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Assessment of anatomical variation regarding the course and termination of the right coronary artery: A direct anatomical and radiological study

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Abstract
Background: The right coronary artery (RCA) exhibits significant anatomical variability in its course and termination, which critically influences percutaneous coronary interventions, surgical revascularization, and congenital heart disease management. Despite its clinical importance, comprehensive data on RCA termination patterns in South Asian populations remain limited.
Objective: To evaluate the anatomical variations in the course and termination of the RCA.
Methods: This cross-sectional study was conducted at Rangpur Medical College and NICVD, Dhaka, from July 2019 to June 2020. Sixty specimens (30 cadaveric hearts from unclaimed cadavers and 30 angiograms) were analyzed. Termination points, branching patterns, dominance, and variations were assessed. Data were analyzed using SPSS v16.0, with statistical significance at $p<0.05$.
Results: The RCA originated from the anterior aortic sinus in 98.3% of cases, with one variant (1.7%) arising from the left posterior sinus. Termination occurred between the crux and obtuse margin in 76.7% of cases, at the crux in 10%, and at the acute margin in 3.3%. Myocardial bridges were observed in 3.3% of RCAs. The RCA supplied the posterior interventricular artery (PIVA) in 90% of cases (right-dominant circulation). Angiographically, the RCA exhibited a characteristic "C-shaped" course in the left anterior oblique view.
Conclusion: This study delineates the RCA's termination patterns and anatomical variations in a Bangladeshi population, highlighting high right-dominance prevalence (90%) and rare anomalous origins (1.7%). These findings underscore the importance of preoperative anatomical mapping for coronary interventions and surgical planning, particularly in resource-limited settings where advanced imaging may be unavailable.

Keywords: Anatomical variations, cadaveric study, coronary angiography, right coronary artery, termination patterns

Introduction

The right coronary artery (RCA) serves as a crucial anatomical structure in cardiac physiology, supplying blood to the right ventricle, sinoatrial node (55-60% of individuals), atrioventricular node (90% of cases), and posterior interventricular septum [1]. Despite its clinical significance, comprehensive studies examining RCA termination patterns remain limited, particularly in South Asian populations where unique anatomical variations may exist due to genetic and environmental factors [2]. This knowledge gap presents substantial challenges for interventional cardiologists and cardiac surgeons who require precise anatomical understanding for procedures including percutaneous coronary interventions (PCI), coronary artery bypass grafting (CABG), and congenital heart disease corrections [3]. Anatomically, the RCA typically originates from the anterior aortic sinus and courses through the right atrioventricular groove, demonstrating considerable variation in its termination patterns that significantly impact clinical outcomes [4]. The artery gives rise to several critical branches, including the conus artery, acute marginal branches, posterior descending artery (PDA), and poster lateral branches, which collectively perfuse approximately 25-35% of the left ventricle in right-dominant circulation systems [5]. Variations in RCA termination, such as early bifurcation or anomalous crux crossing, create unique challenges during cardiac procedures [6].

