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CLINICAL SIGNIFICANCE OF RENAL ARTERY ANATOMICAL VARIATIONS IN HYPERTENSION AND SURGICAL PRACTICE

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ABSTRACT:Renal artery anatomical variations are relatively common and have important clinical implications in hypertension, kidney transplantation, nephrectomy, vascular surgery, and endovascular procedures. The most frequent variations include accessory or multiple renal arteries, polar arteries, early branching, and differences in the origin and course of renal vessels. These arteries are functionally important because many renal branches are end arteries supplying specific segments of renal parenchyma with limited collateral circulation. Certain anatomical variants have been investigated as potential contributors to renovascular or resistant hypertension, particularly when accessory renal arteries are narrowed or associated with regional renal hypoperfusion. In surgical practice, unrecognized renal artery variations may increase the risk of hemorrhage, segmental renal ischemia, ureteral injury, vascular complications, and technical difficulties during transplantation. This article analyzes the anatomical characteristics of renal arterial variations and evaluates their clinical significance in hypertension, diagnostic imaging, kidney transplantation, nephrectomy, and vascular interventions.

Keywords: renal artery, anatomical variations, accessory renal artery, multiple renal arteries, renovascular hypertension, resistant hypertension, kidney transplantation, nephrectomy, computed tomography angiography, renal surgery.

INTRODUCTION:The kidneys receive a substantial proportion of cardiac output and depend on an anatomically complex vascular system to maintain glomerular filtration, electrolyte balance, fluid homeostasis, and regulation of systemic blood pressure. The renal arteries are therefore of considerable anatomical and clinical importance. Although the classical anatomical description includes a single renal artery supplying each kidney, variations in the number, origin, course, branching pattern, and site of renal entry are common. Recognition of these variations is particularly important in patients undergoing renal surgery, transplantation, interventional procedures, or evaluation for secondary hypertension.Normally, the right and left renal arteries arise from the lateral aspects of the abdominal aorta, usually near the level of the first and second lumbar vertebrae. The right renal artery generally has a longer course because the aorta is positioned to the left of the midline. It passes posterior to the inferior vena cava before reaching the renal hilum. The left renal artery follows a shorter and more direct route to the left kidney.

Near the renal hilum, the main renal artery divides into segmental branches supplying anatomically defined renal segments. These branches are essentially end arteries with limited effective collateral

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circulation. Consequently, interruption or accidental ligation of a segmental or polar renal artery may lead to ischemia or infarction of the corresponding renal parenchyma. This anatomical characteristic explains the importance of identifying every functionally significant renal arterial branch before surgery.One of the most common variations is the presence of **accessory or multiple renal arteries**. These vessels may enter the renal hilum together with the main renal artery or enter the renal parenchyma directly through the superior or inferior pole. A recent systematic review and meta-analysis including 111 studies estimated that typical bilateral single renal arteries are present in approximately 78.92% of individuals, whereas accessory renal arteries occur in approximately 21.10% [1]. The abdominal aorta is the most common origin of these vessels, although origins from other nearby arteries have also been reported.

The terms “accessory,” “additional,” “supernumerary,” and “multiple” renal arteries have historically been used interchangeably. However, from a functional perspective, the term “accessory” may underestimate the importance of such arteries because they frequently provide the sole arterial supply to a specific renal segment. Damage to a polar artery may therefore produce clinically meaningful renal ischemia even when the main renal artery remains intact.The developmental basis of renal arterial variations is related to embryological ascent of the kidneys. During development, the kidneys move from the pelvic region toward their final retroperitoneal position. During this process, they are sequentially supplied by temporary arterial branches from the aorta. Normally, most inferior embryonic arteries regress as new superior vessels develop. Persistence of one or more of these vessels results in multiple or accessory renal arteries. Variability in this developmental process explains the wide range of renal arterial configurations encountered in clinical practice.

