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Angiographic Evaluation of Coronary Artery Variations, Calcification and Disease Burden in a South Indian Population

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Abstract: *Background: The coronary arterial system exhibits substantial anatomical variability in origin, branching pattern, dominance, and course, with important implications for myocardial perfusion, clinical presentation, and interventional planning. This current study is to evaluate the origin, branching patterns, and anomalies of the right and left coronary arteries in both genders using coronary angiography; to determine the pattern of coronary artery dominance; and to analyse age-wise variations in the severity of coronary artery calcification.*

Methods: This cross-sectional observational study was conducted in the Cardiac Catheterization Laboratory of Mahatma Gandhi Medical College and Research Institute, Puducherry, South India. A total of 180 consecutive adult patients undergoing diagnostic coronary angiography over an 18-month period were included. Coronary artery origin, left main branching pattern, dominance, anomalies, coronary artery disease (CAD) patterns, and calcification severity were systematically assessed. Data were analysed using SPSS version 26, with categorical variables expressed as frequencies and percentages. Associations were evaluated using the Chi-square test.

Results: Right coronary artery dominance was observed in 136 patients (75.6%), followed by left dominance in 23 (12.8%) and co-dominance in 21 (11.7%). Left main coronary artery bifurcation was the predominant branching pattern (146, 81.1%), with trifurcation noted in 30 patients (16.7%). Normal coronary origin was present in 157 participants (87.2%). Coronary artery anomalies were identified in 30 patients (16.7%), most commonly myocardial bridging of the left anterior descending artery (14, 7.8%). Severe coronary calcification was observed in 23 participants (12.8%). Age showed significant associations with coronary dominance patterns ($p \leq 0.05$), coronary calcification severity ($p=0.028$), and CAD extent ($p=0.020$). Gender was not associated with anatomical variations but showed a significant association with CAD burden ($p=0.001$).

Conclusion: Coronary arterial anatomy remains largely consistent across genders, whereas age significantly influences calcification severity and CAD burden. Integrating anatomical assessment with age-related risk stratification is essential for optimal clinical decision-making

Keywords: Coronary Angiography; Coronary Artery Dominance; Coronary Artery Anomalies; Left Main Coronary Artery; Coronary Calcification

1. INTRODUCTION

The coronary arterial system is highly anatomically variable in terms of origin, pattern of branching, dominance, and course that have significant implications on myocardial perfusion, clinical presentation, and interventional planning.[1–3] Proper definition of these characteristics is necessary when performing diagnostic coronary angiography and computed tomography (CT) coronary angiography, which are the two modalities of the gold standard that can be used to assess the in vivo coronary anatomy.[4,5] Although a number of anatomical variants are harmless, some of the configurations, especially configurations with an abnormal genesis or dangerous routes, can predispose to ischemia, arrhythmias, or sudden cardiac death.[3,6–8]

Sizable angiographic and CT-based series have shown that right coronary artery dominance is most common in adults, with an occurrence of about 62-87 per cent, then left coronary and 3-9 co-dominance.[9–12] These patterns of dominance are found to be quite consistent even among strata of adults and this indicates that there is no major change in the baseline coronary dominance as age goes up. Yet, left pre-eminence has been related to a greater burden of the ischemic heart disease, and co-dominance might be connected with greater involvement of right coronary artery lesions. Anatomical observations also indicate a normal length of the left main coronary artery to be about 11-15 mm, most of them bifurcating into the left anterior descending (LAD) and left circumflex (LCx), with a trifurcation and higher order branching being less common.[9,13] The form of intermediate (ramus intermedius), diagonal, and marginal branches exhibit broad numeric range and are taken as a normal variation and not an anomaly.

Other than ventricular supply, atrial coronary branches create a specific vascular network that has their own dominance properties. In over 90 percent of individuals the sinus node artery is the dominant atrial branch and often occurs as a result of non-proximal coronary divisions.[6,14] Notably, the patterns of atrial and ventricular dominance are concordant in less than 50 percent indicating the complexity of the coronary circulation as compared to traditional classifications of dominance.[14,15] The actual coronary artery anomalies are actually rare in nature whereby the overall prevalence is about 0.3-2.6 percent in the general population.[2,12,16–18] In cases of benign variants, CT cohorts indicate coronary variants or anomaly in up to 18-20% of individuals, but the anomalies of origin and course normally contribute not more than 1%. The age factor is important in alteration of the clinical manifestation of certain anomalies.[9,11,14]

Coronary dominance and branch patterns should therefore be considered to be relatively constant across ages, but age has a strong effect on the clinical presentation, risk factor and prognosis of coronary artery anomalies.[15,16,19] Thorough angiographic and CT-based analysis is thus critical in proper mapping of the anatomy, risk prioritization, and sound clinical decision-making. The study aims to evaluate the origin, branching patterns, and anomalies of the right and left coronary arteries in both genders using coronary angiography in a tertiary care centre in south India.

