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Anatomical variations of the renal arteries and their relevance in urological and transplant procedures: A systematic review and meta-analysis

Brandon Richardson^{1*}

¹Associate Professor, Southwest Medical University, Albuquerque, New Mexico.

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Abstract

Background: Differences in renal arterial anatomy, especially accessory renal arteries and early prehilum bifurcation are normal and have significant consequences in kidney transplantation, nephron-sparing surgery and minimally invasive urological surgery. This systematic review assessed the frequency of these anatomical variants and their clinical implication. **Procedures:** The review followed PRISMA 2020 guidelines and the Evidence-Based Anatomy framework. Cadaveric and angiographic studies published between 2020 and 2025 reporting accessory renal arteries were included. Pooled prevalence was estimated using a random-effects model with Freeman-Tukey double arcsine transformation, and heterogeneity was assessed using the I^2 statistic. **Findings:** Eight studies involving 4,617 participants met the inclusion criteria, of whom 1,257 had at least one accessory renal artery. The pooled prevalence of accessory renal arteries was 22.9% (95% CI: 15.5-31.2), with high heterogeneity ($I^2 = 96.0\%$). Most accessory arteries originated from the abdominal aorta and supplied the lower pole or renal hilum. They were generally solitary and occurred slightly more frequently on the left side and in males. Early prehilum branching was reported in 5-17% of subjects. Although kidneys with multiple renal arteries required longer reconstruction and ischemia times, recent studies demonstrated comparable graft function, patient survival, and transplant outcomes to kidneys with a single renal artery. **Conclusion:** Accessory renal arteries are normal anatomical variants, which must be identified by preoperative CT angiography to optimize surgical planning and donor selection.

Keywords: Renal artery, Accessory renal artery, Anatomical variation, Kidney transplantation, Partial nephrectomy, CT angiography, Living donor

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1. Introduction

The kidneys are normally retroperitoneal and receive a single renal artery from the abdominal aorta near the 1st or 2nd lumbar vertebral level which then bifurcates at the hilum into anterior and posterior divisions. These give rise to five segmental arteries. Each segmental artery will supply its own area and no more; and there will

* Corresponding author: Brandon Richardson, Associate Professor, Southwest Medical University, Albuquerque, New Mexico.

be no connection between the various arteries. When one is tied off or torn the portion of kidney it supplies with blood dies. This is the only reason why surgeons are interested in the branching pattern of the renal artery beyond an anatomist (Graves, 1954).

Anatomical studies consistently demonstrate that the renal arterial supply is among the most variable components of the arterial circulation (Triantafyllou *et al.*, 2025). These two varieties account for the most yield in surgical round. The first is the accessory renal artery which, in one or more cases, brings an extra vessel into a kidney through the hilum or directly into a pole. The second type is early (or pre) hilar branching, in which the main artery splits very near the aorta. There are other variations, such as an unusual origin, and a vessel originating from the iliac artery, but they are less common. The results of both the major variants have direct implications in the two areas in which the hilum is opened regularly-transplantation and urology (Weld *et al.*, 2005).

The sequence is logical to the development. The metanephros moves up from the pelvis to the lumbar region during weeks 6-9 and is derived from a series of temporary vessels from the aorta, which eventually disappear, with only one remaining. If only a lower vessel survives, it results in an inferior accessory artery at the hilum of the kidney or inferior polar accessory artery. If one of the higher is still present then a superior polar is observed. Incomplete early consolidation of the arterial network, early branching of the artery. Thus, the lower pole is the location of choice for accessory arteries, they have a side preference, and they tend to coexist with venous anomalies.

Changes over time are primarily in the clinical context. Living donation has blossomed because there are more kidneys wanted than available and programmes have now embraced kidneys with more than one artery which were previously turned down (Tabbara *et al.*, 2022). As the same time, the vascular course of donor nephrectomy (laparoscopic and robot-assisted) and partial nephrectomy requires the accurate determination of the course of arteries in advance to allow for pre-planned clamping of the artery to avoid warm ischaemia, bleeding and graft loss (Meng *et al.*, 2015). A current, quantitative understanding of their prevalence and the impact on the outcome is therefore helpful to radiologists, urologists and transplant surgeons.

The purpose of this review was to approximate the incidence of accessory renal artery from recent studies based on the number of patients involved. Second, summarizing frequency, and surgical significance of early branching and other origin variants. Thirdly to assess evidence on the effect of these variations to urological and transplant procedures and outcomes.

