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CT Angiographic Evaluation Of Anatomical Variations Of Renal Arteries And Veins In Prospective Living Renal Donor

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Abstract
Background: *Preoperative evaluation of renal vascular anatomy is essential for safe living donor nephrectomy and successful kidney transplantation. Multidetector computed tomography angiography is the preferred imaging modality for identifying renal arterial and venous variations that may influence surgical planning.*
Methods: *This prospective observational study was done over 18 months in the Department of Radiodiagnosis in collaboration with the Department of Urology at SRMS-IMS, Bareilly. Forty-five prospective living renal donors underwent multidetector CT angiography using a standardized renal donor protocol. Renal arterial and venous anatomy was evaluated for the presence of accessory arteries, early arterial branching, multiple renal veins, retroaortic left renal vein, late venous confluence, and other vascular variations.*
Results: *The mean age of donors was 39.8 ± 10.7 years, with males comprising 60.0% of the study population. Accessory renal arteries were detected in 40.0% of donors.. Early arterial branching was identified in 17.8%, multiple renal veins in 20.0%, late venous confluence in 8.9%, and retroaortic left renal vein in 4.4% of donors. No significant differences were observed between right- and left-sided arterial (p=0.277) or venous (p=0.30) variations. Similarly, vascular variations were not significantly associated with donor sex (p=0.42).*
Conclusion: *CT angiography provides accurate and comprehensive evaluation of renal vascular anatomy in prospective living renal donors. Preoperative identification of vascular variations facilitates optimal surgical planning, enhances donor safety, and contributes to successful renal transplantation.*
Keywords: *Computed tomography angiography; Kidney transplantation; Renal donor; Renal artery variations; Renal vein variations.*

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I. Introduction

Kidney transplantation is the preferred treatment for patients with end-stage renal disease (ESRD), offering better survival and quality of life than dialysis. Living donor kidney transplantation has become important due to the persistent shortage of deceased donor organs. Successful donor nephrectomy and transplantation require detailed preoperative evaluation of renal vascular anatomy to ensure donor safety and optimize surgical outcomes.[1]Renal vascular anatomy shows variation due to the complex embryological development of the kidneys. Variations like multiple renal arteries, early arterial branching, accessory renal arteries, and anomalous renal veins, including retroaortic and circumaortic left renal veins, are frequently encountered.[2] These anatomical variations may increase the technical complexity of donor nephrectomy and vascular anastomosis, potentially affecting operative time and the risk of perioperative complications. Therefore, accurate identification of these variations is essential during donor assessment.[3]

Multidetector computed tomography angiography (CTA) is the imaging modality of choice for evaluating prospective living renal donors because of its high spatial resolution, rapid image acquisition, and excellent three-dimensional visualization of renal arteries and veins.[4] CTA provides comprehensive information regarding the number, origin, course, branching pattern, and caliber of renal vessels, enabling precise surgical planning and donor selection.[5]

Although the prevalence of renal vascular variations has been reported in different populations, their frequency and patterns may vary according to ethnicity and geographic region. The present study was undertaken to evaluate the anatomical variations of renal arteries and veins in prospective living renal donors using CT angiography and to determine their prevalence, thereby providing valuable information for preoperative planning and improving the safety and success of renal transplantation.

II. Methodology:

This prospective observational study was done in the Department of Radiodiagnosis in collaboration with the Department of Urology at tertiary care hospital, Bareilly, Uttar Pradesh, after obtaining approval from the Institutional Ethics Committee. The study was carried out over a period of 18 months and included 45 consecutive prospective living renal donors who were referred for pre-transplant imaging evaluation.

All adult individuals (≥18 years) undergoing CT renal angiography as part of the routine living donor work-up were eligible for inclusion. Only donors with normal renal function who were fit to receive intravenous iodinated contrast and provided written informed consent were enrolled. Individuals with a history of previous renal surgery or renal transplantation, congenital renal anomalies affecting vascular anatomy, impaired renal function (estimated glomerular filtration rate <60 mL/min/1.73 m²), known hypersensitivity to iodinated contrast media, pregnancy, or poor-quality CT images due to motion or technical artifacts were excluded from the study.

All participants underwent multidetector computed tomography (MDCT) renal angiography using the institutional renal donor protocol. Intravenous non-ionic iodinated contrast medium was administered through an 18–20-gauge intravenous cannula using a power injector at a dose of approximately 1.5 mL/kg body weight (maximum 120 mL) at a flow rate of 4–5 mL/s, followed by a saline flush. The imaging protocol consisted of non-contrast, arterial, nephrographic, and excretory phases. Thin-section images (0.5–1.0 mm) were reconstructed and post-processed using multiplanar reconstruction (MPR), maximum intensity projection (MIP), and three-dimensional volume-rendered (VR) techniques to facilitate comprehensive evaluation of the renal vasculature.