2. MATERIALS AND METHODS:

Study Design and Setting

This cross-sectional observational study was conducted in the Cardiac Catheterization Laboratory of Mahatma Gandhi Medical College and Research Institute (MGMCRI), Puducherry, a tertiary care teaching hospital in South India.

Study Duration and Sample Size

A total of 180 consecutive patients undergoing diagnostic coronary angiography were enrolled over an 18-month period. The sample size was determined based on an anticipated right coronary artery dominance prevalence of 81.6%, as reported in previous angiographic studies.

Ethical Considerations

The study protocol was reviewed and approved by the Institutional Ethics Committee and Research Committee of MGMCRI. Written informed consent was obtained from all participants prior to enrolment, in accordance with ethical principles for biomedical research.

Inclusion Criteria

- Adult patients aged 18 years and above
- Patients undergoing coronary angiography for standard clinical indications
- Willingness to provide written informed consent

Exclusion Criteria

- History of prior coronary artery bypass graft surgery
- Poor-quality angiographic images that precluded adequate anatomical assessment

Data Collection and Angiographic Assessment:

Demographic details, including age and gender, were recorded for all participants. Patients were categorized into five age groups: 30–40 years, 41–50 years, 51–60 years, 61–70 years, and >70 years. Coronary angiography was performed using standard techniques, with multiple projections obtained to ensure optimal visualization of all coronary segments. Angiographic images were systematically analysed for the following parameters:

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1. **Coronary artery origin:** Number of ostia and presence of separate or common origins
2. **Branching pattern:** Bifurcation or trifurcation of the left main coronary artery
3. **Coronary dominance:** Classified as right dominant, left dominant, or co-dominant based on the artery supplying the posterior descending artery and posterolateral branches
4. **Coronary artery anomalies:** Including myocardial bridging, abnormal origin, course variations, and fistulous connections
5. **Atherosclerotic disease patterns:** Single-, double-, or triple-vessel disease, and variants involving the left anterior descending artery and left main coronary artery

3. Statistical Analysis:

Data were entered and analysed using SPSS Statistics version 26. Categorical variables were expressed as frequencies and percentages. Associations between categorical variables were assessed using the Chi-square test. A p-value of <0.05 was considered statistically significant.

RESULTS:

