and its branches the left anterior descending artery, left circumflex artery (LCX), and posterior interventricular artery (PIVA) were traced sequentially. Coronary dominance classification followed the rules set out in reference [2], and was divided into three categories: right-dominant, left-dominant, and balanced. The corresponding criteria for each type are as follows: the PIVA originates from the RCA for the right-dominant type; the PIVA originates from the LCX for the left-dominant type; and both vessels send branches into the posterior interventricular sulcus for the balanced type. All coronary artery diameters were uniformly measured at a standardized site 1 cm from the vessel's ostium, using a vernier caliper with a precision of 0.01 mm. Meanwhile, morphological information including the location of coronary ostia, accessory ostia, high-origin arteries, and supernumerary branches was recorded, and all data were entered into a structured data collection form.

Inclusion Criteria

(i) Formalin-fixed adult human cadaveric hearts with intact proximal aortic roots enabling identification of coronary ostia; (ii) hearts from donors of both sexes above the age of 18 years; (iii) specimens with grossly patent coronary arteries permitting complete macroscopic tracing; (iv) hearts procured with appropriate ethical clearance and consent documentation.

Exclusion Criteria

(i) Hearts with evidence of previous cardiac surgery, including CABG grafts, valve replacement, or septal repair; (ii) specimens with severe atherosclerotic calcification precluding vessel identification; (iii) congenitally malformed hearts including those with transposition of great arteries, tetralogy of Fallot, or anomalous coronary origin; (iv) specimens with extensive post-mortem decomposition or autolytic changes obscuring coronary anatomy; (v) paediatric hearts from donors below the age of 18 years.

Data Collection Procedure

In the anatomical specimen study of this research, two trained anatomists independently entered all data into a pre-designed structured recording form during dissection procedures. When discrepancies arose, a unified conclusion was reached through consensus. The 7 anatomical variables to be recorded include the origin of the posterior interventricular artery, the outer diameter of the left and right coronary artery openings measured 1 cm from the ostium, opening variation, the number of terminal branches of the right coronary artery and left circumflex artery, and gross morphological variation, among others. All specimens were photographed and archived using a designated calibrated model of digital camera, and all measurements were completed by the same researcher to ensure intra-observer consistency.

Statistical Data Analysis

All collected data were entered into Microsoft Excel 2019 and analysed using SPSS Statistics version 26.0 (IBM Corp., Armonk, NY). Descriptive statistics including frequencies, percentages, means, and standard deviations were computed for all continuous and categorical variables. The association between coronary dominance pattern and sex was assessed using the Chi-square test. The relationship between dominance type and age group was evaluated using the Fisher's exact test owing to low expected cell counts. A p-value of < 0.05 was considered statistically significant. Results were presented in tabular and graphical form. Morphological measurements were expressed as mean ± standard deviation (SD).

RESULTS

This study enrolled 30 human cadaveric heart specimens, and the detailed demographic data of the samples are shown in Table 1: the sample included 18 males (60%) and 12 females (40%), with an age range of 21 to 70 years. The largest age subgroup was the 41–50 year group (n=8, 26.67%). Data on coronary artery classification are presented in Table 2 and Figure 2. The right-dominant coronary pattern was the most common (21 cases, 70%), followed by the left-dominant pattern (5 cases, 16.67%) and the balanced type (4 cases, 13.33%). The average outer diameter of the right coronary artery measured 1 cm outside its opening was 3.41±0.52 mm, while the average outer diameter of the left main coronary artery was 4.12±0.61 mm. The average length of the posterior interventricular artery in right-dominant cases was 7.3±1.2 cm, which was significantly longer than the 5.8±0.9 cm recorded for left-dominant cases. This observed difference is consistent with the findings reported in reference [14].

In the sample of this study, the origin of the posterior interventricular artery (PIVA) of all subjects matched their dominant coronary artery supply type. The sample included 21 cases of right-dominant hearts, 5 cases of left-dominant hearts, and 4 cases of balanced hearts. When analyzed separately by gender, there were 18 male subjects and 12 female subjects. A chi-square test confirmed that there was no statistically significant association between gender and coronary supply dominance type ($p=0.932$). The relevant data on these types are listed in Table 3, and the age group distribution is recorded in Figure 1.

