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Anatomical variations of renal arteries in adult cadavers in Andhra Pradesh: A multicentric cross-sectional cadaveric study.

Dr. Pratyusha Challa[1], Dr. Ranzeetha D[2], *Dr.* ***Venkata Pavana Kumari Komarolu[1], Dr. Lakkireddy Vasanthi[3, *]***

[1]*Associate Professor, Department of Anatomy, Government Medical College, Ongole, Andhra Pradesh, India*

[2]*Associate Professor, Department of Anatomy, Guntur Medical College, Guntur, Andhra Pradesh, India*

[3]*Associate Professor, Department of Anatomy, Government Medical College, Rajamahendravaram, Andhra Pradesh, India.*

Abstract

Background

Anatomical variations in renal artery morphology hold crucial significance in surgical, urological, and radiological procedures. Comprehensive knowledge of these variations enhances the success of renal transplantation, angiography, and retroperitoneal surgeries.

Objectives

To investigate and document the prevalence and patterns of anatomical variations in renal arteries, including origin, number, branching patterns, and morphometry, in adult cadavers across multiple centers.

Methods

This multicentric observational study was conducted on 60 adult cadavers during routine anatomical dissection in medical institutions. Detailed dissection of the abdominal region was performed to trace the renal arteries from their origin at the abdominal aorta to their termination at the renal hilum. Parameters such as the number, origin (related to the superior and inferior mesenteric arteries), branching pattern, presence of accessory and polar arteries, and arterial dimensions were recorded.

Results

Renal artery variations were observed in 16 cadavers (26.7%). Bilateral variations were seen in 6 cadavers and unilateral variations in 10, predominantly on the right side (n=8). Accessory renal arteries were present in 13 cadavers. Early division of renal arteries occurred in 3 cases, all within 1 cm of the superior mesenteric artery. Pre-segmental and pre-hilar branching patterns were observed in 3 and 11 arteries, respectively. Polar arteries were found in 8 cases. The length and breadth of renal arteries ranged from 1.0–9.0 cm and 0.2–0.9 cm, respectively.

Conclusion

This study revealed a 26.7% prevalence of renal artery anatomical variations, with a predominance of unilateral right-sided anomalies. Understanding these variations is essential for minimizing intraoperative complications and optimizing outcomes in renal surgical and interventional procedures.

Recommendations

Preoperative imaging to identify renal artery variations is essential for planning renal surgeries, transplantations, and interventions, minimizing intraoperative risks, and improving surgical outcomes and vascular access success rates.

Keywords: *Renal artery, anatomical variation, accessory renal artery, cadaveric study, superior mesenteric artery, polar artery.*

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Corresponding Author: *Dr. Lakkireddy Vasanthi*
Email ID: ***drvasulaki@gmail.com***
Associate Professor, Department of Anatomy, Government Medical College, Rajamahendravaram, Andhra Pradesh, India.

Introduction

The renal arteries, typically described as paired lateral branches arising from the abdominal aorta at

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the L1–L2 vertebral level, are crucial for supplying blood to the kidneys. While the classical description involves a single renal artery to each kidney, anatomical studies have consistently demonstrated a broad range of variations in terms of number, origin, course, and branching patterns (1). These vascular anomalies, though frequently asymptomatic, have substantial clinical implications, especially in the context of renal transplantation, laparoscopic renal surgeries, donor nephrectomies, and interventional radiological procedures (4, 5).

Accessory renal arteries, polar arteries, and early divisions are among the most common and clinically significant variants. Their presence may complicate surgical procedures due to challenges in achieving complete vascular control and an increased risk of inadvertent injury or inadequate perfusion if unrecognized (2, 3). Notably, accessory arteries can originate anomalously close to major abdominal vessels such as the superior mesenteric artery (SMA) or inferior mesenteric artery (IMA), increasing the potential for iatrogenic complications during abdominal operations (5, 6). Additionally, pre-hilar and pre-segmental branching can make hilar dissection and renal mobilization particularly complex in both open and minimally invasive approaches (4).

Previous studies conducted across diverse populations have highlighted the ethnic and regional variability in renal artery anatomy, suggesting that reliance on generalized anatomical descriptions may be insufficient in clinical planning (5). Consequently, there is a growing recognition of the need for region-specific cadaveric studies, which offer direct visualization and precise measurement, and remain the gold standard for elucidating such vascular nuances (6, 7).

Therefore, the aim of this multicentric cross-sectional cadaveric study was to investigate and document the prevalence and anatomical patterns of renal artery variations including their origin, number, branching characteristics, and morphometric details in adult cadavers from multiple medical teaching institutions across different regions of Andhra Pradesh.