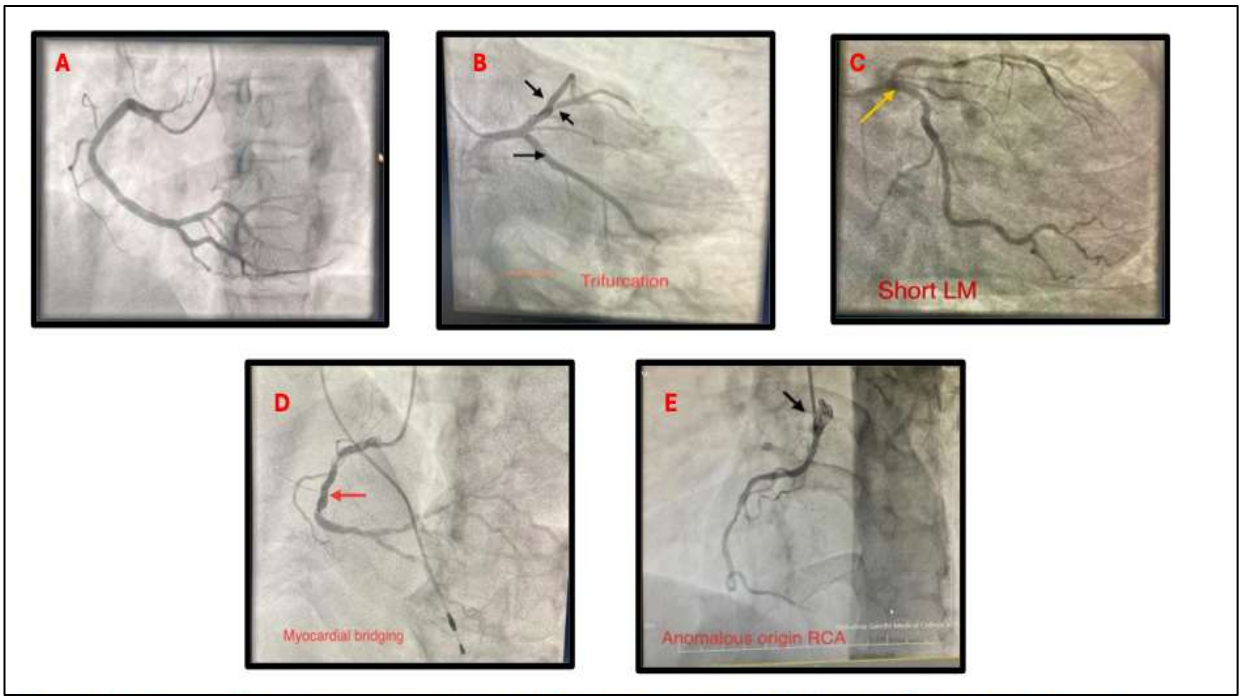

Figure: 1 Representative Coronary Angiographic Images Demonstrating: A) Right coronary artery dominance B) Trifurcation of left main C) Short left main D) Myocardial bridging E) Anomalous origin RCA

Table 1. Baseline Demographic Characteristics, Comorbidities, and Coronary Anatomical Features of the Study Population (N = 180)

Domain	Category	Frequency (n)	Percentage (%)
Age distribution (years)	<30	1	0.6
	31–40	12	6.7
	41–50	38	21.2
	51–60	63	35.2
	61–70	53	29.6
	>70	12	6.7
Gender	Female	45	25.0
	Male	135	75.0
Diabetes mellitus	Yes	80	44.4

	No	100	55.6
Systemic hypertension	Yes	71	39.4
	No	109	60.6
Dyslipidaemia	Yes	3	1.7
	No	177	98.3
Coronary artery branching pattern	Bifurcation	146	81.1
	Trifurcation	30	16.7
	Separate LAD–LCX origin	4	2.2
Coronary artery origin status	Normal	157	87.2
	Diseased / anomalous	23	12.8

A total of 180 participants were included in the study. The age distribution showed a predominance of middle-aged and elderly individuals. The largest proportion belonged to the 51–60 years age group (63 participants, 35.2%), followed by 61–70 years (53, 29.6%). Participants aged 41–50 years accounted for 38 (21.2%). Younger (<40 years) and very elderly (>70 years) individuals were relatively fewer, each constituting less than 7% of the cohort. Males predominated the study population with 135 participants (75.0%), while females constituted 45 participants (25.0%).

With respect to comorbidities, diabetes mellitus was present in 80 participants (44.4%), whereas systemic hypertension was observed in 71 participants (39.4%). Dyslipidaemia was uncommon, noted in only 3 participants (1.7%). Anatomical evaluation revealed that bifurcation was the most common coronary artery branching pattern, seen in 146 participants (81.1%), followed by trifurcation in 30 (16.7%) and separate origin of LAD and LCX in 4 participants (2.2%). Normal coronary artery origin was observed in 157 participants (87.2%), while diseased or anomalous origin was identified in 23 participants (12.8%).

Table 2. Coronary Dominance Patterns, Anomalies, and Coronary Calcium Score Distribution (N = 180)

Domain	Category	Frequency (n)	Percentage (%)
LCX Dominance Pattern	Dominant	31	17.2
	Co-dominant	14	7.8
	Non-dominant	135	75.0
RCA Dominance Pattern	Dominant	136	75.6
	Co-dominant	21	11.7
	Non-dominant	23	12.8
Coronary Artery Anomalies	No anomaly	150	83.3
	Myocardial bridging – LAD	14	7.8
	Short left main	5	2.8
	Separate coronary origin	3	1.7
	Anomalous origin from left sinus	2	1.1
	Short LM + myocardial bridging	2	1.1
	Ectatic RCA	1	0.6
	Long LM with ectasia	1	0.6
	Ramus myocardial bridging	1	0.6
	Right subclavian loop	1	0.6

Domain	Category	Frequency (n)	Percentage (%)
Coronary artery Calcium Score	None	128	71.1
	Mild	15	8.3
	Moderate	14	7.8
	Severe	23	12.8

