

ANATOMICAL STUDY OF RENAL ARTERY VARIATIONS IN HUMAN CADAVERS

Dhivya S¹, Kalai Anbusudar², Srimuthalage M³

Received : 31/07/2026

Received in revised form : 28/08/2026

Accepted : 11/09/2026

Keywords:

Anatomy, Anatomic Variation, Cadaver, Kidney, Renal artery.

Corresponding Author:

Dr. Dhivya S,

Email: drsdhivya99@gmail.com

DOI: 10.47009/jamp.2026.8.5.102

Source of Support: Nil,

Conflict of Interest: None declared

Int J Acad Med Pharm
2026; 8 (5); 652-656¹Professor, Department of Anatomy, Government Medical College, Namakkal, Tamilnadu, India²Professor, Department of Anatomy, Government Mohan Kumaramangalam Medical College, Salem, Tamilnadu, India³Tutor, Department of Anatomy, Government Medical College, Namakkal, Tamilnadu, India

ABSTRACT

Background: Renal arterial variations are common anatomical findings with important implications for renal surgery, transplantation, and interventional procedures. This study aimed to identify the vascular anatomy of the kidneys with respect to the origin, course, branching pattern, and anatomical variations of the Renal arteries in human cadavers. **Materials and Methods:** This descriptive cadaveric study was conducted on 20 well-preserved adult human cadavers (40 kidneys). The abdomen was dissected using Cunningham's Manual of Practical Anatomy and both kidneys were exposed and examined. The renal arteries were traced from their origin to distribution, and observations regarding their number, origin, course, branching pattern, accessory renal arteries, anatomical relationships, and photographic documentation were systematically recorded. **Result:** Accessory renal arteries were identified in seven (35%) cadavers, comprising unilateral arteries in six (30%) and bilateral arteries in one (5%) cadaver, with bilateral origin of the testicular arteries from bilateral accessory renal arteries observed in one (5%) cadaver. Hilar and polar accessory renal arteries were identified in eight (20%) and six (15%) kidneys, respectively. Early renal artery division occurred in eight (20%) kidneys. The anterior branching patterns were Type I (55%), Type II (35%), and Type III (10%), whereas the posterior branching pattern was predominantly Type I (80%) compared with Type II (20%). **Conclusion:** Renal arterial variations are frequent and should be recognised to facilitate accurate surgical planning, transplantation, and safe vascular interventions.

INTRODUCTION

The renal arteries are the main blood vessels supplying the kidneys, which receive approximately 20-25% of the cardiac output to maintain filtration, electrolyte balance, acid-base balance, and blood pressure. Each kidney is supplied by a single renal artery that arises from the lateral aspect of the abdominal aorta just below the superior mesenteric artery at the level of intervertebral disc between L1-L2. Before entering the renal hilum, the artery divides into anterior and posterior segmental branches that supply different segments of the kidney. Since these are end arteries with very little collateral circulation, damage or blockage of a segmental artery can lead to segmental ischaemia or infarction, making the preservation of the renal blood supply essential during surgery and interventional procedures.^[1] However, this classical pattern is not observed in every individual.

Variations in the renal arteries are among the most common vascular variations found in the abdomen. These include accessory renal arteries, multiple hilar

arteries, superior and inferior polar arteries, early prehilum branching, and differences in the origin or course of renal arteries.^[2-4] Although most renal arteries arise from the lateral side of abdominal aorta, they may occasionally originate from the anterolateral or posterolateral aspect.^[5,6] These variations develop during embryonic life as the kidneys ascend from the pelvis to the lumbar region of the spine. During this process, temporary arteries from the dorsal aorta supply blood to the kidneys. These vessels usually disappear as new arteries develop, but persistence of one or more embryonic arteries results in accessory or multiple renal arteries, while altered vascular remodelling may produce unusual origins or early branching patterns.^[6,7] The reported frequency of renal arterial variations differs across populations and study methods. Multiple renal arteries are found in approximately 18-30% of individuals, with double renal arteries being the most common variation.^{1,2} Accessory renal arteries have been reported in approximately 20-40% of cases, and early prehilum branching has also been observed in a considerable number of