Methodology

Study Design and Setting

This descriptive, multicentric cross-sectional cadaveric study was conducted in the Departments of Anatomy at various medical teaching institutions across Andhra Pradesh, including Government Medical College, Ongole; Guntur Medical College, Guntur; and Siddhartha Medical College, Vijayawada. The study carried out from November 2019 to February 2025, aimed to investigate anatomical variations in the renal arteries of adult cadavers through meticulous dissection and comprehensive morphometric analysis.

Sample Size

A total of 60 adult cadavers (both male and female) were included in the study. All cadavers were preserved in formalin and were free from gross pathological or surgical abnormalities in the abdominal region.

Inclusion Criteria

- Adult cadavers aged above 18 years
- Well-preserved cadavers without signs of trauma or surgical alterations in the retroperitoneal region
- Intact renal arteries traceable from their origin to termination

Exclusion Criteria

- Cadavers with congenital anomalies of the urinary tract
- Cadavers with mutilated or dissected abdominal vasculature
- Pediatric or fetal specimens

Dissection Procedure

A standard midline abdominal incision was made to access the retroperitoneal space. The abdominal aorta was identified and followed laterally to trace the renal arteries bilaterally. Careful dissection was carried out to expose the arteries up to their termination at the renal hilum. The following parameters were recorded for each artery:

- Number and laterality (right/left, unilateral/bilateral)
- Origin (about SMA and IMA)
- Course (anterior/posterior to renal vein or ureter)
- Branching pattern (pre-hilar, pre-segmental)
- Presence of accessory and polar arteries
- Length and external diameter (breadth) measured using digital calipers

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Data Recording and Analysis

All findings were systematically documented using a standardized data sheet. Descriptive statistics including frequency, percentages, and range (minimum-maximum) were used to summarize the data. Tables were prepared to illustrate the distribution and morphometric characteristics of renal artery variations.

Ethical Considerations

Institutional ethical clearance was obtained from the Government Medical College, Ongole. The study was conducted according to the ethical principles outlined in the Declaration of Helsinki, and cadavers were utilized solely for educational and research purposes.

Results

A total of 60 adult cadavers were examined for variations in renal arterial anatomy. Renal artery variations were observed in 16 cadavers (26.7%) (Table 1, Figure 1,2).

Table 1. Overview of Renal Artery Variations

Type of Variation	Number of Cadavers
Total cadavers examined	60
Cadavers with renal artery variations	16
Bilateral variations	6
Unilateral variations	10
Right-sided unilateral	8
Left-sided unilateral	2

Figure 1. Bilateral Early Division of Renal Artery with Right-Sided Pre-Hilar Branching

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Figure 2. Unilateral Right-Sided Double Renal Arteries with Upper Renal Artery Giving Branch to Testis

Among these, bilateral variations were present in 6 cadavers (10%), while unilateral variations were noted in 10 cadavers (16.7%), predominantly on the right side (n = 8), with only 2 cases involving the left side.

Figure :3. Right-Sided Polar Artery Arising from Renal Artery and Left-Sided Early Division of Renal Artery

Accessory renal arteries were identified in 13 cadavers (21.7%) (Table 2, Figure 3,4). In 2 cadavers, four accessory renal arteries were observed arising from the abdominal aorta, while in 11 cadavers, two accessory arteries were present on either side.

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Figure .4: Unilateral Right-Sided Double Renal Artery with Early Division of Upper Renal Artery Giving Rise to Middle Suprarenal Artery, and Lower Accessory Renal Artery Entering into Lower Part of Renal Hilum

Table 2. Accessory Renal Arteries

Observation	Number of Cadavers
Cadavers with accessory renal arteries	13
Cadavers with 4 accessory renal arteries (from aorta)	2
Cadavers with 2 accessory renal arteries (from aorta)	11

Figure 5. Left Kidney with Two Arteries and Right Kidney with Four Arteries

Most of these vessels originated anterolaterally from the abdominal aorta and typically traversed anterior to the renal vein to reach the renal hilum.

Early division of the main renal artery was noted in 3 cadavers (5%), all occurring within 1 cm of the origin from the abdominal aorta, in close proximity to the superior mesenteric artery (SMA). Furthermore, 14 accessory renal arteries were found to originate within 1 cm of the SMA, indicating a frequent anatomical clustering near this major visceral branch. Additionally, renal arteries in 2 cadavers originated at the level of the inferior mesenteric artery (IMA), further highlighting positional variability (Table 3, **Figure 5**).