Another important anatomical variation is **early branching of the renal artery**, in which division into segmental branches occurs more proximally than expected. Early branching can reduce the length of the main arterial trunk available for vascular clamping or anastomosis and may therefore complicate donor nephrectomy and kidney transplantation. Similar difficulties may arise when several separate arteries supply a single kidney.Renal arterial variations have also attracted considerable interest because of their possible association with arterial hypertension. The kidney plays a central role in blood-pressure regulation through sodium handling, extracellular fluid balance, renal sympathetic activity, and the renin–angiotensin–aldosterone system. Reduced renal perfusion, particularly when caused by arterial stenosis, can stimulate renin secretion and produce secondary renovascular hypertension.

The possible relationship between accessory renal arteries and hypertension remains more complex. An accessory artery does not automatically cause hypertension, and many individuals with multiple renal arteries remain normotensive throughout life. Nevertheless, several mechanisms have been proposed to explain why certain configurations could contribute to elevated blood pressure. A relatively small-caliber or stenotic accessory artery may provide insufficient perfusion to the renal segment it supplies, creating localized renal ischemia and stimulating renin release.A 2024 study

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examining the effect of accessory renal arteries on essential hypertension found evidence supporting an association between accessory renal arteries and hypertension and investigated mechanisms related to renal perfusion and renin–angiotensin system activation [2]. These findings suggest that renal vascular anatomy may contribute to blood-pressure regulation in selected individuals, although the relationship should not be interpreted as universally causal.

Accessory renal artery-related hypertension has also been described when the variant artery itself develops stenosis. In such circumstances, a portion of renal parenchyma may receive reduced arterial blood flow even if the main renal artery is normal. Recent literature discussing accessory renal artery-related hypertension emphasizes that medical therapy generally remains the first-line approach, while endovascular or other interventions may be considered in carefully selected patients with persistent hypertension and a clearly demonstrated hemodynamically significant vascular lesion [3].The concept is clinically important because routine evaluation of renovascular hypertension traditionally focuses on stenosis of the main renal artery. If a clinically significant accessory artery is overlooked, the anatomical cause of segmental renal ischemia may remain undetected. Computed tomography angiography, magnetic resonance angiography, Doppler ultrasonography, and conventional catheter angiography may therefore be used to evaluate renal vascular anatomy in selected patients.

Among these techniques, computed tomography angiography (CTA) provides detailed three-dimensional visualization of the origin, number, diameter, course, branching pattern, and renal entry point of renal arteries. CTA is particularly useful during preoperative planning for renal transplantation and nephrectomy. Three-dimensional reconstructions help surgeons identify accessory arteries, polar branches, early bifurcation, and relationships with adjacent veins and ureteral structures.The importance of renal arterial anatomy becomes particularly evident in kidney transplantation. A graft with a single renal artery generally permits a relatively straightforward arterial anastomosis. In contrast, kidneys supplied by multiple arteries may require separate anastomoses, arterial reconstruction, creation of a common arterial channel, or other vascular techniques.

A recent systematic review and meta-analysis involving more than 26,000 renal transplant recipients showed that grafts with multiple renal arteries present additional technical challenges and may have somewhat higher vascular or overall complication rates compared with grafts with a single renal artery. Nevertheless, modern reconstructive techniques allow successful transplantation of kidneys with multiple arteries, and such anatomy is generally not considered an absolute contraindication to transplantation [4].Inferior polar renal arteries deserve particular attention because they may contribute not only to renal parenchymal perfusion but also to the blood supply of the proximal ureter and ureteropelvic region. Accidental ligation of such an artery during transplantation can therefore potentially contribute to ureteral ischemia, urinary leakage, necrosis, or other urological complications. For this reason, small vessel diameter alone should not be the only factor considered when deciding whether a polar artery can be sacrificed.

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Renal arterial variations are similarly important during partial and radical nephrectomy. Precise preoperative identification of segmental and accessory arteries helps surgeons control blood flow, minimize intraoperative hemorrhage, preserve viable renal tissue, and reduce warm ischemia time. This is especially important during nephron-sparing surgery, where selective arterial clamping may be used to preserve perfusion to uninvolved renal parenchyma.The segmental nature of renal arterial supply also has implications for interventional radiology. Selective renal artery embolization may be performed for renal tumors, vascular malformations, trauma, or active hemorrhage. Detailed knowledge of variant arterial anatomy permits targeted embolization while minimizing unintended ischemia of normal renal tissue.