individuals.^[3,4,8] These differences are likely due to ethnic diversity, developmental factors, and variations in the study design. Knowledge of these variations is important in clinical practice. As each segmental artery supplies a specific part of the kidney, accidental injury or ligation of an accessory or aberrant artery may reduce blood flow and cause segmental infarction. Detailed understanding of renal arterial anatomy is essential during renal transplantation, donor nephrectomy, partial nephrectomy, vascular reconstruction, endovascular procedures, and interventional radiology.^[2,9]

Multiple renal arteries increase the complexity of transplantation because each artery must be preserved and reconstructed to maintain adequate graft perfusion.^[10] Early branching and accessory arteries increase the risk of bleeding and postoperative renal dysfunction during nephron-sparing surgery and may affect procedures such as renal artery stenting, embolisation, aneurysm repair, and renal denervation.^[9,10] Accessory renal arteries have also been studied for their possible role in renovascular hypertension, although this relationship is still being investigated.^[11] Modern imaging techniques, such as multidetector CT angiography and MR angiography, have improved the preoperative assessment of renal vessels. However, cadaveric dissection remains the gold standard because it allows direct examination of the origin, course, branching pattern, and relationships of the renal arteries.^[9] Differences in ethnicity, sample size, methodology, and classification have resulted in inconsistent findings across studies.^[2,3] Hence, further cadaveric studies are needed to improve our understanding of renal arterial anatomy. Therefore, the present study was undertaken to examine the origin, course, branching pattern, and variations of the renal arteries in human cadavers and to evaluate their clinical and surgical significance.

Aim: This study aimed to identify the vascular anatomy of the kidneys with respect to the origin, course, and any other anatomical variations in the vessels.

MATERIALS AND METHODS

This descriptive cadaveric study was conducted on 20 well-preserved adult human cadavers (40 kidneys) obtained from the Department of Anatomy, Government Medical College, Namakkal. Institutional permission was obtained from the Department of Anatomy, Government Medical College, Namakkal, before the commencement of the study. All cadavers used in the study were legally donated and handled with due respect, maintaining confidentiality and ethical standards throughout the study.

Inclusion and Exclusion criteria

This study included well-preserved human adult cadavers of both sexes, aged between 60 and 80 years, with intact kidneys and well-preserved renal

vasculature. Cadavers with congenital anomalies, gross pathological changes, previous renal surgery, traumatic injury, or damage to the renal vessels during dissection were excluded from the study.

Materials

The materials used in this study included standard dissection instruments, Cunningham's Manual of Practical Anatomy, a predesigned data collection sheet, a digital camera for photographic documentation, and the materials required for cadaveric dissection.

Methods

The abdomen was opened according to the standard procedure described in Cunningham's Manual of Practical Anatomy. The anterior abdominal wall was reflected, and the abdominal viscera were carefully removed to expose the retroperitoneum. Both kidneys were identified in situ. The renal arteries were meticulously dissected and traced from their origin to their distribution. Both the right and left kidneys were examined separately. The renal arteries were assessed for their number, site of origin, course, branching pattern, and presence of accessory renal arteries. The renal veins were also examined for their numbers and anatomical courses. The relationship between the renal vessels and important anatomical landmarks was carefully observed. All observations were recorded using a pre-designed data collection sheet. Representative photographs were taken during dissection to document the anatomical findings, and the data were presented as frequency and percentage.

RESULTS

Accessory renal arteries were present in 7 (35%) cadavers, while 13 (65%) showed a normal renal arterial pattern. Unilateral accessory renal arteries were more common, occurring in six (30%) cadavers, whereas bilateral accessory renal arteries were found in only one (5%) cadaver. In this bilateral case, both testicular arteries arose from the accessory renal arteries (1; 5%). Hilar accessory renal arteries were observed more frequently than polar arteries, involving 8 (20%) and 6 (15%) kidneys, respectively. Overall, accessory renal arteries were observed in 14 (35%) kidneys, whereas 26 (65%) had a normal pattern. Early division of the renal artery occurred in eight (20%) kidneys, whereas 32 (80%) kidneys showed normal branching [Table 1, Figure 1-4].