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Table 3. Early Division and Arterial Origin

Observation	Number of Cadavers
Cadavers with early division of renal artery	3
Early divisions within 1 cm of Superior Mesenteric Artery (SMA)	3
Accessory renal arteries originating within 1 cm of SMA	14
Renal arteries originating at the level of Inferior Mesenteric Artery (IMA)	2

Table 4. Branching Pattern Variations

Branching Pattern	Number of Arteries
Pre-segmental branching	3
Pre-hilar branching in main renal arteries	5
Pre-hilar branching in accessory renal arteries	6

Branching pattern variations were also documented. Pre-segmental branching was seen in 3 renal arteries, while pre-hilar branching was observed in 5 main renal arteries and 6 accessory renal arteries (Table 4).

These early divisions before entering the hilum may impact surgical planning and vascular interventions.

Polar arteries were detected in 8 instances. In 2 cases, they originated directly from the abdominal aorta, while 4 arose from accessory renal arteries, and 2 from the main renal arteries, supplying either the superior or inferior poles of the kidney (Table 5).

Table 5. Polar Arteries

Source of Polar Arteries	Number of Polar Arteries
Directly from abdominal aorta	2
From accessory renal arteries	4
From main renal arteries	2

Morphometric analysis revealed that the length of renal arteries ranged from 1.0 cm to 9.0 cm, while their breadth varied between 0.2 cm and 0.9 cm. The longest renal artery (9.0 cm) and the broadest artery (0.9 cm) were both observed on the right side (Table 6)

Table 6. Renal Artery Morphometry (Range)

Parameter	Minimum (cm)	Maximum (cm)
Length	1.0	9.0
Breadth	0.2	0.9

Discussion

The present multicentric cadaveric study reinforces the anatomical complexity and clinical significance of renal arterial variations, echoing findings across global literature. In this study, renal artery variations were noted in 26.7% of the examined cadavers, aligning with earlier reported prevalence rates ranging between 20% and 30% (8, 9, 11). These findings underscore the importance of preoperative vascular mapping, particularly in renal transplantation and trauma surgeries, where unrecognized anomalies can jeopardize surgical outcomes (8, 14).

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Unilateral variations, particularly those on the right side (80%), were more frequently observed than bilateral anomalies. This trend has been attributed to asymmetrical embryological regression patterns between the renal arteries (9, 12). A notable proportion (21.7%) of the specimens demonstrated accessory renal arteries, often arising anterolaterally from the abdominal aorta and coursing anterior to the renal vein, consistent with findings from other cadaveric and radiologic studies (9, 10, 14). These vessels pose considerable surgical risks if not properly identified, especially during donor nephrectomy or endovascular interventions (12, 14).

In this study, 5% of the cadavers exhibited early bifurcation of the renal arteries, occurring within a distance of 1 cm from their point of origin on the abdominal aorta. This variation, often located near the superior mesenteric artery (SMA), has been noted to increase surgical complexity due to limited extrarenal length and challenging vascular control (11, 13). Such patterns require heightened attention during hilar dissection to avoid inadvertent vascular injury (8, 11).

Pre-hilar bifurcation and pre-segmental branching were among the identified branching anomalies. These findings corroborate earlier studies that highlight their potential to compromise visibility and maneuverability during laparoscopic and robotic renal procedures (9, 13, 15). Furthermore, polar arteries were identified in eight specimens, originating variably from both main and accessory arteries. If not preoperatively recognized, polar arteries may contribute to segmental renal ischemia following partial or total nephrectomy (10, 14).

From a morphometric perspective, the renal arteries demonstrated variable lengths (1.0–9.0 cm) and diameters (0.2–0.9 cm), influencing the technical considerations for vascular anastomosis, especially in the setting of short or narrow arterial pedicles (12, 13). These dimensions align with other regional and international anatomical reports, which emphasize the heterogeneity in renal vasculature (8, 11).

Finally, the regional data generated in this study not only corroborate but also expand the anatomical understanding from prior literature across diverse populations (9, 10, 12, 15). Recognizing such localized patterns is crucial for optimizing surgical outcomes and guiding interventional planning in renal surgeries.

Generalizability

Although this study provides valuable insights into renal artery variations among cadavers from Andhra Pradesh, the findings may not be fully generalizable to other populations due to potential regional and ethnic anatomical differences. However, the multicentric nature of the study enhances its applicability within the South Indian context and provides a reference point for comparative anatomical and surgical studies.