Regarding coronary dominance, LCX was non-dominant in the majority of participants (135, 75.0%), with dominance and co-dominance seen in 31 (17.2%) and 14 (7.8%), respectively. In contrast, RCA dominance was the predominant pattern, observed in 136 participants (75.6%), while 21 (11.7%) showed co-dominance and 23 (12.8%) had a non-dominant RCA. Coronary artery anomalies were absent in most participants (150, 83.3%). Among those with anomalies, myocardial bridging of the LAD was the most frequent finding (14, 7.8%), followed by short left main (5, 2.8%) and separate coronary origin (3, 1.7%). Other anomalies were rare, each occurring in less than 1.5% of participants. Coronary artery calcium scoring showed that 128 participants (71.1%) had no detectable calcification, while severe calcification was present in 23 participants (12.8%).

Table 3. Angiographic Pattern of Coronary Artery Disease (N = 180)

Type of CAD	Frequency(n)	Percentage (%)
Normal coronaries	42	23.3
Single vessel disease	44	24.4
Double vessel disease	35	19.4
Triple vessel disease	43	23.9
Slow-flow coronaries	8	4.4
Single vessel + branch vessel disease	2	1.1
Recanalized LCX	3	1.7
Recanalized RCA	1	0.6
RCA dominant Epicoronaries	1	0.6
SCAD (LAD + LCX)	1	0.6

Angiographic evaluation demonstrated that 42 participants (23.3%) had normal coronaries. Single vessel disease was the most common CAD pattern (44, 24.4%), followed closely by triple vessel disease (43, 23.9%) and double vessel disease (35, 19.4%). Less frequent findings included slow-flow coronaries (8, 4.4%) and other rare patterns (<2%).

Table 4. Gender-wise Distribution of Angiographic Characteristics and Coronary Artery Disease Patterns (N = 180)

Domain	Category	Female (n = 45) n (%)	Male (n = 135) n (%)	P value
Branching pattern	Bifurcates	37 (82.2)	109 (80.7)	0.418
	Separate origin LAD/LCX	2 (4.4)	2 (1.5)	
	Trifurcates	6 (13.3)	24 (17.8)	
Coronary artery origin	Diseased	8 (17.8)	15 (11.1)	0.246
	Normal	37 (82.2)	120 (88.9)	
LCX dominance	Co-dominant	4 (8.9)	10 (7.4)	0.710
	Dominant	6 (13.3)	25 (18.5)	
	Non-dominant	35 (77.8)	100 (74.1)	
RCA dominance	Co-dominant	5 (11.1)	16 (11.9)	0.346
	Dominant	37 (82.2)	99 (73.3)	
	Non-dominant	3 (6.7)	20 (14.8)	
Coronary anomalies	No anomaly	36 (80.0)	114 (84.4)	0.499
	Myocardial bridging – LAD	4 (8.9)	10 (7.4)	
	Short left main	1 (2.2)	4 (3.0)	
	Separate origin	1 (2.2)	2 (1.5)	
	Short LM + myocardial bridging	1 (2.2)	1 (0.7)	
	Anomalous origin from left sinus	0 (0.0)	2 (1.5)	

	Ectatic RCA	0 (0.0)	1 (0.7)	
	Long LM with ectasia	0 (0.0)	1 (0.7)	
	Ramus myocardial bridging	1 (2.2)	0 (0.0)	
	Right subclavian loop	1 (2.2)	0 (0.0)	
Coronary artery calcium	None	30 (66.7)	98 (72.6)	0.758
	Mild	5 (11.1)	10 (7.4)	
	Moderate	3 (6.7)	11 (8.1)	
	Severe	7 (15.6)	16 (11.9)	
Type of CAD	Normal coronaries	18 (40.0)	24 (17.8)	**0.001***
	Single vessel disease	8 (17.8)	36 (26.7)	
	Double vessel disease	4 (8.9)	31 (23.0)	
	Triple vessel disease	8 (17.8)	35 (25.9)	
	Slow-flow coronaries	6 (13.3)	2 (1.5)	
	Single + branch vessel disease	0 (0.0)	2 (1.5)	
	Recanalised LCX	0 (0.0)	3 (2.2)	
	Recanalised RCA	0 (0.0)	1 (0.7)	
	RCA dominant epicoronaries	1 (2.2)	0 (0.0)	
	SCAD (LAD + LCX)	0 (0.0)	1 (0.7)	

Gender-wise analysis showed no significant differences in branching pattern, coronary origin, dominance patterns, coronary anomalies, or calcium scores. However, a significant difference was observed in the type of CAD (p = 0.001). Normal coronaries were more frequent among females (18, 40.0%) compared to males (24, 17.8%), while males had a higher burden of single, double, and triple vessel disease.