Figure 1: Unilateral accessory renal arteries



Figure 2: Bilateral accessory renal arteries with bilateral origin of testicular arteries



Figure 3: Hilar accessory renal artery



Figure 4: Inferior polar accessory renal artery

Type I was the most common anterior renal artery branching pattern, seen in 22 (55%) kidneys, followed by Type II in 14 (35%), while Type III was

least common, occurring in 4 (10%) kidneys. For the posterior division, Type I branching, where the artery entered as a single vessel, was found in 32 (80%) kidneys, whereas Type II branching with bifurcation was observed in eight (20%) kidneys [Table 2, Figure 5-8].



Figure 5: Early division of the renal artery



Figure 6: Type I anterior branching pattern



Figure 7: Type II anterior branching pattern



Figure 8: Type I posterior branching pattern

Table 1: Prevalence and anatomical variations of accessory renal arteries and early division of the renal artery among the studied kidneys

		N (%)
Cadavers With Accessory Renal Artery	Yes	7 (35%)
	No	13 (65%)
Accessory Renal Artery (n=7)	Unilateral	6 (30%)
	Bilateral	1 (5%)
Type of Accessory Renal Artery	Hilar	8 (20%)

Total kidneys with Accessory Renal Artery	Polar	6 (15%)
	Yes	14 (35%)
	No	26 (65%)
Early division of Renal Artery	Present	8 (20%)
	Absent	32 (80%)

Table 2: Branching patterns of the anterior and posterior divisions of the renal artery

		N (%)
Branching pattern of Renal Arteries	Anterior Division	Type I
		22 (55%)
		Type II
		14 (35%)
		Type III
	Posterior Division	4 (10%)
		Type I
		32 (80%)
		Type II
		8 (20%)

DISCUSSION

In our study, accessory renal arteries were identified in 35% of kidneys, with unilateral accessory renal arteries being more common than bilateral accessory renal arteries. A similar pattern was reported by Kaushik et al., who found accessory renal arteries in 5 of 60 kidneys (8%), including three right-sided (5%) and two left-sided (3.3%) arteries, with one pair of kidneys showing bilateral accessory renal arteries. All accessory renal arteries arose directly from the abdominal aorta and included two superior polar arteries (3.3%) and three inferior polar arteries (5%).^[12] Similarly, Munnusamy et al. observed renal arterial variations in 51% of prospective kidney donors, with 38% having accessory renal arteries and 13% showing early renal artery division. They also reported an equal right- and left-sided distribution (13% each) and bilateral accessory renal arteries in 12% of individuals.^[13] The variation in prevalence across studies is probably related to differences in sample size, study population, methodology, and whether cadaveric dissection or CT angiography was used in the study.

In the present study, the hilar accessory renal arteries were more common than the polar accessory renal arteries. Although Kaushik et al. mainly classified accessory arteries by their location, they reported superior polar arteries in 3.3% and inferior polar arteries in 5% of kidneys.^[12] Similarly, Cai et al. described an accessory renal artery entering the lower pole and classified it as an inferior polar artery.^[6] These observations suggest that both hilar and polar accessory arteries are common, although their frequency differs among populations and study methods.