2. Materials and methods

2.1. Reporting and protocol

The review was conducted and then documented in accordance to PRISMA 2020 (Page *et al.*, 2021) reporting recommendations given by the Evidence-Based Anatomy Workgroup for anatomical prevalence studies (Henry *et al.*, 2017).

2.2. Eligibility criteria

Studies were included if original quantitative information concerning the incidence (%) of Accessory Renal Arteries (ARA) per subject obtained from cadaveric dissection and/or from a catheter angiography or CT/MRI was provided in the study, and if a numerator and denominator were provided that could be read directly off the publication. Studies were required to be published during 2020-2025. Case reports and small case series, reviews, editorials, abstracts without usable denominators, animal studies and any report whose denominator could not be determined were excluded. When a particular study provided information for each kidney, it was excluded from the main pooled analysis where unit of analysis was an individual, for consistency, but is mentioned in the text. In cases where the same patients were reported by both of two reports, the more complete was used.

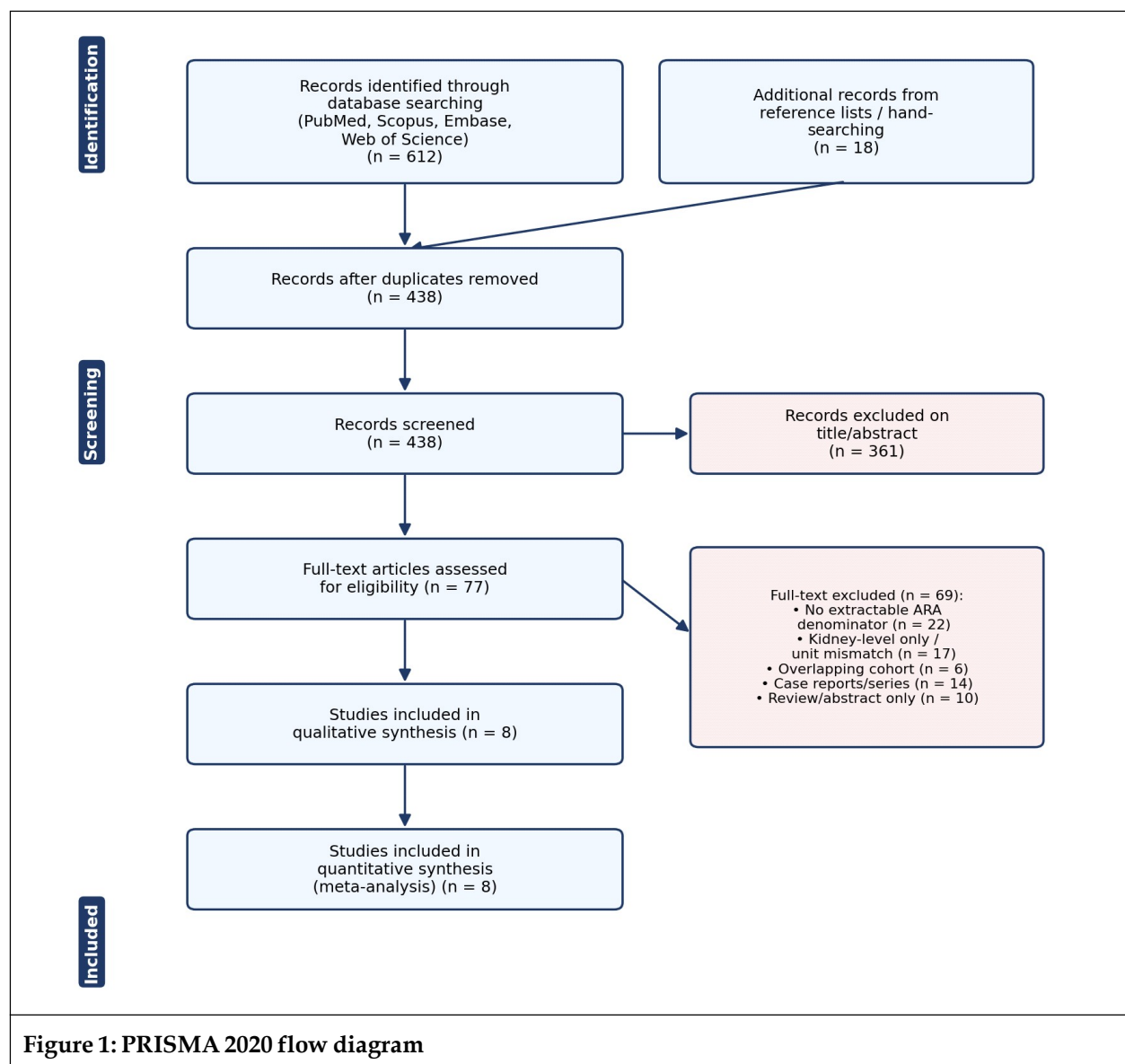
2.3. Search strategy

The period was 2020-2025, and PubMed was searched along with Scopus, Embase, and Web of Science which were also supplemented by a hand search of the reference lists of articles obtained and the reference lists of relevant reviews. The search included MeSH terms, free-text of the vessel, and variation (renal artery, accessory