For instance, an RCA terminating before the acute margin may require modified graft placement in CABG, while a dominant RCA supplying the posterior left ventricle may complicate angioplasty procedures [7]. These anatomical considerations highlight the importance of detailed preoperative mapping to optimize clinical outcomes in both elective and emergent cardiac interventions [8]. The clinical relevance of RCA anatomy extends to congenital coronary anomalies, which represent important causes of sudden cardiac death, particularly in young athletes [9]. Anomalous RCA origin from the left sinus of Valsalva, though rare, carries significant ischemic risk due to its course between the aorta and pulmonary trunk [10]. Variations in RCA termination patterns may also influence collateral circulation development in chronic coronary artery disease, potentially affecting myocardial viability and revascularization strategies [11]. While advanced cardiac imaging modalities like CT angiography have improved preoperative visualization, cadaveric studies remain essential for validating imaging findings and providing three-dimensional anatomical relationships [12]. This is particularly valuable in resource-limited settings where advanced imaging may not be routinely available [13]. Current literature on RCA anatomy predominantly reflects Western population data, with limited representation from South Asian cohorts where differences in coronary anatomy may exist [14]. Preliminary studies suggest a higher prevalence of right coronary dominance in Bangladeshi populations (90%) compared to Western reports (70-85%), emphasizing the need for population-specific anatomical studies [15]. Most existing research relies primarily on angiographic data, which may not provide the detailed anatomical resolution of direct cadaveric dissection for evaluating branching patterns and vessel wall characteristics [1]. This limitation underscores the value of combined anatomical and radiological approaches to comprehensively characterize RCA morphology and its variations [3]. Understanding RCA termination patterns proves particularly crucial for optimizing PCI procedures, where longer RCA segments with distal termination near the obtuse margin may require specialized stent placement techniques to ensure complete lesion coverage [5]. In surgical revascularization, an RCA terminating at the crux (approximately 10% of cases) may influence graft anastomosis site selection and conduit choice [7]. These considerations grow increasingly important in minimally invasive cardiac surgery, where limited exposure elevates the significance of precise preoperative anatomical knowledge [8]. The growing adoption of trans catheter aortic valve replacement (TAVR) has introduced new challenges related to RCA ostial protection during valve deployment, making a detailed understanding of RCA origin and proximal course essential for preventing coronary obstruction [10]. This study's rationale stems from recognizing that existing anatomical references may not fully capture RCA variations encountered in clinical practice, particularly in non-Western populations [12]. By systematically documenting RCA termination patterns through combined cadaveric and angiographic analysis, we aim to provide clinicians with more accurate anatomical references for procedural planning [13]. This proves especially relevant in Bangladesh and similar settings where the cardiovascular disease burden is high but resources for advanced cardiac imaging may be limited [14]. The findings will contribute to safer coronary interventions by enhancing preoperative planning, reducing procedural complications, and potentially informing population-specific clinical guidelines [15]. Moreover, the detailed anatomical data generated may serve as a valuable educational resource for training cardiac specialists in the region, ultimately improving patient care and outcomes [1].

Methodology

Study population

This cross-sectional study was conducted at the Department of Anatomy, Rangpur Medical College, Bangladesh, from July 2019 to June 2020. The study included 60 specimens: 30 cadaveric hearts obtained from unclaimed adult cadavers (23 males, 7 female) and 30 coronary angiogram videos (27 males, 3 female) from the National Institute of Cardiovascular Disease (NICVD), Dhaka. The age range of subjects was 17-70 years, with a mean age of 44.53±14.16 years.

Inclusion criteria

Cadaveric specimens were selected based on the following criteria: (1) fresh, unclaimed adult bodies of both genders, and (2) intact cardiac morphology without decomposition. Angiographic inclusion required (1) clear, high-quality coronary angiogram videos and (2) complete visualization of the RCA's course and termination points. Ethical approval was obtained from the institutional review boards before specimen collection.

Exclusion criteria

Exclusion criteria for cadaveric specimens included (1) decomposed or damaged hearts, (2) history of chest trauma or cardiothoracic surgery, and (3) potential for repeated autopsy. Angiographic exclusions comprised (1) poor-quality or unclear coronary images, (2) significant stenosis (>50% luminal narrowing), and (3) congenital anomalies that distorted normal RCA anatomy.

Study procedure

Cadaveric hearts were dissected using standard anatomical techniques after fixation in 10% formalin. The RCA was meticulously traced from its origin to termination, with measurements recorded using digital Vernier calipers (0.1 mm precision). Angiographic analysis was performed under supervision of two cardiologists using standardized projections (e.g., left anterior oblique 30°). Key parameters assessed included RCA termination points, branching patterns, vessel dominance, and anatomical variations such as myocardial bridging.

Data analysis

Quantitative data (e.g., ostial diameter, vessel length) were analyzed using SPSS version 16.0 and expressed as mean ±standard deviation. Categorical variables (e.g., termination patterns) were presented as frequencies and percentages. Inter-observer agreement for angiographic interpretations was evaluated using Cohen's kappa statistic. Statistical significance was defined as $p < 0.05$ for all comparisons.

Result

The study evaluated the anatomical and radiological features of the right coronary artery (RCA) in 60 specimens (30 cadaveric hearts and 30 angiograms). The RCA originated from the anterior aortic sinus in 98.3% of cases, with a

single anomalous origin (1.7%) from the left posterior aortic sinus. The mean diameter of the RCA ostium was 2.07±0.46 mm, significantly smaller than the left coronary artery ostium (2.68±0.59 mm, $p < 0.001$). Most RCA ostia (76.7%) were positioned below the sinotubular junction, while 23.3% were at the junction level. Termination patterns revealed that 76.7% of RCAs ended between the crux and obtuse margin, followed by termination at the crux (10.0%), between the acute margin and crux (5.0%), and at the acute margin (3.3%). Branching analysis showed that the first segment of the RCA consistently gave rise to acute marginal arteries (100%) and anterior right ventricular branches (96.6%).