Table 5. Age-wise Distribution of Angiographic Characteristics, Coronary Artery Disease Patterns, and Comorbidities (N = 180)

Domain	Category	<30 yrs (n=2)	31–40 yrs (n=12)	41–50 yrs (n=38)	51–60 yrs (n=63)	61–70 yrs (n=53)	>70 yrs (n=12)	P value
Branching pattern	Bifurcates	2 (100.0)	9 (75.0)	29 (76.3)	52 (82.5)	46 (86.8)	8 (66.7)	0.649
	Separate origin LAD/LCX	0 (0.0)	0 (0.0)	2 (5.3)	1 (1.6)	0 (0.0)	1 (8.3)	
	Trifurcates	0 (0.0)	3 (25.0)	7 (18.4)	10 (15.9)	7 (13.2)	3 (25.0)	
Coronary origin	Diseased	0 (0.0)	2 (16.7)	4 (10.5)	5 (7.9)	10 (18.9)	2 (16.7)	0.567
	Normal	2 (100.0)	10 (83.3)	34 (89.5)	58 (92.1)	43 (81.1)	10 (83.3)	
LCX dominance	Co-dominant	1 (50.0)	0 (0.0)	6 (15.8)	4 (6.3)	3 (5.7)	0 (0.0)	0.05
	Dominant	1 (50.0)	4 (33.3)	4 (10.5)	13 (20.6)	6 (11.3)	3 (25.0)	
	Non-dominant	0 (0.0)	8 (66.7)	28 (73.7)	46 (73.0)	44 (83.0)	9 (75.0)	
RCA dominance	Co-dominant	2 (100.0)	0 (0.0)	6 (15.8)	9 (14.3)	3 (5.7)	1 (8.3)	**0.003***
	Dominant	0 (0.0)	8 (66.7)	28 (73.7)	46 (73.0)	46 (86.8)	8 (66.7)	
	Non-dominant	0 (0.0)	4 (33.3)	4 (10.5)	8 (12.7)	4 (7.5)	3 (25.0)	
	No anomaly	1 (50.0)	9 (75.0)	30 (78.9)	54 (85.7)	48 (90.6)	8 (66.7)	0.695

Coronary anomalies	Myocardial bridging – LAD	1 (50.0)	1 (8.3)	5 (13.2)	3 (4.8)	1 (1.9)	3 (25.0)	
	Other anomalies*	0 (0.0)	2 (16.7)	3 (7.9)	6 (9.5)	4 (7.5)	1 (8.3)	
Coronary calcium	None	2 (100.0)	11 (91.7)	34 (89.5)	38 (60.3)	33 (62.3)	10 (83.3)	**0.028***
	Mild	0 (0.0)	0 (0.0)	3 (7.9)	8 (12.7)	4 (7.5)	0 (0.0)	
	Moderate	0 (0.0)	0 (0.0)	1 (2.6)	3 (4.8)	9 (17.0)	1 (8.3)	
	Severe	0 (0.0)	1 (8.3)	0 (0.0)	14 (22.2)	7 (13.2)	1 (8.3)	
Type of CAD	Normal coronaries	1 (50.0)	2 (16.7)	7 (18.4)	17 (27.0)	13 (24.5)	2 (16.7)	**0.020***
	Single vessel disease	0 (0.0)	2 (16.7)	12 (31.6)	17 (27.0)	9 (17.0)	4 (33.3)	
	Double vessel disease	0 (0.0)	4 (33.3)	9 (23.7)	14 (22.2)	6 (11.3)	2 (16.7)	
	Triple vessel disease	0 (0.0)	2 (16.7)	6 (15.8)	10 (15.9)	21 (39.6)	4 (33.3)	
	Other CAD patterns†	1 (50.0)	2 (16.7)	4 (10.5)	5 (7.9)	4 (7.5)	(0.0)	

*-statistically significant as p value is less than 0.05

Age-wise analysis revealed significant associations between age and LCX dominance (p = 0.05), RCA dominance (p = 0.003), coronary calcium score (p = 0.028), and type of CAD (p = 0.020). Triple vessel disease was most prevalent in the 61–70 years age group (21, 39.6%). No significant age-wise association was observed for diabetes, hypertension, or dyslipidaemia.

