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ANATOMICAL VARIATIONS OF SEGMENTAL AND ACCESSORY RENAL ARTERIES: A CADAVERIC, CORROSION CAST, AND RADIOLOGICAL STUDY.

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ABSTRACT

Background: Segmental and accessory renal arteries play a crucial role in determining the vascular supply of the kidney. Their variations are of immense clinical relevance in nephron-sparing surgery, renal transplantation, and urological interventions.
Objective: To document the anatomical variations of apical, upper, middle, lower segmental arteries and accessory renal arteries in 60 adult human kidneys.
Methods: Sixty kidneys (40 cadaveric dissections, 10 corrosion casts, 10 radiological studies) were examined. Segmental arteries and accessory renal arteries were identified and classified. Their frequency and patterns were compared with previous anatomical studies.
Results: The apical segmental artery was present in 93.3% of cases, with origin predominantly from the anterior division. Variations included dual apical arteries (6.7%). Upper segmental arteries were observed in 90% of specimens, often arising from the anterior division, with accessory branches in 10%. Middle segmental arteries showed the highest variability: single in 70%, double in 20%, and absent in 10%. Lower segmental arteries were consistently present, though accessory lower segmental arteries occurred in 8.3%. Accessory renal arteries were noted in 15% of specimens, arising either directly from the aorta or as extra branches of the main renal artery. Most accessory arteries supplied the upper or lower poles.
Conclusion: Segmental and accessory renal arteries demonstrate significant anatomical variability. Awareness of these patterns is vital in planning renal transplantation, managing hydronephrosis, and performing partial nephrectomy. Preoperative imaging should evaluate these arteries to reduce surgical risks.

Keywords: Segmental arteries; accessory renal arteries; apical artery; anatomical variations; renal transplantation.

INTRODUCTION

The kidneys are supplied by the renal arteries, which typically divide into anterior and posterior divisions before further branching into segmental arteries. The classical description, established by Graves[1], identifies five segmental arteries: apical, upper, middle, lower, and posterior. These arteries

are end arteries with minimal collateral circulation, meaning their damage or occlusion results in ischemia of the corresponding renal segment.

However, anatomical studies from different populations have demonstrated considerable variability in the number, origin, and branching pattern of segmental arteries[2,3]. The middle and apical segmental arteries, in particular, are prone to duplication, absence, or anomalous origin. Such variations directly impact surgical practice, as nephron-sparing procedures, renal transplantation, and endourological interventions require precise knowledge of vascular anatomy to prevent complications such as haemorrhage or segmental infarction.

Accessory renal arteries, which arise directly from the abdominal aorta or from the main renal artery, are also well documented. Their incidence varies between 10% and 30% in different populations[4,5]. They most commonly supply the renal poles and have been implicated in conditions such as hydronephrosis when lower polar accessory arteries compress the ureteropelvic junction[5]. In renal transplantation, accessory arteries demand additional vascular anastomosis, increasing surgical complexity.

Given the clinical significance of these variations, it is essential to establish baseline data for specific populations. This study examines segmental and accessory renal arteries in 60 kidneys using dissection, corrosion casting, and radiological imaging, and compares the findings with classical and contemporary anatomical studies.

MATERIALS AND METHODS

Study design and sample: This was an observational, descriptive anatomical study performed on 60 human kidneys.The sample comprised 40 cadaveric kidneys obtained during routine undergraduate dissections in the Department of Anatomy, Index Medical college & Hospital Indore from June 2023 to march 2025, 10 kidneys studied using corrosion cast technique, and 10 kidneys studied using radiological methods. Only adult kidneys with intact vascular pedicles were included. Pathological or damaged specimens were excluded.

Cadaveric dissection (40 specimens):

- The renal hilum and pedicle were carefully dissected to expose the renal artery and its segmental branches.
- Each segmental artery (apical, upper, middle, and lower) was identified and traced into the renal substance.
- Variations in number, origin, and branching were recorded.

Corrosion cast method (10 specimens):

- Renal arteries were injected with colored silicone or plastic resin.
- Kidneys were then placed in hydrochloric acid solution for corrosion of the soft tissue.
- The resulting vascular casts were studied to document branching patterns of segmental arteries and presence of accessory arteries.