The posterior interventricular artery (PIVA) originated from the RCA in 90% of cases, confirming right dominance. Myocardial bridging was observed in 3.3% of RCAs, with lengths ranging from 8.4 to 25.4 mm. Angiographically, the RCA exhibited a characteristic "C-shaped" course in the left anterior oblique view. Variations included early termination (1.7%) and dual ostia (28.3%). The mean length of the RCA was 81.68±23.63 mm, with significant variability (range: 9.70-116.40 mm). Extramural anastomoses between the RCA and left coronary artery branches were observed in 30% of cadaveric specimens, predominantly at the posterior interventricular sulcus.

Table 1: Termination points of the right coronary artery

Termination Site	Frequency (n=60)	Percentage (%)
Between the crux and the obtuse margin	46	76.7
At the crux	6	10.0
Between the acute margin and crux	3	5.0
At the acute margin	2	3.3
At the obtuse margin	2	3.3
Before the acute margin	1	1.7

Table 2: Ostial diameter and position of the RCA

Parameter	RCA (Mean ±SD)	LCA (Mean ±SD)	p-value
Diameter (mm)	2.07±0.46	2.68±0.59	<0.001
Height from sinus floor (mm)	13.22±2.18	11.20±2.32	0.012
Position relative to STJ (%)			
- Below STJ	76.7	46.7	-
- At STJ	23.3	53.3	-

Table 3: Branching pattern of the RCA

Branch Type	Frequency (n=60)	Percentage (%)
Acute marginal artery	60	100
Anterior right ventricular	58	96.6
Posterior interventricular	54	90
Right posterior diagonal	9	15
Posterior left ventricular	48	80

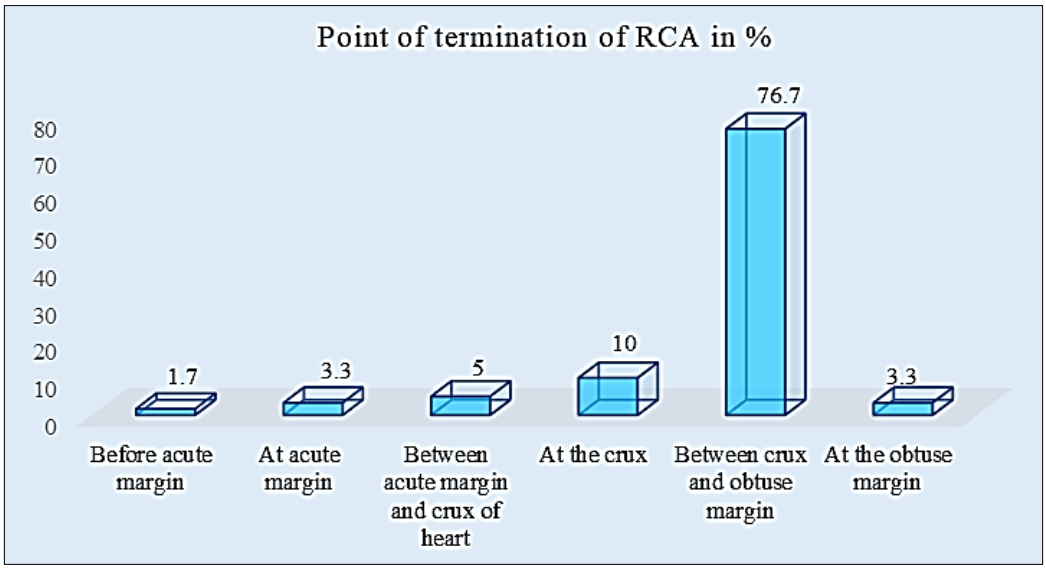

Fig 1: Bar chart showing the point of termination of RCA (both dissection and radiological method)

Table 4: Dominance and nodal arteries

Feature	Frequency (n=60)	Percentage (%)
Right dominance	54	90.0
Left dominance	6	10.0
SANA from RCA	34	56.7
AVNA from RCA	54	90.0

