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Review Article

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Beyond the Single Artery: A Mini-Review of Multivessel Renal Anatomy in Transplantation

Ampuriire Nyakubaho[1*], Brendah Ayikoru[3], Monica Acen Okwir[3], Robert Kalyesubula[4], John Kukiriza[1] and Kawooya G Michael[2]

ORCID: *0009-0006-9035-302X*; ***ORCID:*** *0009-0004-3422-1722*; ***ORCID:*** *0009-0005-0510-2238*; ***ORCID:*** *0000-0003-3211-163X*; ***ORCID:*** *0000-0003-0727-0655*; ***ORCID:*** *0000-0002-4017-2910*

[1]*Department of Anatomy, Ernest Cook University (ECU), Kampala Uganda;*

[2]*Department of Radiology, Ernest Cook University (ECU), Kampala Uganda*

[3]*Department of Radiology, Makerere College of Health Sciences, Kampala Uganda*

[4]*Department of Physiology, Makerere College of Health Sciences, Kampala Uganda*

***Corresponding author:** AMPURIIRE Nyakubaho, Department of Anatomy and Department of Radiology, Ernest Cook University (ECU), Mengo, Kampala Uganda; ampuriire.nyakubaho@ecu.ac.ug / nyakubaho7@gmail.com

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Abstract

Renal artery variations are critical determinants in living donor kidney transplantation. This mini-review broadly discusses a recent case report describing a very rare simultaneous occurrence of a left accessory renal artery and right double accessory renal arteries in a single donor, identified via Multidetector Computed Tomography (MDCT) angiography. The findings highlight the importance of high-resolution preoperative imaging in detecting such anomalies, which significantly impact surgical planning and donor eligibility. We summarize the embryological basis, current detection methodologies, clinical implications, and controversies in management of renal artery variations. The integration of advanced imaging into donor workflows is emphasized, alongside future directions including artificial intelligence and 3D surgical simulation. This review highlights how detailed vascular mapping is indispensable for transplant safety and success.

Keywords: Accessory renal artery; Kidney donation; Donor eligibility; Surgical planning; Multidetector computed tomography angiography; Renal angiography

Brief historical perspective

This mini-review discusses a recent case report describing the rare simultaneous occurrence of a left accessory renal artery and right double accessory renal arteries in a single donor, identified via multidetector computed tomography (MDCT) angiography [1]. The study of renal vascular anatomy dates to the early 20th century, primarily through cadaveric dissection. The advent of digital subtraction angiography in the 1970s allowed in vivo visualization but was invasive and risk-laden. The introduction of Computed Tomography Angiography (CTA) in the 1990s, and subsequently MDCT, revolutionized preoperative assessment by providing non-invasive, high-resolution 3D vascular mapping [2]. Landmark studies in the 2000s established MDCT as the gold standard for living donor evaluation, correlating imaging findings with surgical outcomes and paving the way for the precise anatomical characterization seen in contemporary practice [2,3].

Summary of the established principles

The anatomical principles underlying renal artery variations are rooted in embryology. During fetal ascent from the pelvis, the kidneys

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are supplied by multiple transient aortic branches, which typically regress to leave a single dominant renal artery [4,5]. Persistence of these branches results in accessory renal arteries, occurring in 20–30% of the population [6,7]. While often hemodynamically silent in the donor, these variants become surgically paramount during transplantation [1,3]. Established clinical principles dictate that preoperative identification is essential to avoid intraoperative bleeding, ensure graft perfusion, and reduce urologic complications [1,8]. MDCT angiography provides the necessary detail for surgical planning, aligning with the principle of "primum non nocere" in donor care [9,10].

Current state of the art

MDCT angiography remains the cornerstone of donor evaluation, offering sub-millimeter resolution and 3D reconstructions [2,3]. Recent meta-analyses confirm accessory renal artery prevalence and subtypes, enhancing preoperative risk stratification [6,7]. Controversies persist regarding the management of multiple arteries: Some centers advocate for advanced reconstruction techniques (e.g., pantaloon anastomosis), while others may defer donors with complex anatomy due to increased surgical risk [1,8,11]. Current research gaps include a lack of large-scale genomic studies on the etiology of variations, limited long-term data on grafts with multiple arteries, and variability in institutional protocols for donor eligibility based on vascular anatomy [7,12].