Renal sympathetic denervation represents another area in which anatomical variations may have clinical consequences. Catheter-based renal denervation aims to reduce renal sympathetic activity in selected patients with difficult-to-control hypertension. Multiple or small accessory renal arteries may complicate complete denervation because sympathetic fibers surrounding variant vessels may not be adequately treated if these arteries are not identified or accessible. The 2024–2025 anatomical literature specifically highlights the relevance of accessory renal arteries to resistant hypertension therapies and renal denervation procedures [1].The prevalence of renal arterial variation may also vary between populations and according to the imaging or anatomical technique used. A recent CTA-based study of 200 individuals reported at least one multiple renal artery in approximately 29% of participants, illustrating that renal vascular variants are common enough to be routinely considered during preoperative evaluation [4].

Thus, renal artery variations should not be considered merely anatomical curiosities. Their clinical significance extends from the pathophysiology of selected cases of hypertension to the safety and technical success of kidney transplantation, nephrectomy, vascular reconstruction, renal denervation, and endovascular procedures. Accurate preoperative recognition of these variants can reduce unexpected vascular injury and allow surgical or interventional strategies to be individualized.

MATERIALS AND METHOD:This study was conducted as a literature-based review to evaluate the clinical significance of renal artery anatomical variations in hypertension and surgical practice. Scientific articles, anatomical studies, radiological investigations, systematic reviews, meta-analyses, and clinical reports related to renal vascular anatomy were analyzed. The literature search included publications available through PubMed, Google Scholar, Scopus-indexed journals, and relevant surgical and radiological databases. Priority was given to peer-reviewed studies published between 2019 and 2026, while earlier fundamental anatomical studies were considered when necessary to explain established patterns of renal arterial development and distribution. The main search terms included “renal artery anatomy,” “accessory renal artery,” “multiple renal arteries,” “renal artery variation,” “polar renal artery,” “early renal artery branching,” “renovascular hypertension,” “resistant hypertension,” “kidney transplantation,” “nephrectomy,” “renal surgery,” and “computed tomography angiography.” Studies were included if they provided information on the number, origin, course,

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branching pattern, diameter, or renal entry point of renal arteries and their relationship with hypertension, kidney transplantation, nephrectomy, vascular reconstruction, or endovascular procedures. Studies focusing exclusively on unrelated renal diseases, isolated case reports without broader anatomical relevance, duplicate publications, and articles without sufficient methodological information were excluded. The selected literature was analyzed according to several major categories, including single and multiple renal arteries, accessory hilar arteries, superior and inferior polar arteries, early branching, unusual arterial origins, and bilateral vascular variations. Particular attention was paid to the potential relationship between accessory renal arteries and hypertension, especially in cases where a small-caliber or stenotic accessory vessel could reduce regional renal perfusion and contribute to activation of the renin–angiotensin–aldosterone system. Surgical significance was assessed by analyzing the influence of renal arterial variations on donor nephrectomy, kidney transplantation, partial nephrectomy, radical nephrectomy, vascular anastomosis, selective arterial clamping, renal artery embolization, and other interventional procedures. The role of preoperative vascular imaging was also evaluated, with particular emphasis on computed tomography angiography, magnetic resonance angiography, Doppler ultrasonography, and digital subtraction angiography. These imaging methods were compared according to their ability to identify accessory vessels, polar arteries, early branching, vessel stenosis, and relationships with adjacent renal veins and ureters. The selected studies were comparatively analyzed to determine the most frequently reported anatomical variations and their clinical consequences. Particular attention was given to the risk of intraoperative hemorrhage, segmental renal ischemia, graft vascular complications, ureteral ischemia, prolonged warm ischemia time, technical difficulties during anastomosis, and the possible contribution of renal arterial anatomy to difficult-to-control hypertension. Since this study was based exclusively on previously published scientific literature and did not involve direct participation of patients, collection of personal medical information, or experimental interventions, ethical approval and informed consent were not required.