The CT angiographic images were independently reviewed by two experienced radiologists, and any discrepancies were resolved by consensus. The number, origin, course, and branching pattern of the renal arteries were evaluated, with particular attention to the presence of accessory renal arteries, multiple renal arteries, and early arterial branching. Renal venous anatomy was assessed for the number of renal veins, drainage patterns, presence of multiple renal veins, retroaortic or circumaortic left renal vein, and late venous confluence. Any incidental renal or extra-renal findings that could influence donor selection were also documented. Renal vascular anatomy was classified according to standard anatomical definitions described in the study.

The primary outcome measure was the prevalence and pattern of anatomical variations of the renal arteries and veins detected on CT angiography. Secondary outcomes included the distribution of vascular variations according to the side involved, the frequency of unilateral and bilateral vascular variations, and the incidence of incidental renal and extra-renal findings.

The collected data were entered into Microsoft Excel and analyzed using the Statistical Package for the Social Sciences (SPSS) version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± SD, whereas categorical variables were presented as frequencies and percentages. Associations between categorical variables were analyzed using the Chi-square test or Fisher's exact test, as appropriate. A p-value of <0.05 was considered statistically significant.

III. Result

Table 1. Age distribution of Living Renal Donors (N = 45)

Age	n(%)
18–20	2 (4.4)
21-30	9 (20)
31–40	14 (31.1)
41–50	13 (28.9)
51-60	7 (15.6)

Age (years), Mean ± SD	39.8 ± 10.7

The mean age of the participants was 39.8 ± 10.7 years, with the majority belonging to the 31–40 years (31.1%) age group, followed by 41–50 years (28.9%), 18–30 years (24.4%), and more than 50 years (15.6%).

Table 2. Gender distribution of Living Renal Donors (N = 45)

Gender	n (%)
Male	27 (60.0)
Female	18 (40.0)

Male donors constituted 60.0% (n=27) of the study population, while females accounted for 40.0% (n=18).

Table 3. CT Angiographic Findings of Renal Arteries (N = 45)

Variable	Right n (%)	Left n (%)	Total (%)	P value
Accessory renal artery	7 (15.6)	11 (24.4)	18 (20.0)	0.292
Early arterial branching	3 (6.7)	5 (11.1)	8 (8.9)	0.459

Table 3shows the CT angiographic findings of the renal arteries. Accessory renal arteries were identified more frequently on the left side (24.4%) than on the right (15.6%). Early arterial branching was also more common on the left (11.1%) than the right (6.7%). However, the difference in arterial variations between the two sides was not statistically significant.

Table 4. CT Angiographic Findings of Renal Veins (N = 45)

Variable	Right n (%)	Left n (%)
Multiple renal veins	6 (13.3)	3 (6.7)
Retroaortic left renal vein	—	2 (4.4)
Late venous confluence	—	4 (8.9)
Fisher's Exact Testp value = 0.30		

Table 4 shows the CT angiographic findings of the renal veins. A single renal vein was present in the majority of kidneys, occurring in 86.7% of right kidneys and 93.3% of left kidneys. Multiple renal veins were identified in 13.3% of right kidneys and 6.7% of left kidneys. Among left-sided venous variations, retroaortic left renal vein and late venous confluence were observed in 4.4% and 8.9% of donors, respectively. The distribution of venous variations between the sides was not statistically significant ($p = 0.30$).

Table 5. Association Between Sex and Presence of Any Renal Vascular Variation

Sex	Vascular Variation Present	No Variation	Total
Male (n=27)	12 (44.4)	15 (55.6)	27 (60.0)
Female (n=18)	6 (33.3)	12 (66.7)	18 (40.0)
Total	**18 (40.0)**	**27 (60.0)**	**45 (100.0)**
χ^2 = 0.64, p value= 0.42			

Table 5 shows the association between donor sex and the presence of any renal vascular variation. Vascular variations were detected in 44.4% of males and 33.3% of females, while no variation was observed in 55.6% and 66.7%, respectively. Although vascular variations were relatively more frequent among male donors, the association between sex and vascular variation was statistically insignificant ($\chi^2 = 0.64$, $p = 0.42$).