renal artery, multiple renal arteries, supernumerary, polar artery, prehilary or early branching, anatomical variation) which were stringed together with “AND”, and was limited to kidney transplantation, living donor, donor nephrectomy, and partial nephrectomy using “OR”.

2.4. Selection and data extraction

After removing duplicates and screening by the title/abstract the full text of the remaining articles were read, and assessed for eligibility (Figure 1). For every study reported on we noted first author and year of publication, country of study, design of study, imaging technique, number of accessory arteries found and the number of subjects included in the study. If there were data available, accessory arteries, including the number of these arteries, where they arose from and ended, laterality, symmetry and sex distribution were also noted, and the reported frequency of early branching was also noted. All reviews for screening and extraction were undertaken by a single reviewer from the published reports and confirmed on each figure against the source of information.



2.5. Risk of bias

The Anatomical Quality Assessment (AQUA) tool was used to assess quality in its five domains: objectives and characteristics, study design, methodology, descriptive anatomy and reporting. For each domain an individual score was obtained: low, high or unclear risk. Anatomical prevalence studies were likely to report on demographics loosely and would include whomever had been scanned (pts in/pts out), so we would expect several studies to fit into the high-risk domain in one aspect, if not more.

2.6. Statistical analysis

Data was pooled in per-subject proportions based on a random-effects model. Each proportion was double-arc sine transformed with Freeman and Tukey's method (Freeman and Tukey, 1950) to make the variance for proportions near 0 or 1 reasonable before pooling, and the pooled variability of the double-arc sine transformed values was back transformed to get a pooled proportion using the harmonic-mean sample size of the individual studies (DerSimonian and Laird, 1986). 95% Confidence intervals are provided for the results. The heterogeneity was assessed using I-squared and Cochran's Q, and exact (Clopper and Pearson) confidence intervals were used for each study. The comparisons were carried out using Python 3, NumPy & SciPy and the pooled value was verified with the large published benchmark meta-analysis as an external check.

3. Results

3.1. Included studies

The search and screening are shown in Figure 1. Eight studies were included in the analysis that were published in 2020-2025, and included 4,617 participants in total, which satisfied the criteria and were used both in the narrative and pooled analysis (Table 1). The eight countries they belong to were South Korea, Nepal, Turkey, China and Slovakia as well as two distinct groups of Sudan and Oman, they employed cadaveric dissection or CT and MR angiography. Sample sizes ran from 40 to 3,000.

Table 1: Included studies and their Accessory Renal Artery (ARA) prevalence, 2020 to 2025					
Study (year)	Country	Design/modality	Subjects (n)	With ARA (n)	ARA % [95% CI]
Song <i>et al.</i> (2020)	South Korea	MDCT angiography (donors)	314	116	36.9 [31.6 to 42.5]
Paudyal <i>et al.</i> (2023)	Nepal	CECT	125	27	21.6 [14.7 to 29.8]
Hekimoglu and Ergun (2022)	Turkey	CT angiography	460	107	23.8 [19.9 to 28.0]
Shen <i>et al.</i> (2021)	China	CT angiography	3000	903	30.1 [28.5 to 31.8]
Vecanova <i>et al.</i> (2023)	Slovakia	Cadaveric dissection	40	8	20.0 [9.1 to 35.6]
Mohammed <i>et al.</i> (2024)	Sudan	CT	400	24	6.0 [3.9 to 8.8]
Osman <i>et al.</i> (2025)	Sudan	CT angiography (donors)	160	41	25.6 [19.1 to 33.1]
Al Lawati <i>et al.</i> (2025)	Oman	CT angiography	128	31	24.2 [17.1 to 32.6]
Note: ARA, accessory renal artery; CECT, contrast-enhanced CT; MDCT, multidetector CT.					

3.2. Pooled prevalence

In the eight studies (4,617 participants, 1,257 having at least one accessory artery) the random-effects pooled prevalence of accessory renal arteries was 22.9% (95% CI 15.5 to 31.2) (Figure 2). Differences in method and population were represented by heterogeneity (I-squared 96.0, tau-squared 0.066, Cochran's Q 175.4, $p < 0.001$) which is typical of anatomical prevalence data. The mere crude prevalence of the combined sample was 27.2. The combined figure converts near the baseline of approximately 21% via a synthesis of 111 studies aiding in certainty that the data that was extracted are solid.

