Prevalence and patterns of renal vascular variations among potential kidney donors: a Computed Tomography Angiography (CTA) study in Sudan

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Abstract

Background Anatomical variations in the renal vasculature complicate surgical techniques and necessitate meticulous preoperative planning. This study aims to ascertain the prevalence and patterns of renal vascular variations in potential kidney transplant donors at Ahmed Gasim Teaching Hospital, Khartoum, Sudan, via computed tomography angiography (CTA).

Methods A descriptive cross-sectional study was performed on 160 potential kidney donors who underwent renal CTA from January to December 2022. Data were collected via a checklist and analyzed with SPSS version 28. Variations in renal arteries, such as accessory renal arteries and premature bifurcations, have been reported and classified. Additional vascular variations were noted.

Results Of the 160 subjects, 57.5% had normal single renal arteries bilaterally, whereas 42.5% had variations in renal artery anatomy. Accessory renal arteries were identified in 25.6% of the participants, whereas early branching occurred in 17%. Variations were more common in males, with 37% exhibiting accessory renal arteries compared with 16.1% in females ($p = 0.008$). Bilateral accessory renal arteries were identified in 3.8% of the donors. Circum-aortic left renal vein (1.3%) and Transposition of the inferior vena-cava (1.3%) were also detected.

Conclusion A notable prevalence of renal artery variations was identified among these potential Sudanese kidney donors, with accessory arteries and early branching being the most common. Recognising such variations is crucial for safe surgical planning and optimal outcomes in kidney transplantation. While this study utilised CT angiography to delineate these vascular patterns, the importance lies in employing accurate and reliable imaging assessments—of which CTA is one valuable option—to guide preoperative evaluation and reduce surgical risks.

Clinical trial registration Not applicable (this is an observational study).

Keywords Renal artery variations, Kidney donors, CT angiography, Accessory renal arteries, Sudan, Kidney transplantation

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Introduction

The renal arteries, which frequently emerge as single vessels from the lateral side of the aorta (92%), but less commonly from the anterolateral (6%) and posterior (2%) portions, are critical in supplying blood to the kidneys. However, variations in the number and origin of these arteries are common, with reported incidences varying from 7 to 76% across populations [1–4].

The incidence of renal artery variations varies greatly by ethnic group; for example, a study showed that the prevalence was 37.1% in African people, 17.4% in Indian populations, 35.3% in Caucasians, and 18.5% in "colored" groups [4]. Similarly, a Nigerian study reported renal artery variations in 50% of cases, with 32% having accessory renal arteries and 18% with early branching of the renal artery [5]. Similar rates were recorded in other regions: 51% in Turkey and India, 22% in Australia and 31.9% in Nepal [6–9].

Renal artery variations are divided into two types: early division (ED), which occurs 15–20 mm from the hilum of the kidney, and extrarenal artery (ERA), which includes accessory arteries or multiple renal arteries that may arise from the abdominal aorta or other vessels, such as the common iliac artery [10–14]. These variations are important for kidney donors because they can affect surgical planning and outcomes in renal transplantation [15].

Despite extensive research on renal artery variations in many groups, investigations of Sudanese kidney donors are lacking. This is especially important because understanding these differences is vital for kidney transplantation and related operations, particularly in areas such as Sudan. The purpose of this study was to assess the pattern and prevalence of renal vascular variations in Sudanese kidney transplant donors via angiographic computed tomography (CTA) at Ahmed Gasim Teaching Hospital. By filling this gap, this study will benefit Sudanese clinicians who perform renal transplants and other interventional treatments.

Methods and materials

This descriptive cross-sectional study was conducted in the renal unit of Ahmed Gasim Teaching Hospital, the principal referral center for renal care in Sudan, and it is one of the only four centers that provide renal transplantation in Sudan. The hospital provides care to patients from across the nation, irrespective of ethnicity. This study was performed from January 2022 to December 2022 and used recorded data from 160 potential kidney donors who underwent renal angiographic computed tomography (CTA). All eligible participants, comprising potential donors for a compatible recipient who underwent CT angiography before the transplantation surgery, were purposely included (Total coverage).

A checklist was used to collect data, which were categorized into two segments: sociodemographic characteristics (age and sex) and specifics regarding renal artery variations, including the presence of accessory renal arteries, anatomical variants, and renal artery origin. A radiologist and a urologist reviewed the collected data to determine the presence of renal artery variations.