This study included 30 cardiac anatomical specimens to carry out coronary artery detection and statistical analysis. A total of 10 cases of coronary artery morphological variations were detected, accounting for 33.33% of all specimens, as detailed in Table 4. These variations cover 6 specific types, including 3 cases of accessory coronary artery ostia. Among them, the 1 case with abnormal origin of the left anterior descending artery (LAD) from the right coronary artery (RCA) was determined to have the most significant clinical implications. Via ANOVA analysis, the average diameter of the RCA in right-dominant hearts was 3.61±0.49 mm, which was significantly larger than that of left-dominant hearts (2.84±0.38 mm) and balanced-type hearts (3.12±0.42 mm), with $p=0.018$, as detailed in Table 5.

Table 1: Demographic Profile of the Study Sample (n = 30)

Age Group (Years)	Male (n)	Female (n)	Total (n, %)
21–30	3	0	3 (10.00%)
31–40	4	3	7 (23.33%)
41–50	5	3	8 (26.67%)
51–60	4	3	7 (23.33%)
61–70	2	3	5 (16.67%)
Total	18 (60%)	12 (40%)	30 (100%)

Table 2: Overall Distribution of Coronary Artery Dominance (n = 30)

Dominance Pattern	Number of Hearts	Percentage (%)	PIVA Origin
Right Dominant	21	70.00	Right Coronary Artery
Left Dominant	5	16.67	Left Circumflex Artery
Balanced/Co-dominant	4	13.33	Both RCA and LCX
Total	30	100.00	–

Table 3: Sex-wise Distribution of Coronary Artery Dominance (n = 30)

Dominance Pattern	Male (n=18)	Female (n=12)	Total (n=30)	p-value
Right Dominant	13 (72.22%)	8 (66.67%)	21 (70.00%)	0.932
Left Dominant	3 (16.67%)	2 (16.67%)	5 (16.67%)	
Balanced	2 (11.11%)	2 (16.67%)	4 (13.33%)	

Chi-square test; p > 0.05 = not significant

Table 4: Morphological Variations Identified in the Study Sample (n = 30)

Morphological Variation	Number of Hearts (n)	Percentage (%)
Accessory coronary ostium (right aortic sinus)	3	10.00
High-origin RCA (above sinotubular junction)	2	6.67
Absent left main stem (LAD + LCX separate ostia)	2	6.67
Anomalous LAD origin from RCA	1	3.33
Separate conus artery ostium	1	3.33
Single ostium with early bifurcation	1	3.33
Total specimens with variations	10	33.33

Table 5: Mean Coronary Artery Calibre by Dominance Pattern (n = 30)

Parameter (mean ± SD)	Right Dominant (n=21)	Left Dominant (n=5)	Balanced (n=4)
RCA diameter at 1 cm (mm)	3.61 ± 0.49	2.84 ± 0.38	3.12 ± 0.42
LCA main stem diameter (mm)	4.01 ± 0.58	4.53 ± 0.67	4.22 ± 0.55
PIVA length (cm)	7.30 ± 1.20	5.80 ± 0.90	6.40 ± 1.10
No. of terminal RCA branches	4.19 ± 0.87	3.20 ± 0.45	3.75 ± 0.50