3.3. Number, and morphological patterns of accessory renal arteries

In the reported studies, one accessory vessel was much more frequently found than two or more in conformity with benchmark percentages of approximately 18.7% having a single accessory artery, 1.8% having two vessels and less than 0.1% having three or more. The abdominal aorta gave rise to most of the accessory arteries either above or below the main renal artery and a few of these arteries were supplied by the common iliac or other vessels. They either terminated at the lower pole or at the hilum. In a local analysis, a lower-pole entry was 42% and a hilar entry was 39% based. They were unilateral, in about three-quarters of the cases of affected kidneys, with an insignificant left-sidedness, about 57. Male excess was brought up several times (Abdu *et al.*,

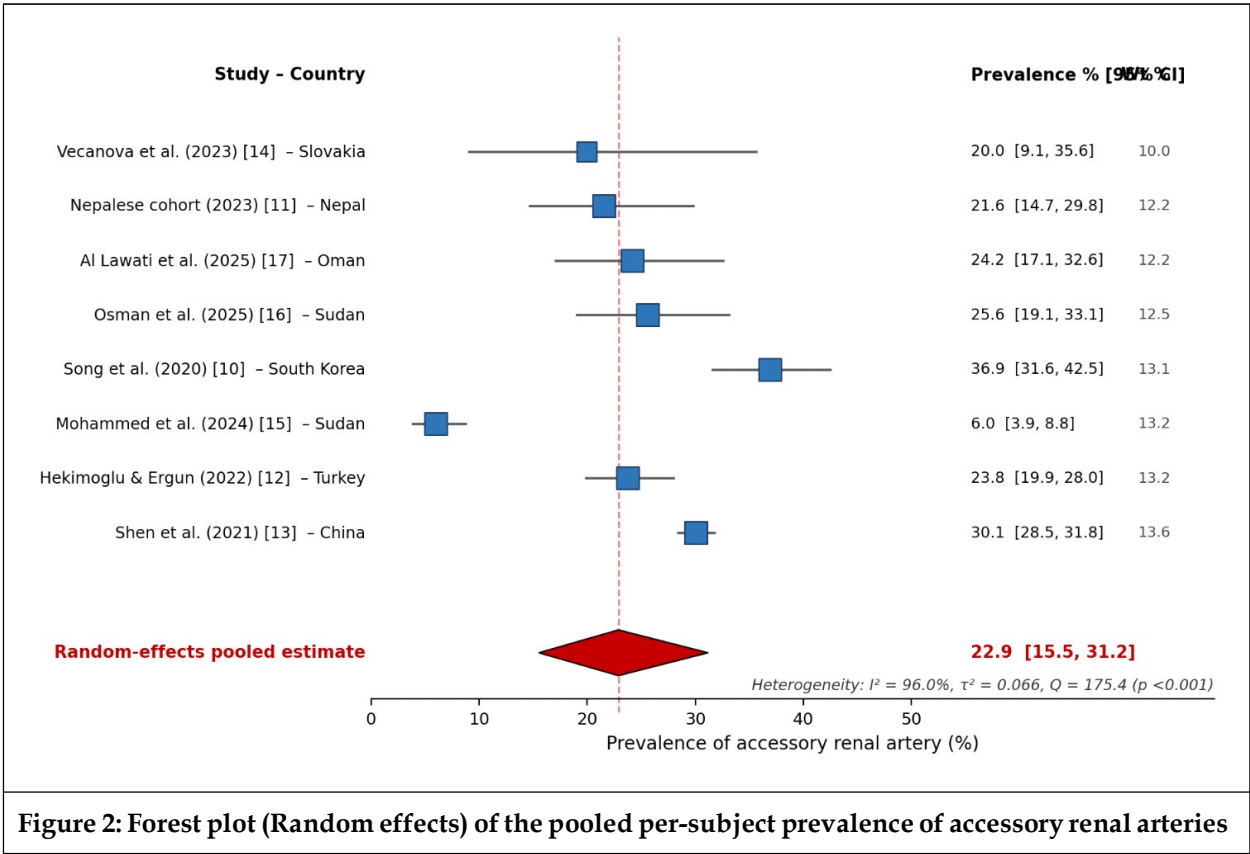


Figure 2: Forest plot (Random effects) of the pooled per-subject prevalence of accessory renal arteries

2026). A single cohort of donors detected accessory arteries in 37% of the men and 16% of women ($p = 0.008$) (Osman *et al.*, 2025). These patterns are consistent with the developmental theory, where there are lower vessels that develop into lower-pole and hilar accessory arteries.