Conclusion

This multicentric cadaveric study revealed a high prevalence of anatomical variations in renal arteries, including accessory arteries, early divisions, and diverse branching patterns. Notably, unilateral variations were more common than bilateral, with a predominance on the right side. Accessory renal arteries frequently originate near the superior mesenteric artery and often coursed anteriorly to the renal vein. Pre-hilar and polar artery patterns further highlight the complexity of renal vasculature. These variations have significant clinical implications, particularly in renal transplantation, laparoscopic surgeries, and interventional radiology. A thorough understanding of such variations and the use of detailed preoperative vascular imaging are essential for optimizing surgical outcomes and reducing complications.

Limitations

While cadaveric dissection remains the gold standard for anatomical studies, the absence of post-mortem imaging limits correlation with radiological findings. Additionally, demographic details such as age, sex, and laterality-based statistical comparison were not analyzed due to the nature of cadaver availability.

Recommendations

Based on the findings of this study, it is recommended that surgeons, nephrologists, and interventional radiologists routinely assess renal vascular anatomy using high-resolution imaging modalities such as CT angiography or MR angiography before any renal surgical or interventional procedure. Preoperative identification of accessory, polar, and early-branching arteries is essential to minimize intraoperative complications, prevent inadvertent vascular injury, and ensure

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adequate renal perfusion. Medical curricula should emphasize anatomical variations in renal arteries during cadaveric dissection training. Further large-scale, population-specific studies are encouraged to better understand regional differences and their implications in renal transplant planning and vascular surgery.

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Abbreviations

SMA – Superior Mesenteric Artery
IMA – Inferior Mesenteric Artery
cm – Centimeter
mm – Millimeter

Source of funding

The study had no funding.

Conflicts of interest

The author declares no conflict of interest.

Data Availability

Data Available upon request

Author Biography

Dr. Pratyusha Challa is currently serving as an Associate Professor in the Department of Anatomy at Government Medical College, Ongole. She completed her MBBS and MD in Anatomy from Guntur Medical College, Guntur. With over Eleven years of teaching experience, she has been actively involved in educating undergraduate medical students and mentoring academic growth. Dr. Challa has published eight research papers in reputed anatomical journals, contributing to the advancement of anatomical science. Her ORCID ID is: https://orcid.org/0009-0001-8198-6419

Dr. Ranzeetha D. is currently serving as an Associate Professor in the Department of Anatomy at Guntur Medical College, Guntur, Andhra Pradesh, India. She completed her MBBS from Katuri Medical College, Chinakakani, and earned her MD in Anatomy from Guntur Medical College, Guntur. With over 12 years of teaching experience, Dr. Ranzeetha has guided several undergraduate students, including those undertaking Indian Council of Medical Research (ICMR)-funded projects. She has authored five research papers in reputed journals, with a focus on anatomical science and public health. Her **ORCID ID** is: https://orcid.org/0009-0000-7994-0529

Dr. Venkata Pavana Kumari Komarolu is currently serving as an Associate Professor in the Department of Anatomy at Government Medical College, Ongole, Andhra Pradesh. She earned both her MBBS and MD in Anatomy from Guntur Medical College, Guntur, and further enhanced her medical education by completing a Postgraduate Diploma in Family Medicine from the prestigious Christian Medical College, Vellore. With over 13 years of teaching experience, Dr. Komarolu has mentored numerous undergraduate students, including those undertaking Indian Council of Medical Research (ICMR)-funded projects. She has published six research papers in reputed journals, with a focus on anatomical sciences and public health. Her **ORCID ID is**: https://orcid.org/0009-0003-9505-481X

Dr. Lakkireddy Vasanthi is currently serving as an Associate Professor in the Department of Anatomy at Government Medical College, Rajamahendravaram, Andhra Pradesh, India. She completed her MBBS from MNR Medical College, Sangareddy, Telangana, and pursued her MD in Anatomy from the prestigious Osmania Medical College, Hyderabad, Telangana. With over 11 years of teaching experience, Dr. Vasanthi has played an active role in academic and research mentorship, guiding several undergraduate students. Her research contributions span the fields of anatomy and public health, with seven publications in indexed journals, including one in the Cureus Journal of Medical Science, a PubMed-indexed

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journal. Her **ORCID ID is: https://orcid.org/0009-0008-3587-4345**

Author's contribution

PC-Concept and design of the study, results interpretation, review of the literature, and preparing the first draft of the manuscript. Statistical analysis and interpretation, revision of the manuscript-Concept and design of the study, results interpretation, review of the literature and preparing the first draft of the manuscript, revision of the manuscript**. Review** of literature and preparing the first draft of the manuscript. Statistical analysis and interpretation.**LV**-Concept and design of the study, results interpretation, review of the literature, and preparing the first draft of the manuscript. Statistical analysis and interpretation, revision of the manuscript.

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