The Ugandan context: Renal transplantation as an emerging field

Renal transplantation in Uganda is a rapidly developing and vital field, offering life-saving treatment for end-stage renal disease where resources for long-term dialysis are limited. Successful renal transplant programs, though still growing in number, represent a significant medical advancement. These initial successes make meticulous donor evaluation even more imperative. As the frequency of living donor transplants increases, Ugandan uro-surgeons will inevitably encounter a spectrum of renal vascular anatomy. Therefore, comprehensive knowledge of potential variations their prevalence, embryology, and surgical implications is critical. Preoperative identification of complex variants, as in this case, allows for rational surgical planning or prudent donor deferral, directly protecting both the donor and the viability of the precious graft. Training of surgeons to recognize and manage anatomical variants is an investment in the sustainability and success of the national transplant program.

The radiologist's eye: Increasing detection and the need for local data

From the vantage point at the Radiology department in Ernest Cook University, this case is not an isolated curiosity but part of an emerging pattern. We are increasingly detecting a wide array of renal vascular variations in potential donors referred for MDCT angiography. The role of radiology extends well beyond preoperative planning, with renal doppler ultrasonography playing a pivotal role in the postoperative assessment of renal allografts. It is indispensable for evaluating graft morphology and perfusion, particularly during the immediate and early post-transplant periods, where timely detection of vascular and parenchymal complications is critical [13]. This highlights the critical role of radiology as the gatekeeper of anatomical discovery in not only the transplant pathway but anatomy generally. However, a significant knowledge gap exists: there is a pressing need for localized, systematic studies to establish the prevalence and specific types of renal arterial variations within our potential donor population. Furthermore, research should correlate these imaging findings with the subsequent decisions of transplant boards. How often does complex anatomy lead to donor deferral? When do surgeons proceed, and what are the outcomes? Establishing such a database would provide invaluable evidence to guide national protocols, optimize donor-recipient matching, and ultimately improve transplant outcomes in our specific context.

Dynamic renal scintigraphy plays an indispensable role in the comprehensive assessment of potential living donors for renal transplantation. Uganda currently has a SPECT-CT at Mulago National Referral Hospital that enables the performance of Tc-99m DTPA renal studies to accurately evaluate the differential renal function in the donor candidates. While MDCT provides excellent anatomical detail of the renal vasculature, renal scintigraphy offers the additional and crucial advantage of functional assessment. This functional information is essential in guiding decisions on donor suitability and in selecting the kidney with relatively lower function for donation, thereby preserving optimal renal reserve in the donor. In resource-limited settings like Uganda, identifying a compatible donor can be challenging. Consequently, deferral of a potential donor should only occur when clearly justified by objective findings. Studies [14] have shown that the presence of multiple renal vessels alone should not constitute a reason for donor exclusion, albeit it may increase the technical complexity of the surgery. Therefore, incorporating dynamic renal scintigraphy into the donor evaluation pathway ensures a balanced assessment that integrates both anatomical and functional parameters, supporting safer and more informed transplant decision-making.

The nephrologist's perspective.

Selection of living kidney donors with renal artery variations balances donor safety, recipient outcomes, and surgical feasibility. High resolution vascular imaging and multidisciplinary review are nonnegotiable components of assessment. Renal artery variations are pivotal in living donor kidney transplantation, influencing donor selection, surgical planning, and recipient outcomes. This recent case report described an exceptionally rare combination; one left accessory renal artery and two right accessory renal arteries detected by Multidetector Computed Tomography (MDCT) angiography. Nephrologists and transplant teams prioritize donor safety and residual renal function over anatomy alone. Complex vascular anatomy is not an absolute contraindication when donors have robust renal reserve, normal blood pressure, and no proteinuria [15]. Key selection criteria include clear vascular mapping, artery diameter (with arteries >2–3 mm usually preserved), the proportion of renal parenchyma supplied by accessory branches, and center/surgeon experience [16]. Multidisciplinary review by

nephrology, transplant surgery, and radiology should be mandatory. Surgically, multiple arteries increase bench reconstruction complexity and may prolong warm ischemia time. Techniques such as arterial conjoining, sequential anastomoses, or use of conduits are employed to preserve perfusion.