3.4. Early (prehilar) branching

Most of the angiographic studies found early or prehilar branching, that is, division of the main renal artery at between 1.5 and 2.0 cm of the aorta, but the definition was lost across studies. The included cohorts had per-subject rates of included cohorts between approximately 5 and 17% with approximately 7% in the large Turkish cohort and 5 to 17% in the two Sudanese cohorts respectively (Mohammed *et al.*, 2024). Rates were higher with a looser definition of early hilar division. Since the segmental arteries are end-arteries, the number of levels is what determines the possibility of selectively clamping a branch in case of partial nephrectomy and the amount of anastomotic left after a transplant artery (Jianu *et al.*, 2025). The definitions differed greatly, and hence we capture this variant descriptively as opposed to coerce just a single pooled figure.

3.5. Risk of bias

In the AQUA tool (Anatomical Quality Assessment tool) most of the studies were retrospective single-centre imaging studies or cadaveric series on a convenience sample, and the aspects that were generally weak were

Table 2: AQUA risk-of-bias summary across the eight included studies			
Domain	Low (n)	High (n)	Unclear (n)
Objectives and characteristics	6	1	1
Study design (sampling frame)	2	4	2
Methodology	5	2	1
Descriptive anatomy	6	1	1
Reporting of results	4	3	1

how they described their sampling frame and how thoroughly they have reported their demographics. A number of them thus scored high or unclear in the design and reporting areas (Table 2). This large level of statistical heterogeneity (I-squared of about 96) is both in line with such methodological dispersion and actually with the true variation across populations, and thus the pooled value can be interpreted as a central tendency in a broad distribution instead of a fixed value.

4. Discussion

4.1. Main findings

The prevalence rate for accessory renal arteries in the present analysis was 22.9%, with a wide confidence interval and significant heterogeneity between the populations, suggesting a high level of variability. Practically, it can be assumed that in about 20% of the population an extra renal artery is present. This prevalence is similar to the 21.1% prevalence found in the pooled analysis of larger studies conducted by Triantafyllou *et al.* although the present review only included more recent studies. The agreement between the two estimates is comforting, but the high level of heterogeneity identified in the current analysis indicates that a single prevalence value should not be considered to be applicable across populations. Also from the studies included in this review comes the conclusion that renal arterial variation does not only occur in the presence of a second artery. The site of origin, side involved and branching pattern have all been described repeatedly, with differences relating to each of these noted (Paudyal *et al.*, 2023; Hekimoglu and Ergun, 2022; Shen *et al.*, 2021; Vecanova *et al.*, 2023). In their study, Mohammed *et al.* (2024) found accessory renal arteries in only 6% of their Sudanese CT population, whereas Song *et al.* (2020) found them in 36.9% of subjects. More recently, Osman *et al.* (2025) found accessory renal arteries in 25.6% of potential kidney donors and early branching in 17%. The variation is likely to be due to a mix of population differences and choices of study subjects, and to differences in imaging or anatomical assessment. Therefore, the summary is to be treated as an average of an anatomical variation rather than a population frequency.

4.2. Embryological basis of observed variations

The development and ascent of kidneys can be used to help understand the pattern of accessory renal arteries. In early development, the metanephric kidneys move from a pelvic position to their final position in the lumbar area and get successive branches from the aorta. With the formation of the definitive renal arteries, most of these transient vessels revert. The continued presence of one or more of them is a likely reason for other hilar or polar arteries.

This developmental history also contributes to an understanding of the development of accessory arteries appearing in the kidney away from the hilum. The large meta-analysis performed by Triantafyllou *et al.* (2025) revealed that accessory vessels can differ in their origin as well as their termination and that a single accessory artery was much more frequent than two or three additional arteries. Morphological variation was also apparent in the recent CT and cadaveric studies that were reviewed here. These results confirm the hypothesis that accessory renal arteries are remnants of the fetal vascularization but not collateral vessels.

Early branching should be differentiated from an accessory renal artery. There are two types of early branching: the main renal artery branches early from the aorta, while the accessory has an independent arterial origin. Consistency in applying this distinction is not always observed in anatomical studies and may be a factor in the variations in reported prevalence. The short renal arteries with early division have also been stressed by Jianu *et al.* (2025) as a potential misdiagnosis for multiple renal arteries. When comparing prevalence studies or reporting renal vascular anatomy prior to surgery, clear definition of anatomical location is crucial.