SD = Standard Deviation; ANOVA; p = 0.018 for RCA calibre across groups

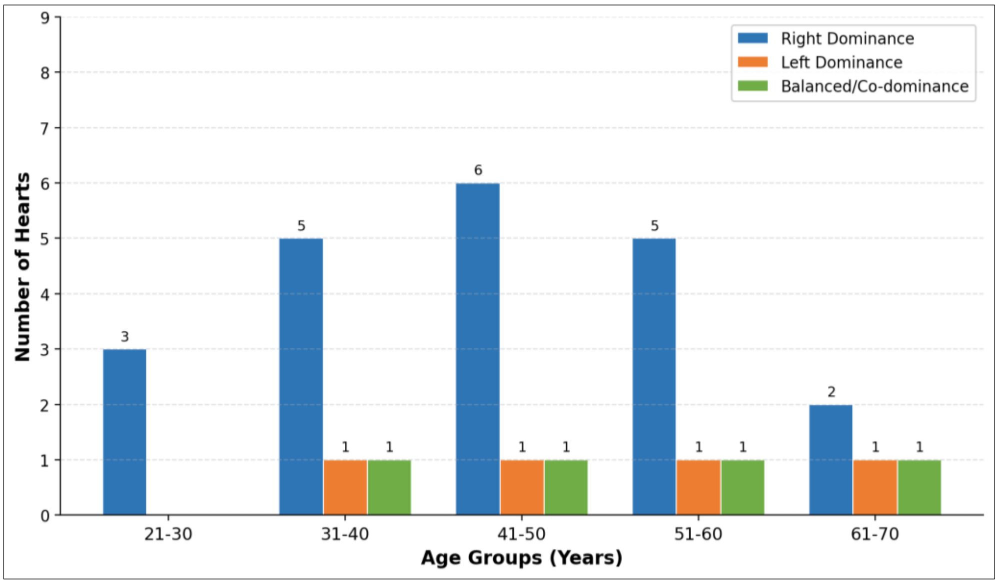

Figure 1: Distribution of Coronary Artery Dominance by Age Group (n = 30)

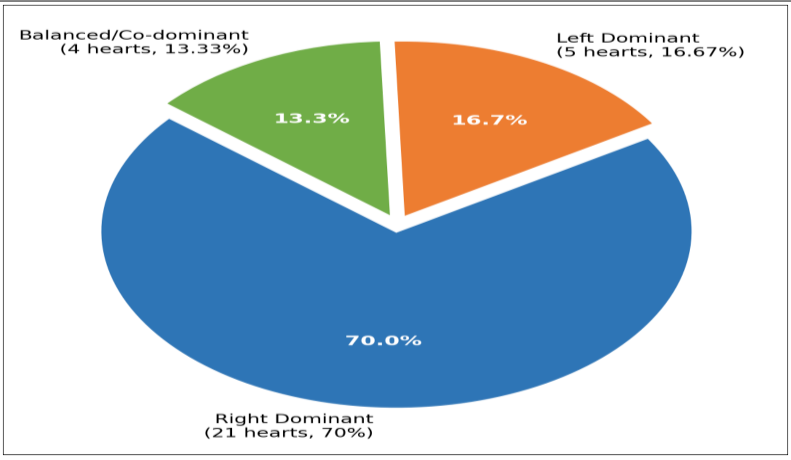

Figure 2: Pie Chart Showing Overall Distribution of Coronary Artery Dominance (n = 30)

DISCUSSION

This study calculated the prevalence of coronary dominance types among the cadaveric hearts collected for this research. The results show that right-dominant circulation made up 70% of cases, while balanced-type circulation accounted for 13.33%. We compared this dataset with field benchmarks: comparable international studies report right-dominant circulation at 70–90%, left-dominant circulation at 5–15%, and balanced-type circulation at 10–20%. In local Indian studies, Patil et al. [9] dissected 100 hearts in Maharashtra, recording a 72% rate of right-dominant circulation; Kaur et al. [10]'s case series from Northern India found right-dominant circulation accounted for 76% of their sample. The minor discrepancies observed across studies may arise either from true morphological differences between populations, or from variations in dissection procedures and the criteria used to define balanced-type circulation. The academic community widely recognizes that classifying the balanced type is more subjective than distinguishing between pure left or right dominance, leading to inter-observer variability. Future work for this study will expand the sample size to verify the lower-than-expected proportion of balanced-type circulation found in the current analysis.

This study generated a series of core findings regarding coronary artery dominance patterns in the Indian population: First, there was no statistically significant difference in coronary artery dominance patterns between males and females ($p=0.932$). This result is consistent with most published studies, indicating that coronary artery dominance is a trait formed during the embryonic heart development stage, and is not significantly affected by postnatal sex-related physiological differences. In this study, the share of right coronary artery dominance among males was 72.22%, slightly higher than the 66.67% among females, a trend that has only been reported in a small number of studies. A study of 50 Indian hearts conducted by Rao and Bhalerao[11] also corroborates this study's conclusion of no significant sex difference in coronary dominance. This study found no significant interaction effect between the sex-age variable and coronary artery dominance type, so its conclusions can be applied to all demographic groups across India. The average diameter of the right coronary artery (RCA) in right-dominant hearts was 3.61±0.49 mm, which was significantly larger than that of left-dominant and balanced-dominant hearts, aligning with the physiological logic that this vessel supplies a larger area of the myocardium. The diameter of the main trunk of the left coronary artery (LCA) in left-dominant hearts was 4.53 mm, which matches its higher blood flow demand. Both sets of results are consistent with conclusions drawn from existing research.

