Original Article

The Radial Artery in Focus: Anatomical Insights and Clinical Applications for Coronary Intervention

Sowmya S[1], Meenakshi Parathasarathy[2], Kotakonda Priyanka[3], Irshad HA[4], Umabharathi M[5]

[1]Associate Professor, Department of Anatomy, SABVMCRI, Bengaluru, India, [2]Professor and Head, Department of Anatomy, SABVMCRI, Bengaluru, India, [3]Tutor, Department of Anatomy, SABVMCRI, Bengaluru, India, [4]Post Graduate, Department of Anatomy, SABVMCRI, Bengaluru, India, [5]Post Graduate, Department of Anatomy, SABVMCRI, Bengaluru, India

Abstract

Background: The radial artery has emerged as a preferred vascular access route for coronary angiography and interventions due to its superficial location and lower bleeding risk compared with the femoral approach. However, anatomical variations such as branching anomalies and tortuosity may complicate procedures, prolong catheter manipulation, and increase failure rates. A thorough understanding of radial artery anatomy is essential for improving procedural safety and efficiency. **Material and Methods:** This cadaveric study was performed on 80 specimens (40 male, 40 female). The radial artery diameter (RAD) was measured at the entry site by dissection. Branching anomalies and tortuosity patterns were identified and analyzed. Sex-related differences in diameter were compared using statistical analysis. **Results:** The mean RAD was 2.57 mm, with a significant difference between males (2.71 mm) and females (2.43 mm; $p < 0.001$). Branching anomalies were present in 3% of cadavers, the most common being high origin of the radial artery (2.5%). Tortuosity was detected in 4% of cases, predominantly S-shaped or Ω-shaped configurations in the proximal antecubital fossa. These anatomical variations are potential contributors to procedural difficulty during transradial coronary interventions. **Conclusion:** Branching anomalies and tortuosity of the radial artery, though infrequent, present clinically relevant challenges in transradial access. Pre-procedural recognition of such variations may reduce complications, optimize procedural time, and enhance overall success rates of coronary interventions. Detailed anatomical assessment of the radial artery should be integrated into clinical planning to improve outcomes.

Keywords: Radial artery; Transradial coronary angiography; Branching anomaly; Vessel tortuosity; Radial artery occlusion.

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Introduction

The transradial approach has become the preferred vascular access route for coronary angiography and percutaneous coronary intervention (PCI). Its advantages include a superficial arterial course, greater patient comfort, early ambulation, and significantly reduced bleeding complications compared with the transfemoral approach.[1,2] Reflecting these benefits, international clinical guidelines such as those of the European Society of Cardiology and the American Heart Association now recommend a radial-first strategy, especially in patients with acute coronary syndromes.[2]

Despite its widespread adoption, the transradial approach presents specific challenges. Anatomical variations of the radial artery—including high origin, loops, tortuosity, hypoplasia, and accessory branches—are strongly associated with procedural failure and technical difficulty.[3] In a landmark multicenter study involving 1,540 patients, radial artery anomalies were detected in 13.8% of cases, with significantly higher failure rates compared to normal anatomy (14.2% vs. 0.9%).[4] Notably, loops and tortuous configurations in the proximal course of the artery complicate catheter navigation and elevate access failure risk.[4,5] Similarly, another clinical study found that 9.1% of patients exhibited radial artery anomalies, which correlated with higher rates of procedural failure and radial artery spasm.[6]

In addition to variations in course, radial artery diameter is a critical determinant of procedural success. Smaller calibers—resulting from hypoplasia, vasospasm, or pathological narrowing—can hinder catheter insertion, predispose to spasm, and increase the risk of failure.[7,8] Careful measurement of diameter is therefore crucial for choosing appropriately sized sheaths and catheters.

Given these anatomical challenges, pre-procedural assessment using ultrasonography or angiographic mapping is increasingly advocated. Such evaluation enables early recognition of anomalies and facilitates informed decision-making, thereby improving both safety and efficiency in transradial coronary interventions.[8,9]

Aims and Objectives

The present study aims to provide a comprehensive evaluation

Address for correspondence: Dr. Kotakonda Priyanka, Tutor, Department of Anatomy, SABVMCRI, Bengaluru, India. E-mail: priyankaroyal225@gmail.com

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of the radial artery with respect to its anatomical features and their clinical relevance in transradial coronary interventions. Specifically, the objectives are to measure the radial artery diameter and assess sex-related differences, to document the incidence and patterns of branching anomalies, and to identify the prevalence and types of vessel tortuosity. By correlating these anatomical findings with their potential impact on procedural success, technical difficulty, and complication rates, the study seeks to highlight the importance of pre-procedural anatomical assessment in optimizing safety, efficiency, and outcomes of coronary interventions performed via the transradial approach.

Materials and Methods

Study Design: This was an observational analytic cadaveric study conducted in the Department of Anatomy at SABVMCRI. A total of 80 cadavers (40 males and 40 females) were examined, contributing 160 upper limbs (80 right and 80 left). The study included adult specimens above 15 years of age, while cadavers with anomalies, burns, or injuries affecting the upper limb were excluded.

Inclusion and Exclusion Criteria

The study included adult cadavers above 15 years of age with well-preserved upper limbs suitable for dissection. Cadavers presenting with gross anomalies of the upper limb, evidence of burns, traumatic injury, or deformities that could alter the course or morphology of the radial artery were excluded to ensure accurate anatomical assessment.

