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Original Article

Computed Tomography-Based Analysis of Renal Artery Anatomy and its Variations

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ABSTRACT

Background: Variations in renal arterial anatomy are common and have significant implications in surgical, radiological, and interventional procedures. Precise preoperative identification is essential to avoid complications.
Objective: To analyze renal artery variations using CT imaging and evaluate their morphometric characteristics and clinical correlations.
Methods: A cross-sectional observational study was conducted on 100 patients undergoing abdominal CT scans. Parameters analyzed included number, origin, branching pattern, length, and diameter of renal arteries. Variations were categorized into accessory and aberrant arteries. Statistical analysis was performed using SPSS, with $p < 0.05$ considered significant.
Results: A high prevalence of renal artery variations was observed. Accessory arteries were more frequent than aberrant arteries, with right-sided predominance. Aberrant arteries showed higher occurrence on the left side. Significant gender differences were observed in arterial length. A statistically significant association was found between renal artery variations and hypertension ($p < 0.001$).
Conclusion: Renal artery variations are highly prevalent and clinically relevant. CT angiography is an effective non-invasive tool for evaluation, aiding in improved surgical planning and patient outcomes.

Keywords*: Renal artery, CT angiography, anatomical variation, accessory artery, aberrant artery, hypertension.*

INTRODUCTION

The renal arteries are vital vascular structures supplying the kidneys, typically arising from the abdominal aorta at the level of the first and second lumbar vertebrae. Classical anatomical descriptions suggest a single renal artery per kidney; however, variations are frequently encountered.[1,2]

These variations originate during embryological development due to persistence of lateral mesonephric arteries. The resulting anatomical diversity includes accessory renal arteries, aberrant polar arteries, and early branching patterns.[3,4]

Understanding these variations is critical in modern clinical practice, particularly in renal transplantation, laparoscopic surgery, and interventional radiology. Undetected vascular anomalies may lead to intraoperative hemorrhage, graft failure, or postoperative complications.[5]
Advancements in computed tomography angiography have revolutionized vascular imaging by providing accurate, non-invasive, and high-resolution visualization. Therefore, this study aims to evaluate renal artery variations and their clinical implications using CT imaging.[6]

MATERIALS AND METHODS

Study Design

Cross-sectional observational study.

Study Setting
Conducted at a tertiary care hospital in Lucknow.

Study Population
- Sample size: 100 patients
- Age range: 18–80 years
- Both genders included

Inclusion Criteria
Patients undergoing abdominal CT scans
Age ≥ 18 years

Exclusion Criteria
- History of renal surgery
- Severe renal pathology
- Poor image quality
- Pregnancy

Data Collection
CT angiographic images were analyzed using dedicated imaging software. The following parameters were assessed:
- Number of renal arteries
- Site of origin
- Branching pattern
- Length and diameter
- Presence of accessory or aberrant arteries

Definitions
- Accessory renal artery: Additional artery entering through the hilum
- Aberrant artery: Artery entering directly into renal poles
- Early branching: Division within 1 cm from origin

Statistical Analysis
- Software: SPSS
- Data expressed as mean ± standard deviation
- Chi-square test for categorical variables
- Independent t-test for continuous variables
- Significance level: $p < 0.05$

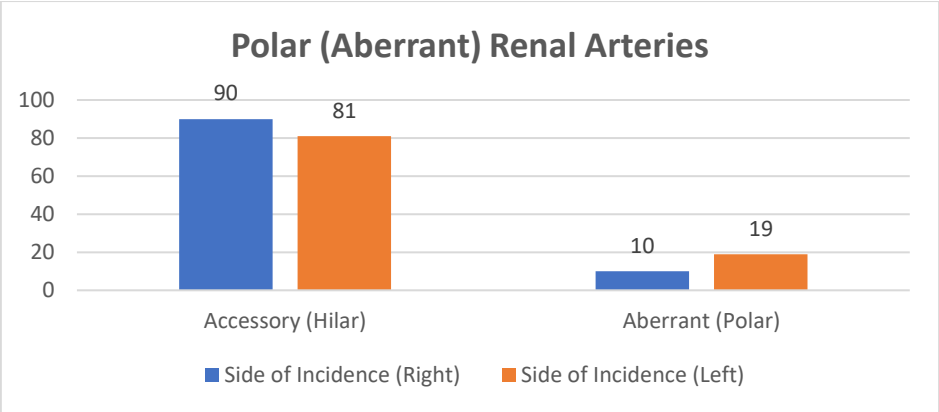
RESULTS
Demographic Distribution
Majority of patients were in the 21–30 years age group, followed by 41–50 years.