Table 6. Distribution of Overall Renal Vascular Variations Detected on CT Angiography

Anatomical Variation	Number (%)
Accessory renal artery	18 (40.0)
Early arterial branching	8 (17.8)
Multiple renal veins	9 (20.0)
Retroaortic left renal vein	2 (4.4)

Late venous confluence	4 (8.9)
Intimate Thickening/Calcification	3 (6.7)
No vascular variation	19 (42.2)

Table 6 presents the overall distribution of renal vascular variations detected on CT angiography. Accessory renal arteries were the most common variation, identified in 40.0% of donors, followed by multiple renal veins (20.0%), early arterial branching (17.8%), late venous confluence (8.9%), Intimate Thickening/Calcification (6.7%), and retroaortic left renal vein (4.4%). Overall, 42.2% of donors did not show any renal vascular variation on CT angiography.

IV. Discussion:

The present study evaluated renal vascular anatomy in 45 prospective living renal donors using CT angiography. The mean age was 39.8 ± 10.7 years, with most donors aged 31–50 years, and males constituted 60.0% of the study population. These findings are similar toDols et al. (2011) study who reported a median age of 46 years (range 18–59) among 422 donors under 60 years in their cohort of 539 living kidney donors, with 56% females. Similarly, a multinational prospective cohort study reported a mean donor age of 47 years, with 66% female donors.[6]

Our donors were relatively younger than those reported in several Western studies. Sommerer et al. (2021) documented an increase in mean donor age from 34.9 ± 11.5 years historically to 53.2 ± 10.2 years during 2011–2016, with 11.4% of donors aged ≥65 years. Likewise, Hiramitsu et al. (2021) showed progressively older donor populations in Japan.[7,8]

Male predominance observed in our study contrasts with many international reports where females comprised the majority of living donors. Kim et al. (2023) reported 57% female donors among 3,523 donor-recipient pairs. Similarly, Dols et al. and Berger et al. also observed female predominance among living donors[6,9–11] This difference may show regional sociocultural and familial factors influencing donor selection in our population.

Accessory renal arteries were present in 20.0%, with no significant side-to-side difference (p = 0.277). These findings are similar to the known anatomical diversity in living kidney donors. Song et al. (2020) documented accessory renal arteries in 25.3% of left and 19.4% of right donor kidneys, while Osman et al. (2025) reported an overall prevalence of 25.6% with early branching in 17%.[12,13]

Similarly, Aremu et al. (2021) reported accessory renal arteries in 32% of donors and early branching in 18%, whereas Ikidag et al. (2019) identified accessory or polar arteries in 28.6% of kidneys.[14,15] The slightly lower prevalence of accessory arteries in our study may show population differences or the relatively smaller sample size. Early branching (8.9%) also falls within the range reported in previous donor studies.[12]These findings further show the value of CT angiography in accurately delineating vascular anatomy before donor nephrectomy, thereby facilitating surgical planning and minimizing operative complications.[16]

Similar to our finding regarding multiple renal vein (20%), it have been reported in approximately 5–15% of individuals, although higher right-sided prevalence has been reported in other studies.[15,17]

Retroaortic left renal vein was identified in 4.4% of our donors, is similar to the prevalence reported by Hostiuc et al. (3%) and Çınar et al. (4.2%). Ikidag et al. similarly reported retroaortic and circumaortic venous variants in potential kidney donors.[15,17,18] Late venous confluence (8.9%) was also similar to the 17% prevalence reported by Chai et al.[19]

Renal vascular variations were more common in males (44.4%) than females (33.3%); however, the difference was statistically insignificant (p = 0.42).[12] Similar observations have been reported in studies showing no association between gender and renal vascular anatomy.[20]

In contrast, Osman et al. (2025), Aremu et al. (2021), and Mehreen et al. (2023) showed significantly higher frequencies of accessory renal arteries and other vascular variations among male donors.[12,14,21] The lack of statistical significance in our study is likely attributable to the relatively small sample size.

Overall, renal vascular variations were frequently encountered, with accessory renal arteries representing the commonest arterial variation, followed by multiple renal veins and early arterial branching.[22] Similar findings have been reported by Hekimoglu et al., Song et al., and Gümüş et al., who documented accessory renal arteries in 23.8%, 36.9%, and 27% of cases, respectively. In contrast, Mohammed et al. reported a lower prevalence of 6% in a Sudanese population..[13,22–24] Differences among studies may be related to ethnicity, imaging protocols, and study populations.