In our study, the bilateral origin of the testicular arteries from bilateral accessory renal arteries was reported which was comparable to that of Cai et al., who reported a 61-year-old male cadaver in whom the testicular artery arose from the right accessory renal artery. Their review showed that accessory renal arteries occur in up to 30% of individuals, with ipsilateral accessory arteries accounting for 30% and bilateral accessory arteries accounting for 12%. The abdominal aorta was the source of the accessory renal arteries in 88.39% of cases, whereas 8.34% originated from the renal artery. The testicular artery arose from an accessory renal artery in 9.60% (16 of

166 cases).^[6] Ali et al. also reported testicular artery variations in 14% of sides, including arched arteries (10%), aberrant origin (8%), double testicular arteries (4%), and retrocaval course (6%). Among the aberrant origins, the renal artery was the source in 6% of cases, and right-sided variations were more frequent (71.4%). They further observed that the testicular artery originated below the renal artery in 92.3% of cases and above it in 1.9% of cases. The mean distance between the renal and testicular artery origins was 3.60 ± 0.36 cm on the right and 2.28 ± 0.92 cm on the left ($P < 0.001$).^[14] These findings support the close embryological relationship between the renal and gonadal arterial systems.

Early division of the renal artery was also observed in the present study. Munnusamy et al. reported early division in 13% of kidney donors, including 5% on the right, 7% on the left, and 1% bilaterally.^[13] Dogra et al. reported a higher prevalence, with prehilal branching observed in 25% of kidneys, including 27% on the right and 23% on the left, with 22% unilateral and 14% bilateral occurrences. They also reviewed previous studies in which the frequency of prehilal branching ranged from 8% in digital subtraction angiography to 26.7% in multidetector CT angiography.^[15] Such variations likely reflect differences in imaging techniques, anatomical definitions, and population characteristics.

The anterior division of the renal artery showed different branching patterns in our study, with one pattern being predominant. In comparison, Dogra et al. classified the anterior division into nine branching patterns using multidetector CT angiography in 200 kidneys, of which 163 were suitable for analysis. They reported Type VII (19.02%) as the most common pattern, followed by Type VIII (16.56%) and Type IV (9.20%) patterns. They also noted that Type VII had not been described in earlier classifications, highlighting the wide variability in anterior-segmental branching.^[15] Kaushik et al. focused on the site of division and reported prehilal division in 38.3% of kidneys and hilar division in 61.6% of kidneys.^[12]

The posterior division showed less variation than the anterior division. This finding is consistent with the findings of Dogra et al., who observed that the posterior division continued as a single posterior segmental artery without further branching in all examined kidneys.^[15] This consistent pattern

suggests that the posterior division is relatively constant, whereas the anterior division exhibits greater variability. Overall, our findings are supported by earlier cadaveric and radiological studies that showed variations in accessory renal arteries, early arterial division, and branching patterns. The differences reported between studies are most likely due to variations in the sample size, ethnicity, study methods, and classification systems. These studies consistently showed the importance of recognising renal arterial variations during renal transplantation, nephron-sparing surgery, vascular reconstruction, and interventional radiological procedures to reduce vascular complications and preserve renal function.

CONCLUSION

Renal arterial variations were commonly observed in this cadaveric study; accessory renal arteries were present in 35% of kidneys, with unilateral arteries occurring more often than bilateral arteries. Hilar accessory renal arteries were more frequent than polar arteries, and a rare bilateral origin of the testicular arteries from the bilateral accessory renal arteries was also noted. Early division of the renal artery was observed in 20% of the kidneys. The anterior division exhibited three branching patterns, with Type I being the most common, whereas the posterior division entered the kidney as a single vessel. These findings reinforce the need for a clear understanding of renal vascular anatomy during renal surgery, transplantation, and endovascular procedures, helping to reduce vascular injury, preserve renal function, and support safer clinical practice.