4.3. What it means for transplantation (Relevance of the kidney transplantation)

Renal artery vascularity is another technical consideration of donor nephrectomy and graft implantation which presents the surgeon with the challenge of preserving or incorporating multiple arteries if they are significant. There are numerous ways to reconstruct depending on the number, size and location of the vessels. Reconstruction can involve a combination of arteries connected together to form a single inflow, implanting a smaller branch into a larger artery, or individual arterial anastomosis. How complicated the arterial anatomy can be treated without excluding the kidney for transplantation is demonstrated in the single-inflow reconstruction approach used for living-donor grafts with multiple renal arteries.

This is not to discount the significance of multiple arteries clinically. A patient level meta-analysis of the two groups (single vs multiple arteries) showed no difference in graft survival or overall recipient survival (Lim *et al.*, 2023). The results corroborate the current trend of using kidneys with more than one artery when the vascular anatomy is well-documented and a surgeon with the proper reconstructive skills is present. The presence of multiple arteries does not necessarily preclude an otherwise appropriate living donor, but does make the operation more complex.

Importance of the site of an accessory artery. Inferior polar arteries are of special interest as they could supply blood to the proximal ureter. If a large lower pole is lost, it may also affect the ability to perfuse the rest of the kidney, and can lead to leakage or stricture of the ureter (Bikauskaite *et al.*, 2021). The size of the vessel to be ligated or reconstructed and the territory it provides should thus be considered, not just the number of renal arteries.

The problem with early branching of the arteries is different. There are fewer vessels to divide and re-join in the main renal artery. If this pattern is identified preoperatively, the transplant team can begin to plan for a modified retrieval or reconstruction approach. For this reason it is more helpful to simply record the presence or absence of an accessory artery in the context of the number of arteries, their size, their polar distribution and the distance to the first major branch than to just note the presence or absence of an accessory artery.

4.4. What it means for urological and nephron-sparing surgery

The renal arterial tree is now recognized as having a segmental structure, which has significant implications for partial nephrectomy. Since segmental arteries communicate with each other in limited fashion, selective control of the branch to the tumour bearing area can minimize the warm ischaemic exposure of renal parenchyma. Meng *et al.* (2015) showed the usefulness of preoperatively evaluating the arterial anatomy with CT angiogram in superselective clamping for laparoscopic partial nephrectomy. Accessory arteries or early branching do not preclude selective clamping but alter the vascular map that needs to be taken into account prior to hilar dissection.

Variations of the arteries are also significant at the pelviureteric junction. The crossing vessel is lower in the pelvis and can be quite close to the ureteropelvic junction, and in certain patients can cause obstruction. Identification is especially crucial when performing the pyeloplasty procedure since the surgical approach may require the preservation of the UPJ and its proper transposition with regard to the crossing vessel (Grasso *et al.*, 2001). This clinical relationship is distinct from the overall prevalence of accessory renal arteries as not all polar vessels will cause obstruction.

The endovascular procedures are also affected by renal arterial anatomy. The accuracy of the identification of the involved vessel supplying the pathological region is the key to selective arterial embolisation, especially in renal vascular injury or pseudoaneurysm after partial nephrectomy (Zorn *et al.*, 2007). Renal branches are end-arterial branches, so that embolisation can be carried out without destroying the uninvolved renal tissue if the branch responsible for the bleeding can be selectively catheterised. Catheter renal denervation is another application. Song *et al.* (2020) studied the renal arterial variations in relation to anatomical suitability for renal denervation. Small caliber vessels & accessory arteries can prevent access of catheter or may not be targeted. Therefore, evaluation of the entire renal arterial tree is important and not just the main renal artery when considering the procedure.

4.5. Imaging and preoperative vascular assessment

Preoperative evaluation of renal vessels has become the focus of multidetector CT angiography, enabling the tracing of renal arteries from their origin from the aorta to their hilar and segmental branches. The recent studies in this review, however, were mostly based in the use of CT assessment and shown to be useful in identifying accessory arteries, early branching and associated vascular variants. Three dimensional reconstructions are very useful in the presence of multiple arteries and when the relationship between a polar vessel and the renal parenchyma should be defined.

Rubin *et al.* (1995) showed the usefulness of computed tomography angiography for use as a diagnostic tool in potential renal donors, with a 100% sensitivity for accessory renal arteries and a 93% sensitivity for renal artery branches in the prehilar area. While these data were collected before the studies used in the current

prevalence analysis, they are more relevant to the diagnostic effectiveness of CT angiography for the present prevalence estimates than to the anatomical prevalence estimates of these studies.