Early arterial branching observed in our study was similar to Osman et al. (17%) but higher than the prevalence reported by Hekimoglu et al. (7.1%) and Çınar et al. (6.5%). Previous studies have similarly showed the surgical importance of early branching because of its implications for vascular control during donor nephrectomy.[18,22]

Multiple renal veins were predominantly right-sided, in agreement with Hekimoglu et al. and Çınar et al., while meta-analyses have reported an overall prevalence of approximately 5–15%.[17,22]

The prevalence of retroaortic left renal vein (4.4%) and late venous confluence (8.9%) in our study was similar with previously published CT angiographic series.[17,22,25]

Overall, our findings show the value of multidetector CT angiography in accurately depicting renal vascular anatomy before living donor nephrectomy. Variations in prevalence across studies likely show differences in ethnicity, sample size, donor selection criteria, and imaging techniques. Comprehensive preoperative vascular mapping remains essential for optimal donor selection, surgical planning, and improved transplant outcomes..[18,22]

V. Conclusion:

The present study showed that multidetector CT angiography is an effective and reliable modality for the preoperative evaluation of prospective living renal donors, providing detailed assessment of renal vascular anatomy and its variations. Accessory renal arteries were the most frequently encountered vascular variation, while venous anomalies like multiple renal veins, late venous confluence, and retroaortic left renal vein were observed less commonly. No significant association was found between vascular variations and donor sex or between the right and left kidneys. Preoperative identification of these anatomical variations is essential for optimal surgical planning, minimizing intraoperative complications, and improving donor safety and transplant outcomes.

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Images

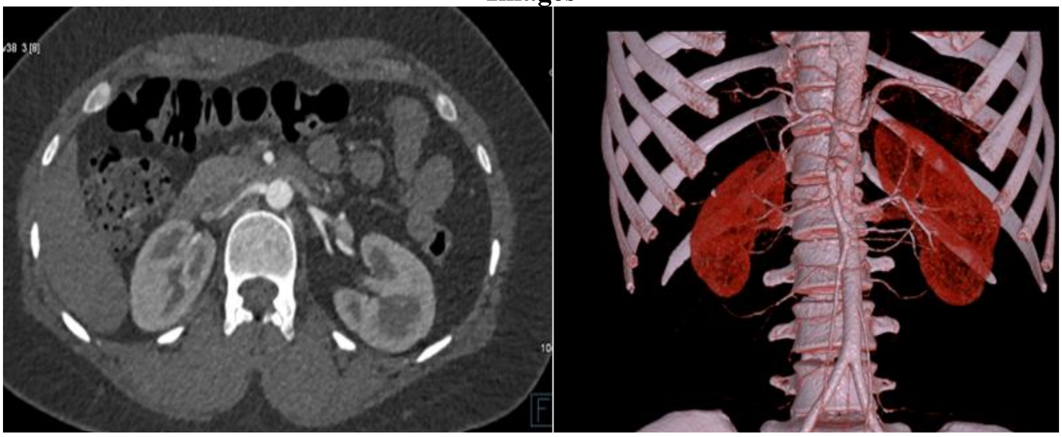

Figure 1 And 2 Early Branching Of Bilateral Renal Artery

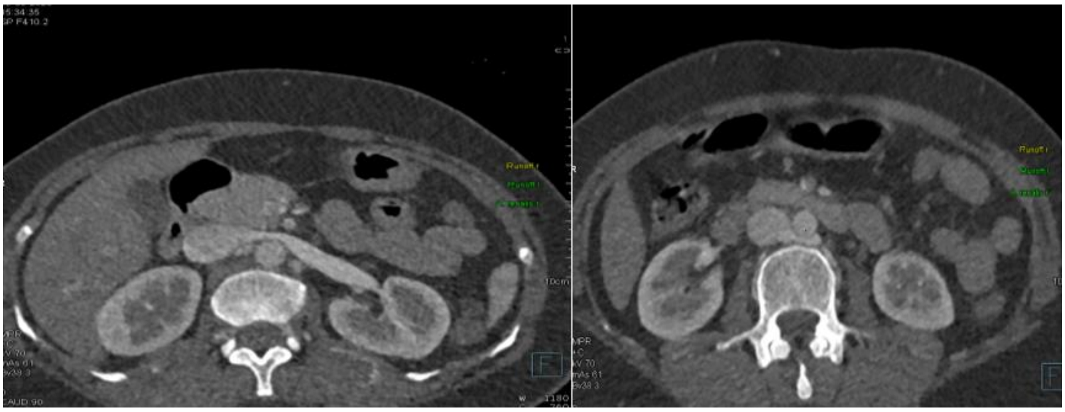

Figure 3 And 4 Duplication Of Left Renal Vein With Anterior Renal Vein Passing Anterior To Aorta And Retroaortic Course Of Posterior Renal Vein.