REFERENCES

1. Majos M, Stefańczyk L, Szemraj-Rogucka Z, Elgalal M, De Caro R, Macchi V, et al. Does the type of renal artery anatomic variant determine the diameter of the main vessel supplying a kidney? A study based on CT data with a particular focus on the presence of multiple renal arteries. *Surg Radiol Anat* 2018; 40:381–8. <https://doi.org/10.1007/s00276-017-1930-z>.
2. Pradhay G, Gopidas GS, Karumathil Pullara S, Mathew G, Mathew AJ, Sukumaran TT, et al. Prevalence and relevance of multiple renal arteries: A radioanatomical perspective. *Cureus* 2021;13: e18957. <https://doi.org/10.7759/cureus.18957>.
3. Mihaylova E, Groudeva V, Nedevska M. Multidetector computed tomography angiography study of the renal arterial vasculature anatomy and its variations in a Bulgarian adult population. *Surg Radiol Anat* 2023; 45:289–96. <https://doi.org/10.1007/s00276-023-03092-0>.
4. Mohammed S, AbdAlla E, Elhag A, El-Mardi A. The prevalence of accessory renal arteries in sudanese population in Khartoum State: a cross-sectional CT study from 2017 to 2020. *BMC Nephrol* 2024; 25:135. <https://doi.org/10.1186/s12882-024-03573-3>.
5. Kim J, Lee J-M, Cho SG, Hong JU. Ectopic vascularization of the right kidney arising from contralateral common iliac artery. *Surg Radiol Anat* 2022; 44:979–81. <https://doi.org/10.1007/s00276-022-02970-3>.
6. Cai W, Shi M, Chan DW, Luo B, Ruze A. Challenging arterial patterns of renal and testicular arteries in a human cadaver: clinical significance and embryological bases revisited. *Anat Cell Biol* 2025; 58:478–82. <https://doi.org/10.5115/acb.24.336>.
7. Raj G, Gunasekaran V, Kishore A, Chand P. Bilateral supernumerary renal arteries with variant ureteric relation and their embryological and clinical significance. *Natl J Clin Anat* 2017; 6:82. <https://doi.org/10.4103/2277-4025.297659>.
8. Manoharan MB, Kuppusamy R, Subramanian M. Exploring the occurrence and clinical implications of accessory renal arteries: A descriptive study in South Indian cadavers. *Fukushima J Med Sci* 2025; 71:155–61. <https://doi.org/10.5387/fms.24-00021>.
9. Bouzouita A, Saadi A, Hermi A, Chakroun M, Bouchiba N, Allouche M, et al. Cadaveric study of arterial renal anatomy and its surgical implications in partial nephrectomy. *Surg Radiol Anat* 2021; 43:1449–59. <https://doi.org/10.1007/s00276-021-02769-8>.
10. Kim J-E. A rare case of thoracic renal artery. *Anat Sci Int* 2021; 96:582–6. <https://doi.org/10.1007/s12565-021-00612-z>.
11. Szczepanik M, Staniak D, Sianos J, Brzusek M, Buczek J, Daniluk A. Accessory renal arteries: Frequency of anatomical variations and clinical aspect. *Eur J Anat* 2025. <https://doi.org/10.52083/kduj8508>.
12. Kaushik RK, Tripathi A, Kausar H, Goel P, Raizady S, Dawani P. Renal artery variants: a comprehensive cadaveric comparative study using morphological and corrosion casting technique. *Int J Res Med Sci* 2024; 12:1182–8. <https://doi.org/10.18203/2320-6012.ijrms20240841>.
13. Munnusamy K, Kasirajan SP, Gurusamy K, Raghunath G, Bolshetty SL, Chakrabarti S, et al. Variations in branching pattern of renal artery in kidney donors using CT angiography. *J Clin Diagn Res* 2016;10:AC01-3. <https://doi.org/10.7860/JCDR/2016/16690.7342>.
14. Ali S, Nallikuzhy T, Verma S, Sakthivel S. Prevalence of testicular artery variations in cadavers: Developmental correlation and clinical implications. *J Morphol Sci* 2020:30–4. <https://doi.org/10.51929/jms.37.6.2020>.
15. Dogra A, Department of Anatomy, Indira Gandhi Medical College, Shimla. Variations in the branching pattern of segmental renal arteries on 64 slice MDCT. *J Med Sci Clin Res* 2017; 05:22885–92. <https://doi.org/10.18535/jmscr/v5i6.14>.