If a renal arterial variation is identified, the imaging report should include more information than just “variation is present,” so that surgical planning can be done. The number of arteries on each side, their source (aortic or not), the size of the arteries, the site of entry of the renal arteries, and the distance between the aorta and the first major arterial division shall be recorded. Polar arteries should be emphasized due to their importance to the parenchymal and ureteric perfusion. An associated renal venous variant should also be noted when it may impact the hilar dissection or donor nephrectomy.

MR angiography may be an alternative method of vascular assessment in certain patients, especially those that cannot tolerate the use of iodinated contrast or ionising radiation. However, the dominance of the CT angiography in the studies included in this review is due to the fact that this is a technique that is routinely used for detailed preoperative study of renal vascular anatomy. The importance of imaging is not just in the recognition of an accessory artery, but also in producing a map of the arteries that can be used directly in the surgical procedure.

4.6. Strengths and limitations

The review adheres to PRISMA 2020 and the Evidence-Based Anatomy framework, has only one fixed unit of analysis, and aggregates proportions in a manner that is conducive to prevalence data, and compares its aggregated figure to a large published benchmark. Their restrictions exist and ought to moderate the interpretation of the numbers. It was a limited search of the past six years and was extracted by a single reviewer reading published reports and therefore is not a comprehensive systematic search, and one of the studies identified requires list of authors to be verified by looking within the source. The heterogeneity was so high, fuelled by the differences between cadaveric and angiographic techniques, the lack of consistent definitions of early branching, inconsistent reporting of demographics, and geographical clustering, and a significant proportion of the primary studies have a high AQUA risk of bias. To maintain homogeneity of the unit they shunned out studies that reported only per kidney which would otherwise leave some data on the table. All these reasons make the pooled value a central value in a range of wide population-depending variation.

5. Conclusion

Diversity in the renal arteries is not a rare condition, but normal. Recent evidence, collected in pools, suggests an accessory renal artery in approximately 22.9%. and early prehilum branching in a smaller, yet surgically significant, number, of individuals, and is consistent in number, origin, termination, side, and sex, with the pattern predicted by embryology. Their variations influence the method of selecting the donor, the process of reconstructing the vessels, and the duration of the kidney in the state of ischaemia during transplantation as well as selective clamping, endourology and work on urethra. A structured report of CT angiography should be done prior to any surgery on the hilum and the presence of more than one artery should no longer be a deficiency to a living donor.

References

- Abdu, S.M., Abdu, H., Seid, E. and Assefa, E.M. (2026). [Prevalence of accessory renal arteries in Africa: A systematic review and meta-analysis using the AQUA checklist.](#) *Health Sci Rep*, 9: e71751. doi: 10.1002/hsr2.71751.
- Al Lawati, A., Abduwani, A., Al Khudhuri, A., Alhabshi, A.N., Balushi, K.A., Das, S. and Baawain, S. (2025). [Computed tomography evaluation of the renal blood vessels in the Omani population.](#) *Appl Sci*, 15(18): 9967. doi: 10.3390/app15189967.
- Bikauskaite, S., Sileikis, A., Zelvyys, A. et al. (2021). [Reconstruction of a lower polar artery for kidney transplantation using donor ovarian vein: Case report with literature review.](#) *Medicina (Kaunas)*, 57(11): 1234. doi: 10.3390/medicina57111234.
- DerSimonian, R. and Laird, N. (1986). [Meta-analysis in clinical trials.](#) *Control Clin Trials*, 7(3): 177-188. doi: 10.1016/0197-2456(86)90046-2.