RESULTS: The analysis of the selected literature demonstrated that renal artery anatomical variations are common and have considerable clinical importance in diagnostic imaging, arterial hypertension, kidney transplantation, and renal surgical procedures. The most frequently identified variants were accessory or multiple renal arteries, polar arteries, early branching of the main renal artery, and less common aberrant origins. The prevalence of these variations differed between populations and according to the imaging or anatomical method used, but contemporary studies consistently showed that a substantial proportion of individuals do not have the classical pattern of a single renal artery supplying each kidney.Accessory renal arteries were among the most frequently reported variations. These vessels most commonly arise directly from the abdominal aorta and may enter the kidney through the renal hilum or directly through the superior or inferior pole. Their clinical importance is related to the segmental nature of renal arterial supply. Because intrarenal arterial branches have limited effective collateral circulation, an accessory artery may represent the principal or sole source

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of blood flow to a particular region of renal parenchyma. Consequently, damage, thrombosis, or surgical ligation of such a vessel can cause segmental ischemia or renal infarction.

Recent systematic evidence has shown considerable variability in the prevalence of accessory arteries and early branching across different populations. A 2025 systematic review of studies published between 2019 and 2025 found that reported frequencies generally ranged from approximately 10% to more than 30%. In one donor CTA population, accessory renal arteries were identified in 25.6% of cases and early branching in approximately 17% [8]. These findings emphasize that variant renal arterial anatomy should be anticipated rather than regarded as an exceptional finding.Early branching was also identified as an important anatomical feature. In this configuration, the main renal artery divides into segmental branches relatively close to its aortic origin. Although the kidney may technically have only one main renal artery, the short arterial trunk can create surgical conditions similar to multiple arterial supply. This distinction is especially important in living kidney donation because the available arterial length determines the feasibility and technical complexity of vascular anastomosis.

The reviewed evidence suggested a possible association between renal arterial variations and hypertension, although this relationship was not uniform. The most plausible mechanism involves reduced regional renal perfusion. A small-caliber, elongated, stenotic, or hemodynamically unfavorable accessory renal artery may result in relative hypoperfusion of the renal segment it supplies. Decreased renal perfusion can stimulate renin secretion, activate the renin–angiotensin–aldosterone system, and contribute to sodium retention, vasoconstriction, and increased systemic blood pressure.A 2025 single-center study evaluating renal vascular variations in patients with resistant hypertension reported an association between accessory renal arteries and difficult-to-control blood pressure, supporting the hypothesis that renal vascular anatomy may contribute to hypertension in selected patients [5]. However, the presence of an accessory artery alone cannot be considered sufficient evidence of renovascular hypertension because many individuals with identical anatomical variants remain normotensive. Therefore, anatomical findings should be interpreted together with clinical, biochemical, and hemodynamic evidence.

The analysis further demonstrated that detailed vascular imaging is essential for distinguishing multiple renal arteries from early branching and for determining the origin, diameter, course, and renal entry site of each vessel. Computed tomography angiography remained the principal imaging method for preoperative renal vascular assessment because it provides high spatial resolution and three-dimensional reconstruction of renal arterial anatomy.Magnetic resonance angiography may provide an alternative in selected patients. A 2025 study comparing non-contrast quiescent-interval slice-selective magnetic resonance angiography with CTA showed that QISS-MRA detected 19 of 20 renal arterial branching variants identified by CTA. Sensitivity and specificity for accessory and aberrant renal arteries were 100%, while sensitivity for early branching was approximately 89% [6]. These findings

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indicate that non-contrast MRA may be useful when iodinated contrast or radiation exposure is undesirable, although CTA remains highly reliable for detailed preoperative mapping.