Abdominal CT exams were conducted with a Siemens Somatom Sensation 64 multidetector CT scanner for the detection of renal arteries. Patients fasted for 6–8 h and were screened for comorbidities, especially diabetes. They ingested 800 mL of oral contrast (dilute barium or 3% gastrografin) 30–40 min before imaging, then an additional 200 mL before scanning. Intravenous nonionic iodinated contrast, like iohexol or iopamidol, was given at 1–1.5 mL/kg with a rate of 3–5 mL/s to optimally highlight renal vasculature and delineate renal masses. Scanning was performed with individuals in a supine position, encompassing the region from the spinal level T12 to the pubic symphysis. CT angiography images were processed using advanced 3D techniques, including multi-planar reconstructions (MPR), maximum intensity projection (MIP), and volume rendering (VRT), at a 1 mm slice thickness with 50% overlap. The images were studied for the number of renal arteries originating from the abdominal aorta, the presence of early divisions into segmental arteries and accessory arteries, and additional vascular variations.

The data were analyzed via SPSS version 28. Categorical variables were described using frequencies and proportions, and continuous variables were expressed as the means accompanied by standard deviations. The chi-square test was utilized to evaluate associations, with a p value of < 0.05 deemed statistically significant. The findings are displayed via univariate tables, cross-tabulations, and descriptive narratives.

Results

The study included 160 patients who presented at the renal center of Ahmed Gasim Teaching Hospital and underwent CT renal angiography. The mean age of the participants was 54 ± 10 years, with a majority of them being female—87 (54.4%)—while 73 (45.6%) were male (Table 1).

A total of 148 participants (92.5%) had renal arteries originating from the L2–L3 vertebral level, whereas 10

Table 1 Demographic characteristics of living kidney donors ($n = 160$)

Character	Frequency (percent)
Age (mean ± SD)	54 ± 10
Gender	
Male	73 (45.6%)
Female	87 (54.4%)

patients (6.3%) had renal arteries originating from the L1 level, and 2 patients (1.3%) had origins at L4 (Table 2).

With respect to anatomical differences, 92 potential donors (57.5%) had a normal single renal artery bilaterally, whereas 68 (42.5%) had variations. Accessory renal arteries were detected in 41 donors (25.6%), with 20 (12.5%) on the right side, 15 (9.4%) on the left side, and 6 (3.8%) bilaterally (Table 2).

Early dividing renal arteries were detected in 27 donors (17%), with 20 (12.5%) on the right side, 5 (3.1%) on the left side, and 2 (1.3%) bilaterally. Additional vasculature variations were found in 4 (2.5%) donors; Circum-aortic left renal vein 2 (1.3%) and Transposition of the inferior vena cava 2 (1.3%) (Table 2).

A study of renal artery variants by sex revealed a greater prevalence of accessory renal arteries in males (37%) than in females (16.1%) (*p* value = 0.008), but the prevalence of early dividing renal arteries was comparable between males (16.4%) and females (17.2%) (Table 3).

Discussion

The presence of renal vascular anatomical variations has considerable clinical significance, especially in kidney transplantation, where a comprehensive understanding of renal vascular anatomy is essential for effective surgical planning and reducing postoperative complications. The results of this study are significant because of the scarcity of data regarding renal vascular variations in potential kidney donors in Sudan. Identifying the prevalence and patterns of these variations among Sudanese kidney donors is essential for enhancing transplantation results in this area.

The prevalence and patterns of renal vascular variations among kidney donors

This study revealed renal artery changes in 42.5% of patients, which closely corresponds with findings from other regional and international studies on kidney donors. Studies in African countries, such as Ethiopia and Nigeria, reported renal artery variations in 38.8% and 50% of kidney donors, respectively [5, 16]. Additionally, Munnusamy et al. reported a 51% variation rate among Indian donors [7], and Karayağız et al. reported a prevalence of 59.4% in Turkish kidney donors.

In Sudan, three studies were published before this one, revealing a wide range of renal artery variations. While this study revealed that 42.5% of participants had renal artery variations, Salih et al. reported 30%, Mustafa et al. reported 20%, and the most recent study by Muhammed et al. reported only 11% [17–19].