- Freeman, M.F. and Tukey, J.W. (1950). Transformations related to the angular and the square root. *Ann Math Stat*, 21(4): 607-611. doi: 10.1214/aoms/1177729756.
- Grasso, M. III, Caruso, R.P. and Phillips, C.K. (2001). UPJ obstruction in the adult population: Are crossing vessels significant?. *Rev Urol*, 3(1): 42-51.
- Graves, F.T. (1954). The anatomy of the intrarenal arteries and its application to segmental resection of the kidney. *Br J Surg*, 42(172): 132-139.
- Hekimoglu, A. and Ergun, O. (2022). Evaluation of renal vascular variations with computed tomography. *Afr J Urol*, 28: 21. doi: 10.1186/s12301-022-00290-x.
- Henry, B.M., Tomaszewski, K.A., Ramakrishnan, P.K. *et al.* (2017). Development of the Anatomical Quality Assessment (AQUA) tool for anatomical studies included in meta-analyses and systematic reviews. *Clin Anat*, 30(1): 6-13. doi: 10.1002/ca.22799.
- Jianu, A.M., Damen, N.S., Vaida, M.A., Grigorita, L.O., Rusu, M.I. and Rusu, M.C. (2025). Early-branched short renal arteries are false multiple renal arteries. *Diagnostics (Basel)*, 15(8): 1046. doi: 10.3390/diagnostics15081046.
- Lim, E.J., Fong, K.Y., Li, J., Chan, Y.H., Aslim, E.J., Ng, L.G. and Gan, V.H.L. (2023). Single versus multiple renal arteries in living donor kidney transplantation: A systematic review and patient-level meta-analysis. *Clin Transplant*, 37(11): e15069. doi: 10.1111/ctr.15069.
- Meng, X., Mi, Q., Fang, S. and Zhong, W. (2015). Preoperative evaluation of renal artery anatomy using computed tomography angiography to guide superselective clamping during laparoscopic partial nephrectomy. *Exp Ther Med*, 10(1): 139-144. doi: 10.3892/etm.2015.2500.
- Mohammed, S., AbdAlla, E., Elhag, A. and El-Mardi, A. (2024). The prevalence of accessory renal arteries in Sudanese population in Khartoum State: A cross-sectional CT study from 2017 to 2020. *BMC Nephrol*, 25: 135. doi: 10.1186/s12882-024-03573-3.
- Osman, S., AbdAlla, E., Ali, L., MohamedAli, H., Taha, B., Elmahdi, T.S.A. *et al.* (2025). Prevalence and patterns of renal vascular variations among potential kidney donors: A computed tomography angiography study in Sudan. *BMC Nephrol*, 26(1): 167. doi: 10.1186/s12882-025-04094-3.
- Page, M.J., McKenzie, J.E., Bossuyt, P.M. *et al.* (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, 372: n71. doi: 10.1136/bmj.n71.
- Paudyal, S., Gupta, M.K., Adhikari, D., Shah, R. and Poudel, B. (2023). Anatomical variations of renal artery studied by computed tomography in a tertiary care center in Nepal. *Int J Health Sci Res*, 13(7): 268-273.
- Rubin, G.D., Alfrey, E.J., Dake, M.D., Semba, C.P., Sommer, F.G., Kuo, P.C. *et al.* (1995). Assessment of living renal donors with spiral CT. *Radiology*, 195(2): 457-462. doi: 10.1148/radiology.195.2.7724766.
- Shen, J., Lyu, L., Wu, X., Ji, J., Zeng, C., Li, S. *et al.* (2021). Correlation between renal artery anatomy and hypertension: A retrospective analysis of 3000 patients. *Evid Based Complement Alternat Med*, 2021: 9957361. doi: 10.1155/2021/9957361.
- Song, W.H., Baik, J., Choi, E.K., Lee, H.Y., Kim, H.H., Park, S.M. and Jeong, C.W. (2020). Quantitative analysis of renal arterial variations affecting the eligibility of catheter-based renal denervation using multi-detector computed tomography angiography. *Sci Rep*, 10(1): 19720. doi: 10.1038/s41598-020-76812-w.
- Tabbara, M.M., Chen, M., Rivas, L. *et al.* (2022). Creating a single inflow orifice from living donor kidney allografts with multiple renal arteries. *Transpl Int*, 35: 10212. doi: 10.3389/ti.2022.10212.
- Triantafyllou, G., Paschopoulos, I., Wegiel, A. *et al.* (2025). The accessory renal arteries: A systematic review with meta-analysis. *Clin Anat*, 38(3): 357-372. doi: 10.1002/ca.24255.
- Vecanova, J., Hvizdosova, N., Hodorova, I. *et al.* (2023). A report on accessory renal arteries incidence in Slovak adults: Cadaveric study and surgical correlation. *Bratisl Lek Listy*, 124(8): 567-571. doi: 10.4149/BLL_2023_088.

- Weld, K.J., Bhayani, S.B., Belani, J., Ames, C.D., Hrubby, G. and Landman, J. (2005). [Extrarenal vascular anatomy of the kidney: Assessment of variations and their relevance to partial nephrectomy.](#) *Urology*, 66(5): 985-989. doi: 10.1016/j.urology.2005.05.023.
- Zorn, K.C., Starks, C.L., Gofrit, O.N., Orvieto, M.A. and Shalhav, A.L. (2007). [Embolization of renal-artery pseudoaneurysm after laparoscopic partial nephrectomy for angiomyolipoma: Case report and literature review.](#) *J Endourol*, 21(7): 763-768. doi: 10.1089/end.2006.0332.