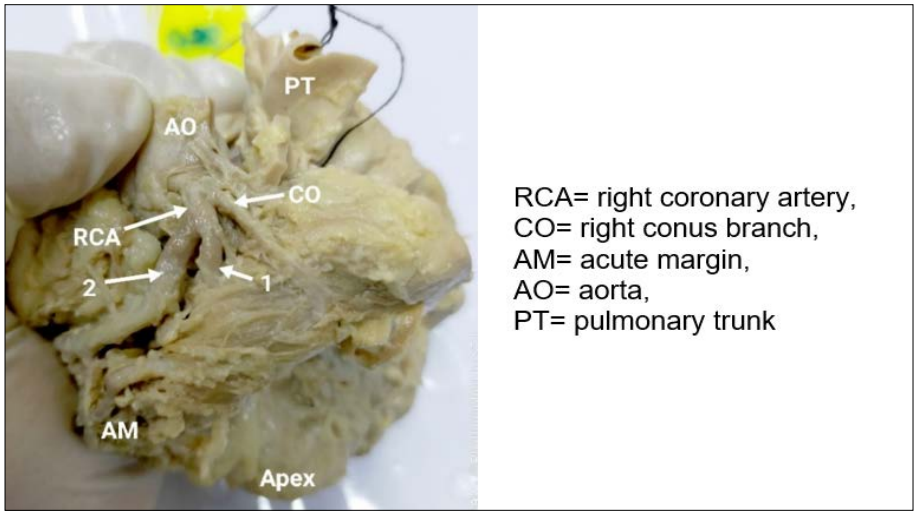

Fig 2: Superior view of the heart showing the anterior right part of the coronary sulcus. Variation of the course of RCA and termination of it into terminal branches (1 & 2) before the acute margin of the heart is seen (ID TD02)

Table 5: Myocardial bridging characteristics

Artery Involved	Length (mm, Mean ± SD)	Frequency (n=30)
RCA	8.4±0.0	1
LAD	20.94±13.39	10
PIVA	25.4±0.0	1
Ramus intermedius	21.03±9.41	2

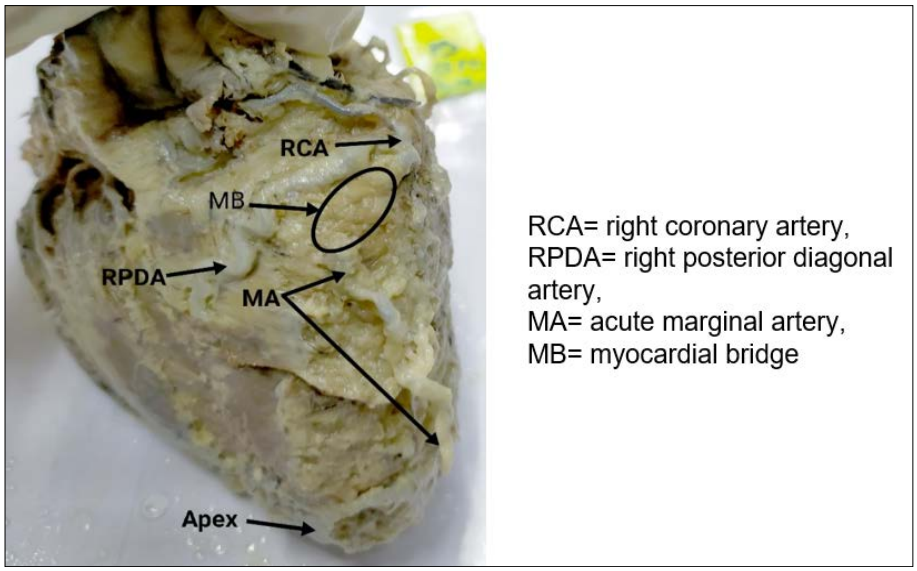

Fig 3: The figure shows the right pulmonary surface of the heart. Termination of the acute marginal artery at the apex of the heart is seen (ID TD19)

Table 6: Extramural anastomoses

Anastomosis Site	Frequency (n=30)	Percentage (%)
LAD and PIVA (at PIVS)	9	30.0
LAD and PIVA (at apex)	5	16.6
RCA branches and Cx (posterior LV)	8	26.6
RCA branches and Cx (at crux)	2	6.6