As a human cadaveric coronary anatomy study, this research identified coronary artery morphological variants that carry important clinical value. This study detected four categories of coronary variants: the detection rate of accessory coronary ostia was 10%; if the secondary ostium, rather than the main ostium of the right coronary artery (RCA), is mistakenly cannulated during invasive coronary angiography, this error will lead to misinterpretation of coronary angiograms [16]; the detection rate of RCA with anomalous high origin was 6.67%, which increases the difficulty of diagnosis and interventional procedures, and raises the risk of coronary ostial dissection [17]; the detection rate of absent left main coronary artery (the left anterior descending artery [LAD] and left circumflex artery [LCX] have separate originating ostia) was 6.67%. Previous angiographic studies reported that the prevalence of this variant was only 0.5-1.5%; the higher prevalence observed in this autopsy series may stem from the small sample size of the current study, or may reflect the true prevalence of this variant in the general population [14]; only 1 case of anomalous origin of the LAD from the RCA was detected, accounting for 3.33% of the study sample. This variant has an anatomical course that runs between the aortic root and the main pulmonary artery, and can cause sudden cardiac death in young people [18]. The overall variant rate in this study was 33.33%. Although this rate is higher than some previously reported figures, the findings of this study still emphasize the necessity of comprehensive coronary assessment before invasive cardiac procedures, and reaffirm the value of autopsies for anatomy education. Autopsy data can address gaps in clinical angiographic research, and provide support to help clinical teams avoid procedural risks [19,20].

LIMITATIONS OF THE STUDY

This study is a preliminary cardiac anatomy investigation conducted at a single tertiary medical institution in Pune, India. A total of 30 heart samples were enrolled for the research. It must be clarified that any interpretation of this study's conclusions must address a series of inherent limitations: First, while the sample size meets the requirements for a preliminary study, it is small in scale. It cannot cover the diversity of coronary artery morphology across India's full population or the local Pune region, which will reduce statistical power and introduce sampling bias. Second, as documented in reference [11], formalin-fixed specimens experience 5%-10% tissue shrinkage, which may lead to a slight underestimation of measured coronary artery caliber. Third, the single-center sample source introduces institutional and regional selection bias; the demographic and pathological characteristics of body donors and autopsy cases cannot match those of the general population. Fourth, age was only estimated based on mortuary records, and estimation errors exist for samples with incomplete documentation. Fifth, no three-dimensional imaging technologies such as coronary CT angiography or micro-CT were used, so three-dimensional details of coronary artery branches could not be obtained. Sixth, histological features and the severity of atherosclerosis were not assessed, nor were anatomical findings linked to clinical outcomes, leading to insufficient clinical relevance. Follow-up research can carry out multi-center studies, expand the sample size, adopt standardized anatomical protocols, and add complementary imaging technologies to generate more representative baseline anatomical data.

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Conclusion

This study is a gross anatomical cadaveric study of human hearts. Samples were collected from a tertiary care center in Pune, India, and the study enrolled a total of 30 human heart specimens. The core findings of this study are as follows: Among the distribution patterns of coronary artery dominance, right coronary dominance accounted for 70%, left coronary dominance for 16.67%, and balanced dominance for 13.33%. This result is consistent with previous global and Indian literature, confirming that right coronary dominance is the normal anatomical state of the Indian population. No statistically significant association exists between coronary artery dominance and sex. The diameter of the right coronary artery in right-dominant hearts is significantly larger than that in left-dominant and balanced hearts, which can support hemodynamic modeling and clinical prediction of ischemic burden. The posterior interventricular artery in right-dominant specimens is longer, a feature that can assist in graft planning for coronary artery bypass grafting surgery.

This study's analysis of study samples from an Indian population found that 33.33% of the samples had coronary artery morphological variations, confirming that the coronary tree has significant anatomical heterogeneity. Among these are two rare, high-risk variations: the left anterior descending artery originating from the right coronary artery, and the absence of the left main coronary artery. If unrecognized, these variations can lead to fatal outcomes. Cardiac surgeons, interventional cardiologists, and radiologists at India's tertiary care institutions must conduct individualized coronary assessments before performing invasive cardiac procedures, to ensure operational safety and support clinical decision-making. This study supplements the standard coronary anatomy database for Indian populations, and can be used for medical education and clinical practice. It is recommended that future multi-center studies incorporating micro-CT and 3D reconstruction technologies be carried out to further clarify the spectrum of coronary variations in the local population, and explore its correlation with cardiovascular disease burden.

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