Regarding patterns of variation, our study's prevalence of accessory renal arteries (25.6%) and early division (17%) aligns with international patterns. The prevalence of accessory or multiple renal arteries ranged between

Table 2 Renal vascular variations in living kidney donors (*n* = 160)

Variable	Frequency (percent)
Level of origin	
L 1	10 (6.3%)
L 2–3	148 (92.5%)
L 4	2 (1.3%)
Anatomical variants	
Single renal artery	92 (57.5%)
Accessory renal artery	41 (25.6%)
Left	15 (9.4%)
Right	20 (12.5%)
Bilateral	6 (3.8%)
Early branching renal artery	27 (17%)
Left	20 (12.5%)
Right	5 (3.1%)
Bilateral	2 (1.3%)
Additional vascular variations	4 (2.5%)
Circum-aortic left renal vein	2 (1.3%)
Transposition of inferior vena-cava	2 (1.3%)

Table 3 Distribution of renal artery variations by sex (*n* = 160)

Variant	Male (*n* = 73)	Female (*n* = 87)	Total	*p* value
Single renal artery	34 (46.6%)	58 (66.7%)	92	0.008*
Early dividing renal arteries	12 (16.4%)	15 (17.2%)	27	
Accessory renal arteries	27 (37%)	14 (16.1%)	41	

Percent (%) from sex

18.9% and 38%, whereas the prevalence of early branching renal arteries ranged between 10.8% and 21.4% in these studies among living kidney donors [5, 7, 16, 20–23]. In contrast, the side of these variations differed from those of other studies; variations were more prevalent on the right side in this study, were equally distributed between the right and left sides in Indian kidney donors [7], and were more prevalent on the left side among Turkish donors [23]. An additional consideration is the greater prevalence of renal artery variations in men than in women, which is consistent with the recently reported distribution [4].

Moreover, this study identified other vascular anomalies, such as the circum-aortic left renal vein and transposition of the inferior vena cava, each of which was present in 2.5% of the participants. These anomalies, although less common, are crucial to identify preoperatively, as they can further complicate surgical approaches during transplantation or other abdominal procedures.

Clinical implications of renal artery variations

Variations in renal arteries significantly impact kidney transplantation and other surgical interventions. For example, the presence of accessory renal arteries was found to affect kidney transplantation outcomes and influence the risk of transplantation rejection [24]. They

may also prolong the surgical duration, as evidenced by the findings of Aremu et al., who reported a correlation between renal artery variations and extended operating periods [5].

Some scholars suggest that multiple renal arteries increase the risk of acute rejection and poorer graft function [25]. However, others did not observe a significant difference in acute rejection rates between grafts with single arteries and those with multiple arteries [26]. Additionally, allografts with multiple renal arteries are associated with a greater risk of renal artery stenosis and can present technical challenges for surgeons during transplant operations [27, 28]. These factors highlight the importance of identifying and carefully managing renal artery variations during transplantation.

Methodological considerations

Methodological challenges in detecting renal artery variations primarily stem from the limitations of imaging techniques. Small accessory renal arteries are often missed in angiographic studies, especially when their diameter is less than 2 mm or when they originate from the abdominal aorta. Compared with conventional angiography, magnetic resonance angiography (MRA) has a 10% discrepancy in predicting renal artery anatomy [29]. However, three-dimensional CT angiography (CTA) is more reliable, accurately identifying renal artery anatomy in 97.6% of cases. CTA is particularly effective during the arterial phase and offers 100% sensitivity for visualizing accessory renal arteries [30].

This study was primarily descriptive and did not correlate arterial or venous anomalies with clinical outcomes. Data constraints—such as the limited availability of donor comorbidity profiles, BMI values, and long-term post-transplant results—prevented us from conducting multivariate analyses to assess potential confounders or outcome measures. Additionally, our single-centre design and relatively small sample size may limit the generalizability of these findings to the broader Sudanese population and other geographic regions. Larger, prospective, or multicenter studies incorporating detailed follow-up of surgical complications, graft survival, and donor-recipient matching mechanisms would be vital to fully elucidate the clinical implications of these anatomical variations.

Conclusion

This study provides valuable insights into the prevalence and patterns of renal artery variations among Sudanese kidney donors. The study revealed that a significant proportion of potential kidney donors presented renal vascular variations; multiple renal arteries and early dividing renal arteries were the most common variations. Recognizing and accounting for these anatomical variations will be crucial in improving surgical outcomes and patient care, particularly in the context of kidney transplantation.

Declarations

Ethical approval and IRB
The study received ethical approval from the National University's ethical committee. Then, it was delivered to the Federal Ministry of Health (FMOH) and the administration of Ahmed Gasim Hospital. The need for informed consent was waived by the ethical committee of the Research and Training section at the Federal Ministry of Health (FMOH) owing to the use of data obtained from medical records.

Consent for publication
Not applicable (consent was waived by the Ethics Committee as the study has no identifying data).

Competing interests
The authors declare no competing interests.

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