Data collection Procedure: Bilateral dissections of the upper limbs were carried out in 80 adult cadavers (40 males and 40 female). The radial artery diameter was measured at its origin and mid-forearm using digital calipers for accuracy. During dissection, branching anomalies and vessel tortuosity were carefully identified, documented, and categorized. All observations were systematically recorded, and the measurements obtained were subjected to statistical analysis using the t-test, with a p-value of <0.05 considered significant.

Statistical Analysis: All observations, including branching anomalies such as high origin and accessory branches, as well as tortuosity patterns categorized as S-shaped, Ω-shaped, or other configurations, were systematically recorded. Quantitative data were expressed as mean ± standard deviation (SD). Comparative analysis between groups was performed using the Student's t-test, and a p-value of less than 0.05 was considered statistically significant.

Results

Table 1: Luminal Diameter of Radial artery at the Trans radial entery (above trapezoid).

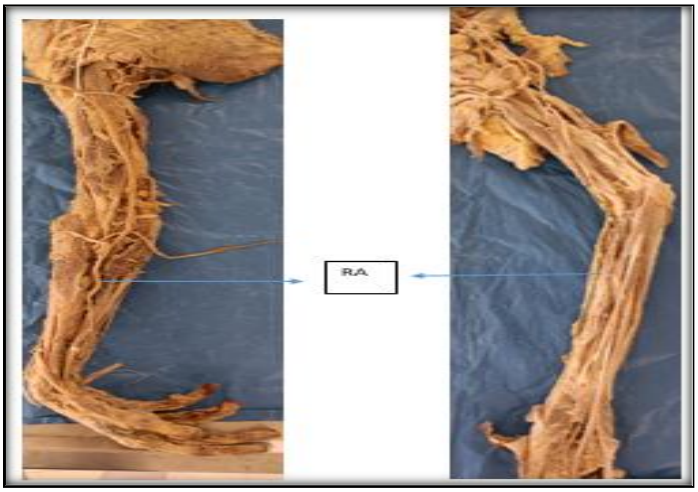
Parameter	Male (n=40)	Female (n=40)	Total (n=80)
Mean Dia (mm) SD	2.71 mm SD- 0.18	2.43 mm SD- 0.16	2.57mm SD- 0.21

Table 2: Branching anomalies

Type of anomaly	Number of limbs	Percentage
Any anomaly (total)	5 / 160	3%
High origin of radial artery	4 / 160	2.5%
Radioulnar loop	1 / 160	0.6%

Table 3: Distribution of IJV Tortuosity Patterns by Sex and Side

Tortuosity Type	Side	Males (n)	Females (n)
S-shape tortuous	Right	2	1
	Left	1	0
Ω-shape tortuous	Right	2	0
	Left	0	0



Discussion

In this cadaveric study, the mean radial artery diameter (RAD) was 2.57 mm (men 2.71 mm; women 2.43 mm), mirroring the consistent sex difference reported in pooled anatomical reviews and clinical series, where adult male RAD averages 2.6–2.7 mm and female RAD averages 2.2–2.4 mm.[6,7] This alignment supports the external validity of our measurements and underscores equipment selection implications, as smaller calibers—more common in women—can increase sheath-to-artery mismatch and spasm risk.[8] In transradial practice, RAD relative to sheath size influences technical success; prior work shows most patients' RAD exceeds a 5 Fr sheath outer diameter, but the margin narrows in smaller arteries, justifying ultrasound sizing and consideration of slender systems.[8] Branching anomalies were infrequent overall (3%), with a predominance of high origin (2.5%). Our rate lies at the lower end of published ranges: clinical angiographic series report abnormal/high origin around 7–8%,[4] while cadaveric studies report rates varying from ~5–9%.[3] Radioulnar loop was seen in 0.6% of limbs, slightly below angiographic estimates (~1–2.3%).[4,5] These loops can be particularly problematic, often necessitating alternative wire strategies or access conversion.[5] Tortuosity was identified in 4% of specimens—mainly S- or Ω-shaped bends in the proximal course—closely matching clinical reports of ~2–5% tortuosity in transradial populations.[4,6] The procedural relevance of such variants is well documented: multicenter and single-center analyses show that anomalous anatomy, including tortuosity, loops, hypoplasia, and high origin, is associated with higher puncture/procedural failure rates, longer procedure times, and greater need for bailout strategies.[2,9] Taken together, our findings reinforce three practical points. First, sex-related RAD differences are substantial enough to influence sheath selection and spasm mitigation protocols.[7,8] Second, even when infrequent, high origin and radioulnar loops should be anticipated because their prevalence can exceed cadaveric estimates and they disproportionately drive procedural difficulty.[4,5] Third, because tortuosity and branching variants are meaningful predictors of complexity, routine pre-procedural ultrasound mapping or early diagnostic angiography after sheath insertion is reasonable to plan strategy and, when appropriate, consider alternate access.[2,9] Overall, the anatomical profile observed here (smaller RAD in women, low but relevant anomaly rates, and ~4% tortuosity) is concordant with the literature and supports an anatomy-informed approach to optimize safety and efficiency in transradial coronary intervention.

Conclusion

The luminal diameter of the radial artery serves as a critical guide in selecting appropriate arterial access for angiographic and interventional coronary procedures. Anatomical variations, including branching anomalies and tortuosity, though relatively infrequent, have a significant impact on procedural success, safety, and technical complexity in the transradial approach. Therefore, awareness of these variations and incorporation of pre-procedural anatomical evaluation are essential to optimize outcomes, minimize complications, and ensure safer and more efficient transradial coronary interventions.

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Conflicts of interest

There are no conflicts of interest.

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