Small polar arteries supplying limited parenchyma or ureteral blood flow may necessitate preservation to avoid segmental ischemia or ureteral complications. Laparoscopic procurement of multi artery grafts can be associated with higher ureteral complication rates in some series, prompting careful intraoperative technique and, when needed, conversion to open surgery [17]. Recipient consequences include slightly higher early postoperative vascular and urological complication rates if accessory arteries are missed or inadequately reconstructed; however, contemporary series show comparable long term graft survival when reconstruction is performed by experienced teams [15]. Donor consequences are mainly increased operative complexity and potentially longer operative time, but long term donor renal outcomes remain similar when selection is rigorous. Practical recommendations emphasize referral of complex cases to high volume centers, mandatory MDCT/CTA with 3D planning, use of virtual or 3D printed models when helpful, and vigilant postoperative Doppler surveillance (Table 1). Remaining evidence gaps include prospective multicenter comparisons of reconstruction techniques and procurement approaches. Overall, with meticulous imaging, multidisciplinary assessment, and surgical expertise, kidneys with multiple arteries can safely expand the living donor pool without compromising donor or recipient outcomes.

Table 1: Summary implications of vascular anatomy on donors and recipients.

Criterion	Rationale	Threshold / Consideration	Impact on donor	Impact on recipient
Vascular anatomy clarity	Precise mapping reduces intraoperative surprises	MDCT/CTA with 3D reconstruction mandatory	Lowers intraoperative risk; informs side selection	Enables tailored arterial reconstruction
Number and size of accessory arteries	Small polar arteries may supply limited parenchyma	Preserve arteries >2–3 mm when feasible	May require more complex bench work; slightly longer warm ischemia	Risk of segmental ischemia if ligated
Early branching / short hilar length	Short stump complicates anastomosis	Consider right vs left kidney choice; plan for arterial extension	Increased technical difficulty during procurement	Higher risk of vascular complications if not reconstructed properly
Donor comorbidity and renal reserve	Single-kidney function must remain robust post-donation	Prefer donors with normal GFR and no hypertension	Longterm donor outcomes similar when selection strict	Recipient outcomes depend on reconstruction quality
Center and surgeon experience	Outcomes correlate with institutional volume and expertise	High-volume centers with vascular reconstruction experience preferred	Lower donor complication rates	Lower graft thrombosis and ureteral complication rates

Highlight of future directions

Future developments should likely integrate artificial intelligence for automated detection and classification of vascular variants, improving diagnostic accuracy and consistency [12]. Advanced imaging techniques, such as 4D flow MRI, may provide functional hemodynamic assessment alongside anatomical data. 3D printing of patient-specific renal vasculature could enhance preoperative surgical simulation [3]. Furthermore, multidisciplinary collaboration platforms bridging radiology, surgery, genetics, and bioinformatics will enable a more holistic understanding of how vascular variations impact donor-recipient outcomes, guiding personalized transplantation protocols [9,11].

Key concepts

a. Accessory Renal Artery – An additional renal artery supplying the kidney, originating from the aorta or other vessels, resulting from persistent embryonic vasculature [4,5].

b. MDCT Angiography – A non-invasive imaging technique using multidetector computed tomography with contrast to visualize vascular anatomy in high resolution [2,9].

c. Embryological Persistence – The failure of transient fetal aortic branches to regress during renal ascent, leading to variant arterial anatomy [1,4,5].

d. Donor Deferral – The decision to exclude a potential living kidney donor based on preoperative imaging findings that indicate high surgical risk or complex anatomy [1,8].

e. Surgical Planning – The preoperative process of designing a surgical approach based on detailed anatomical imaging to minimize complications and ensure graft viability [3,11].

Limitations

The reviewed article is a single case report, limiting generalizability. No intraoperative confirmation of anatomy was available due to donor deferral. The study did not include genetic or embryological analysis to explain the etiology of the variations. Additionally, long-term follow-up data on similar cases are not presented.

Declarations

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Conflict of interests.

None.

Data availability statement

The data that supports the findings of this case report are available from the corresponding author upon reasonable request.

Participant consent

The participant was informed about the need to use the findings of the scan for learning, education and publishing purposes and consent was granted.

Ethics approval

Informed consent was obtained from the subject for this publication.

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