Radiological method (10 specimens):

- Barium sulphate suspension was injected into the renal artery.
- Radiographs were taken to visualize intrarenal arterial segmentation.
- The presence of accessory arteries arising directly from the aorta or as branches of the main renal artery was recorded.

Parameters studied:

- Presence, number, and origin of apical, upper, middle, and lower segmental arteries.
- Presence, number, and source of accessory renal arteries.
- Frequency distribution of each variation.

Classification and analysis:

- Arterial branching patterns were classified according to Graves (2), Kher (3), and Verma (4) with necessary modifications.
- Data were tabulated, and frequencies were expressed as percentages.
- Observed variations were compared with classical descriptions and previous literature.

Ethical approval for use of cadaveric material was obtained as per departmental norms.

RESULTS

A total of 60 kidneys were examined for segmental and accessory arterial variations. The findings revealed that while most kidneys displayed the classical pattern of segmental arteries, deviations were frequent, especially in the middle and apical arteries.

Apical Segmental Artery: The apical artery was present in 93.3% of kidneys, usually arising from the anterior division (85%). In 8.3% of specimens, it originated from the posterior division. Dual apical arteries were noted in 6.7% of specimens, while in another 6.7% the apical artery was absent, with its territory supplied by adjacent arteries. These deviations highlight the variable vascularization of the renal apex.

Upper Segmental Artery: Upper segmental arteries were identified in 90% of specimens, predominantly arising from the anterior division (81.6%). In 10% of cases, accessory upper segmental arteries were documented, reflecting additional vascular supply to the upper pole. In a minority of cases, the artery displayed an aberrant origin from the main renal trunk.

Middle Segmental Artery: The middle segmental artery was the most variable among all segmental arteries. It was present as a single vessel in 70% of specimens, duplicated in 20%, and absent in 10%. When absent, its vascular territory was supplied by enlarged apical or lower segmental arteries, indicating compensatory circulation.

Lower Segmental Artery: The lower segmental artery was consistently present in all specimens (100%). However, accessory lower segmental arteries were identified in 8.3% of cases. These accessory vessels often supplied the lower pole and demonstrated independent entry into the renal parenchyma.

Accessory Renal Arteries: Accessory renal arteries were found in 15% of specimens. Two-thirds (10% of total) originated directly from the abdominal aorta, while one-third (5% of total) arose as additional branches of the main renal artery. The majority supplied either the upper pole (6.6%) or the lower pole (8.3%). Lower polar accessory arteries are particularly important clinically, as they may cross anterior to the ureter and compress the ureteropelvic junction, causing obstruction and hydronephrosis.

Table 1. Distribution of segmental renal arteries (n=60)

Segmental Artery	Pattern	Frequency (%)
Apical	Single	86.6
	Dual	6.7
	Absent	6.7
Upper	Single	81.6
	Accessory	10
Middle	Single	70
	Double	20
	Absent	10
Lower	Single	91.7
	Accessory	8.3

Figure 1. Distribution of segmental renal arteries.