4. DISCUSSION

In this Cross-sectional angiographic study of adults undergoing diagnostic coronary angiography, we evaluated coronary artery origin, branching patterns, dominance, anomalies, and their associations with age, gender, and coronary artery disease (CAD) burden. The findings indicate that core coronary anatomical characteristics are largely consistent across genders, whereas age plays a pivotal role in modulating coronary calcification severity and extent of atherosclerotic disease.

The right coronary artery (RCA) superiority became the most common, which is consistent with the previous cadavers, angiographic, and CT-based research showing that the right dominance is present in about 60-80 percent of adults (Priyadharshini and Sivakumar, 2016; Ravi et al., 2017; Cademartiri et al., 2008).[9,10,13] Left dominance and co-dominance were less common, which goes in line with the observations from the other studies. Even though coronary dominance is thought to be an immutable anatomical feature, the age-related relationships between dominance and RCA and LCX dominance are therefore likely to indicate that dominant can acquire all the greater clinical significance with aging, as opposed to indicating anatomical alteration.

Bifurcation of left main coronary artery was the predominant pattern, and trifurcation and independent LAD-LCX origin was also found in minority. It is a well correlated distribution with available angiographic and anatomical data (Ravi et al., 2017; Kandavadivelu et al., 2024)[13,20]. No gender differences in the patterns of branching and origin are found to be significant which bolsters the idea that sex-based variation in the epicardial coronary anatomy is not much. The inconsistency between the studies is probably due to the discrepancy in the imaging modality, the definition of variants, and the demographics of that population and not actual biological differences.

The incidence of coronary artery anomalies in this cohort was not high with myocardial bridging of the LAD as the most prevalent anomaly. This observation is similar to the findings in big angiographic and CT collections that found myocardial bridging to be the most common intrinsic coronary form (Cademartiri et al., 2008; Anli and Atak, 2024).[9,11] Notably, the majority of abnormalities were incidental and gender independent, which strengthens the existing evidence that most of the coronary variants are benign and not associated with clinical implications, but could be of importance during the interventional process.

The response to this research is a large correlation between age and coronary calcification with CAD severity. Older age groups especially 61-70 years were mostly affected with severe calcification and multivessel disease. Biologically, these findings are credible and indicative of the cumulative quality of atherosclerosis and ageing of the vasculature. Interestingly, the classic risk factors of cardiovascular disease like diabetes and hypertension were not significant with aging in this cohort whereby age could be an integrative measure of a lifetime exposure to both measured and unmeasured risk factors. Since the study is cross-sectional, one should perceive the results as an association, not causal.

In terms of gender wise analysis, the patterns observed included that females were more likely to have angiographically normal coronaries and males were more likely to have obstructive CAD which included multivessel disease. This trend is consistent with the prevailing epidemiological evidence of obstructive CAD cases in women with delayed progression and reduced prevalence. The absence of gender in coronary dominance, branching or anomalies implies that unexplained differences in CAD burden cannot be attributed to gross anatomical variation exclusively.

The strengths of the study are systematic angiographic testing, age-, and gender-stratified testing, as well as an assessment of anatomic and disease-related parameters. The limitations are the cross-sectional design, lack of longitudinal outcome data, and possible residual confounding, and low generalisability as the studyss is conducted in one centre. Longitudinal multicentric cross-anatomical, functional and outcome studies are required to elucidate the prognostic value of coronary dominance and variants into the lifespan.

5. CONCLUSION

This angiographic study demonstrates that coronary artery origin, branching patterns, dominance, and anomalies are largely stable anatomical features across genders, while age significantly influences coronary calcification severity and CAD burden. The most common is right coronary dominance and the most common is myocardial bridging. These results highlight that age and not anatomical variation alone has a leading role in clinical expression and severity of disease and thus age-integrated anatomical assessment is significant in cardiovascular practice.

Conflict of interest: Nil

List of abbreviations:

CAD – Coronary artery disease
CCTA – Coronary computed tomography angiography
CT – Computed tomography
IEC – Institutional Ethics Committee
LAD – Left anterior descending (artery)
LCx – Left circumflex (artery)
LM – Left main (coronary artery)
LMCA – Left main coronary artery
MGMCRI – Mahatma Gandhi Medical College and Research Institute
PDA – Posterior descending artery
PLB – Posterolateral branch(es)
RCA – Right coronary artery
SCAD – Spontaneous coronary artery dissection
SPSS – Statistical Package for the Social Sciences

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