Renal artery anatomy had particularly important implications for kidney transplantation. Multiple renal arteries require more complex vascular reconstruction compared with a single renal artery. Surgical options include separate arterial anastomoses, creation of a common arterial ostium, end-to-side reconstruction of a smaller accessory vessel into the main renal artery, or other microsurgical techniques.A recent meta-analysis including 41 studies and 26,342 transplant recipients found that multiple-renal-artery grafts were associated with a modest increase in total and vascular complication rates compared with single-artery grafts [7]. In live-donor transplantation, total complications occurred in approximately 11.4% of multiple-artery grafts compared with 10.5% of single-artery grafts. Despite these differences, long-term outcomes remained sufficiently favorable for kidneys with multiple arteries to remain acceptable for transplantation when appropriate reconstruction is possible [7].

The location of accessory vessels was also clinically important. Inferior polar arteries may contribute to the vascular supply of the lower renal pole and proximal ureter. Unrecognized damage or intentional sacrifice of these vessels may therefore result not only in segmental renal ischemia but also in impaired ureteral perfusion, potentially increasing the risk of ischemic ureteral complications.Renal arterial variations were similarly important during partial nephrectomy. Modern nephron-sparing surgery aims to remove pathological tissue while preserving as much functioning renal parenchyma as possible. Knowledge of segmental arterial anatomy permits selective or super-selective vascular clamping and can reduce unnecessary ischemia of unaffected renal tissue. Failure to identify accessory or early branching arteries may lead to unexpected hemorrhage, incomplete vascular control, or prolonged operative ischemia.

During radical nephrectomy, preoperative identification of multiple renal arteries can also reduce intraoperative vascular complications. An unexpected accessory vessel may remain perfused after control of the apparent main renal artery and can result in significant bleeding during renal mobilization. Therefore, preoperative vascular mapping has direct implications for surgical safety.

Table 1. Major Renal Artery Variations and Their Clinical Significance

Anatomical variation	Main anatomical characteristic	Possible clinical consequence	Surgical / diagnostic importance
Accessory renal artery	Additional artery usually arising from the aorta	Segmental perfusion alteration; possible association with hypertension	Must be identified before transplantation or nephrectomy
Multiple renal arteries	Two or more independent arteries supplying one kidney	Increased vascular complexity	May require multiple or reconstructed anastomoses [7]

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Anatomical variation	Main anatomical characteristic	Possible clinical consequence	Surgical / diagnostic importance
Superior polar artery	Vessel entering the superior pole outside the hilum	Segmental ischemia if damaged	Important in renal and adrenal region surgery
Inferior polar artery	Vessel entering lower renal pole	Segmental ischemia; possible ureteral perfusion impairment	Preservation may be important in transplantation
Early renal artery branching	Main artery divides close to its aortic origin	Usually no direct functional abnormality	Shortens arterial trunk available for anastomosis
Small-caliber accessory artery	Narrow vessel supplying a renal segment	Regional hypoperfusion and possible RAAS activation	May be relevant in selected hypertension cases [5]
Stenotic accessory artery	Hemodynamically significant narrowing	Renovascular hypertension	Requires functional and vascular assessment
Aberrant renal artery	Unusual origin or entry outside normal hilar pattern	Variable depending on territory supplied	Important for surgery and endovascular procedures
Complex bilateral variation	Multiple abnormalities affecting both kidneys	Increased diagnostic and procedural complexity	Detailed CTA or MRA mapping recommended
Normal single renal artery	One major artery entering each renal hilum	Standard vascular supply	Simplest anatomy for transplantation and surgery

The findings also demonstrated that renal arterial anatomy is important in endovascular procedures. During selective renal artery embolization, detailed identification of segmental and accessory arteries allows the interventional radiologist to target pathological tissue while preserving normal renal parenchyma. Similar anatomical considerations are relevant in endovascular treatment of renal vascular lesions and catheter-based renal sympathetic denervation.Overall, the reviewed evidence indicates that anatomical variation alone does not necessarily produce disease. Most individuals with accessory or multiple renal arteries remain asymptomatic. Clinical significance emerges when the variant affects regional perfusion, develops stenosis, complicates surgical access, or alters the technical feasibility of vascular reconstruction.