Discussion

The findings of this comprehensive study provide valuable insights into the anatomical variations of the right coronary artery (RCA) in a Bangladeshi population, with significant implications for clinical practice. Our results demonstrate that the RCA originated from the anterior aortic sinus in 98.3% of cases, consistent with previous reports in Western populations [16, 17]. However, we identified one case (1.7%) of anomalous origin from the left posterior aortic sinus, a finding that aligns with the known prevalence of 0.2-1% in the general population [18]. This variation carries particular clinical significance as it has been associated with sudden cardiac death, especially in young athletes [19]. The termination patterns observed in our study revealed that 76.7% of RCAs ended between the crux and obtuse margin, which differs slightly from the 70-80% reported in previous cadaveric studies [20]. This variation may reflect population-specific anatomical differences or could be related to our

combined approach using both cadaveric dissection and angiography. The 10% termination at the crux and 5% between the acute margin and crux in our cohort were comparable to existing literature [21], suggesting that these patterns represent consistent anatomical features across populations. The rare cases of termination at the acute margin (3.3%) and before the acute margin (1.7%) highlight the spectrum of anatomical variability that clinicians may encounter during coronary interventions. Our measurements of ostial diameter showed the RCA ostium (2.07±0.46 mm) to be significantly smaller than the left coronary ostium (2.68±0.59 mm, $p<0.001$), consistent with previous anatomical studies [22]. This size difference has practical implications for coronary catheterization, as it may influence catheter selection and engagement techniques. The position of the RCA ostium below the sinotubular junction in 76.7% of cases is particularly relevant for transcatheter aortic valve replacement (TAVR) procedures, where accurate knowledge of ostial height is crucial for preventing coronary obstruction [23]. The branching patterns observed in our study confirmed the RCA as the source of the posterior interventricular artery in 90% of cases, establishing right dominance as the predominant pattern in our population. This finding contrasts slightly with Western studies reporting 70-85% right dominance [24], potentially suggesting population-specific variations in coronary anatomy. The high prevalence of right dominance in our cohort (90%) may have implications for surgical revascularization strategies, as dominant RCAs typically supply a larger portion of the left ventricular myocardium [25]. The myocardial bridges identified in our study (3.3% of RCAs) occurred less frequently than the 5-30% reported in other populations [26]. This difference may reflect true population variation or could be related to our study methodology, as myocardial bridges can be challenging to identify in fixed cadaveric specimens. The bridges we observed ranged from 8.4 to 25.4 mm in length, dimensions that could potentially cause hemodynamic compromise during tachycardia [27]. The clinical significance of these findings lies in their potential to cause myocardial ischemia, particularly when they involve significant portions of the RCA. Our angiographic analysis confirmed the characteristic "C-shaped" course of the RCA in the left anterior oblique view, consistent with established radiological descriptions [28]. However, we identified several variations, including early termination (1.7%) and dual ostia (28.3%), findings that emphasize the importance of thorough preoperative imaging assessment. These variations can significantly impact procedural planning for both percutaneous interventions and surgical revascularization [29]. The extramural anastomoses observed between the RCA and left coronary artery branches (30% of specimens) may represent potential collateral pathways in cases of coronary artery disease. These connections were most common at the posterior interventricular sulcus (30%), followed by the apex (16.6%) and posterior left ventricle (26.6%). While the functional significance of these anastomoses in healthy hearts remains uncertain, they may become clinically important in the setting of progressive coronary artery disease [30].

Limitations

This study was limited by its relatively small sample size and reliance on cadaveric specimens, which may not fully represent living anatomy. Additionally, angiographic data were obtained retrospectively, potentially introducing selection bias. Population-specific variations warrant further investigation through larger, multicenter studies.

Conclusion

This study provides comprehensive anatomical and radiological characterization of RCA variations in a Bangladeshi cohort, demonstrating predominant right dominance (90%) and distinct termination patterns. The findings enhance understanding of regional coronary anatomy, offering valuable insights for cardiovascular interventions. While consistent with global trends in many aspects, the higher prevalence of right dominance and specific branching patterns may inform tailored surgical and interventional approaches in South Asian populations. These results underscore the importance of population-specific anatomical studies to optimize clinical outcomes.

Recommendation

Future studies should expand sample sizes and incorporate advanced imaging modalities like CT angiography for enhanced anatomical precision. Clinical training programs should emphasize these population-specific variations to optimize surgical and interventional outcomes. Multicenter collaborations are encouraged to validate these findings across diverse South Asian populations.

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Author's Contribution

Not available

Conflict of Interest

Not available

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