Prevalence of Renal Artery Variations
A high prevalence of anatomical variations was observed in the study population.

Types of Variations

Type of Variation	Right Side (%)	Left Side (%)
Accessory Artery	90%	81%
Aberrant Artery	10%	19%

Accessory arteries were the most common variation
Aberrant arteries showed left-sided predominance



Morphometric Analysis

Parameter	Male (Mean ± SD)	Female (Mean ± SD)
Right renal artery length	5.11 ± 0.8 cm	4.59 ± 0.7 cm
Left renal artery length	4.92 ± 0.6 cm	4.48 ± 0.5 cm

Clinical Correlation

A statistically significant association was found between renal artery variations and hypertension ($p < 0.001$).

Discussion

One of the most important findings of the present study was the observation of renal artery variations in 100% of the study population. This prevalence is considerably higher than that reported in previous studies. **Osmans**[7] reported variations in 42.5% of Sudanese kidney donors, while **MihaylovaE**[8]. observed variations in 53.7% of patients. Similarly, **MunnusamyK**[9]**.** documented renal artery v ariations in 51% of kidney donors. The higher prevalence in the present study may be due to meticulous CT evaluation, inclusion of subtle vascular anomalies, and possible regional or ethnic differences in the South Asian population. These findings reinforce the concept that renal arterial anatomy is more variable than traditionally described.

Accessory (hilar) renal arteries were the most common variation observed in the present study, occurring in 90% of cases on the right side and 81% on the left side. Similar findings were reported by **MihaylovaE**[10]., who identified accessory renal arteries as the most common variation. **Mansur D**[11]. also documented accessory renal arteries in 26.21% of kidneys. The predominance of accessory arteries supports the embryological theory of persistence of fetal mesonephric arteries.

Aberrant (polar) arteries in the present study showed a greater prevalence on the left side (19%) compared to the right side (10%). This finding is comparable with the observations of **Chhetri K.P**[12]., who reported polar arteries as common renal vascular variations. Aberrant arteries are clinically important because they may compress the ureter and produce hydronephrosis or ureteropelvic junction obstruction. Their higher prevalence on the left side may increase the complexity of left renal surgeries and donor nephrectomies.

The present study also highlights the importance of CT angiography in the evaluation of renal vascular anatomy. **SarierM**[13]. reported that CT angiography has very high accuracy in detecting renal arterial variations in living kidney donors. Similarly, **Gumus H**[14]. emphasized the usefulness of multidetector CT in identifying extra renal arteries and early branching patterns. In the present study, CT imaging provided accurate assessment of renal artery origin, branching pattern, length, and caliber, making it highly valuable for preoperative planning.

From a surgical perspective, multiple renal arteries increase the complexity of renal transplantation and nephrectomy because each additional artery requires separate vascular anastomosis. **Garcia L.E**[15]. reported successful transplant outcomes even in kidneys with multiple arteries when proper vascular reconstruction techniques were used. Nevertheless, accessory arteries increase the risk of complications such as arterial stenosis, thrombosis, and delayed graft function. Therefore, accurate preoperative vascular mapping is essential

Limitations

- Relatively small sample size
- Single-center study
- Lack of longitudinal follow-up
- Possible selection bias

Clinical Implications

- Essential for renal transplantation planning
- Important in vascular and urological surgeries
- Prevents intraoperative complications
- Assists in radiological diagnosis

Conclusion

Renal artery variations are highly prevalent and clinically significant. Accessory arteries are the most common, while aberrant arteries show side-specific distribution.

CT angiography serves as a reliable and non-invasive modality for evaluating renal vascular anatomy. Preoperative identification of these variations is crucial for improving surgical outcomes and minimizing complications.

Declarations

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Conflict of Interest: None

Ethical Approval: Obtained from institutional ethics committee

Informed Consent: Obtained from all participants

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