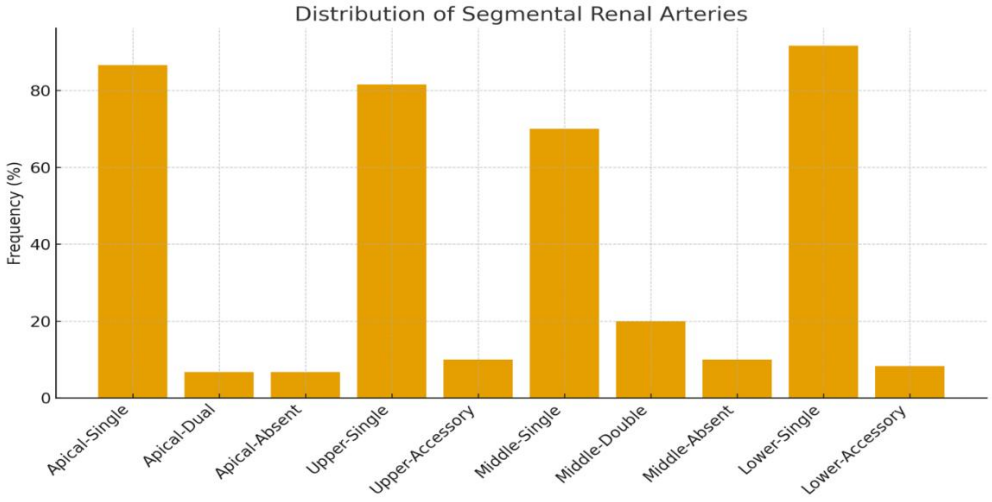
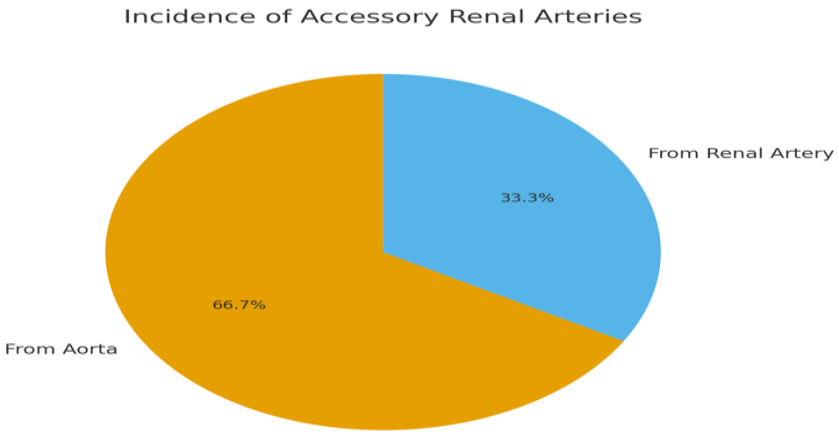


Table 2. Incidence of accessory renal arteries (n=60)

Origin	Frequency (%)	Segment Supplied
Abdominal aorta	10	Upper/lower poles
Main renal artery	5	Upper/lower poles

Figure 2. Incidence of accessory renal arteries.



Comparative Observations:

- The apical artery was consistently present in the majority, but its absence in 6.7% confirms reports of variable apical supply in previous studies (3,4).
- The middle artery showed the greatest variability, supporting earlier findings that it is the least reliable segmental branch.
- Accessory renal arteries (15%) were within the expected range reported in global studies (5–7).
- Lower polar accessory arteries, found in 8.3%, may contribute to ureteric obstruction and hydronephrosis.

These results underscore the complexity of renal vascular anatomy and its surgical importance.

DISCUSSION

The present study highlights the variability of segmental and accessory renal arteries. The apical, upper, middle, and lower segmental arteries generally followed the classical pattern, but significant deviations were observed, particularly in the middle and lower arteries. Dual apical arteries and absent middle arteries are rare but important variations.

Accessory renal arteries were present in 15% of cases, comparable to reports by Sampaio et al[5] and Ajmani[7]. Their origin from the aorta has been extensively reported[4,6] and their presence has major clinical implications. Accessory lower polar arteries are particularly significant in hydronephrosis, as they may compress the ureteropelvic junction. These findings emphasize the importance of detailed preoperative imaging, such as CT angiography, to map segmental and accessory arteries. Such anatomical knowledge reduces complications in nephron-sparing surgeries, ensures successful vascular anastomosis in transplantation, and guides safe endourological procedures.

CONCLUSION

The present study demonstrates that segmental and accessory renal arteries show a wide range of anatomical variations. The apical and upper segmental arteries were generally consistent, while the middle artery displayed the greatest variability, including duplication or absence. Lower segmental arteries were consistently present but occasionally showed accessory branches. Accessory renal arteries were present in 15% of specimens, most frequently arising from the abdominal aorta and supplying the renal poles. These findings are clinically significant because segmental arteries are end arteries, and their damage or ligation can result in segmental infarction. Variations in accessory renal arteries, particularly those crossing the ureteropelvic junction, may cause hydronephrosis. In renal transplantation, the presence of accessory arteries requires multiple vascular anastomoses, increasing surgical complexity. Therefore, preoperative imaging such as CT or MR angiography is indispensable for identifying these variations and minimizing intraoperative and postoperative complications.

In conclusion, the variability of segmental and accessory renal arteries highlights the importance of population-specific anatomical studies. The data from this study provide valuable insights for clinicians performing nephron-sparing surgery, renal transplantation, and urological interventions.

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