Therefore, renal arterial variants should be evaluated according to both their anatomical configuration and functional consequences. Detailed preoperative vascular imaging allows identification of accessory arteries, polar branches, early bifurcation, and unusual origins and provides surgeons and

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interventional specialists with the information necessary to reduce hemorrhagic, ischemic, and vascular complications.

DISCUSSION: The findings of this review demonstrate that renal artery anatomical variations have substantial clinical importance, particularly in the evaluation of hypertension and in planning renal surgical and interventional procedures. Although the classical anatomical pattern consists of a single renal artery supplying each kidney, accessory arteries, multiple renal arteries, polar vessels, and early branching occur frequently enough to be considered part of routine clinical assessment rather than rare anatomical abnormalities.Accessory and multiple renal arteries represent the most common variations. Their clinical importance is largely explained by the segmental pattern of renal blood supply. Renal segmental arteries behave functionally as end arteries, with limited effective collateral circulation. Consequently, obstruction or accidental ligation of an accessory or polar artery may result in ischemia of the renal segment supplied by that vessel. This anatomical principle is particularly important during nephrectomy, renal transplantation, and other procedures requiring vascular control.

The possible association between accessory renal arteries and hypertension remains an important area of investigation. The presence of an accessory renal artery itself does not necessarily produce hypertension, because a large proportion of individuals with such vessels remain clinically asymptomatic. However, specific anatomical conditions, including reduced vessel diameter, stenosis, excessive vessel length, or an unfavorable course, may result in regional renal hypoperfusion. Reduced renal perfusion can activate the renin–angiotensin–aldosterone system, leading to increased renin secretion, vasoconstriction, sodium retention, and elevation of systemic blood pressure.Recent clinical evidence suggesting a higher prevalence of renal vascular variations among patients with resistant hypertension supports the possibility that renal arterial anatomy may contribute to difficult-to-control blood pressure in selected individuals [5]. Nevertheless, an anatomical variant should not automatically be considered the cause of hypertension. Demonstration of a functional relationship between vascular anatomy and renal hypoperfusion is necessary before classifying the condition as renovascular hypertension.

This distinction has important diagnostic implications. If a patient has resistant hypertension and conventional imaging demonstrates no significant stenosis of the main renal arteries, accessory vessels should also be carefully evaluated. A hemodynamically significant lesion affecting an accessory renal artery may otherwise remain undetected. CTA, MRA, Doppler ultrasonography, and, in selected cases, catheter angiography can provide complementary information regarding vessel anatomy and renal perfusion.Computed tomography angiography remains particularly valuable because it provides high-resolution visualization of renal artery number, origin, course, diameter, branching, and relationship with adjacent structures. Three-dimensional reconstruction allows accessory and polar vessels to be identified before surgical intervention. This information can significantly reduce the risk of unexpected vascular injury and intraoperative hemorrhage.

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The development of non-contrast MRA techniques provides an additional diagnostic option. Recent evidence indicates that QISS-MRA can detect most clinically important renal arterial variations with high sensitivity compared with CTA [6]. Such imaging may be particularly useful in patients in whom iodinated contrast administration or ionizing radiation should be minimized. However, CTA remains highly practical and widely used for detailed preoperative vascular mapping.Renal artery variations have particularly important consequences in kidney transplantation. A graft supplied by a single renal artery generally permits technically simpler arterial anastomosis. Multiple arteries may require separate anastomoses or vascular reconstruction, increasing operative complexity and potentially prolonging warm ischemia time. However, current evidence demonstrates that kidneys with multiple arteries can be successfully transplanted with acceptable long-term outcomes [7].

The slightly increased complication rates associated with multiple renal arteries should therefore not be interpreted as a contraindication to transplantation. Instead, they emphasize the importance of accurate preoperative imaging, appropriate donor selection, and careful vascular reconstruction. Given the continuing shortage of donor kidneys, excluding otherwise suitable grafts solely because of multiple arterial supply would unnecessarily reduce the donor pool.Polar arteries require additional attention during transplantation. Inferior polar arteries may contribute to both renal parenchymal and ureteral blood supply. Their accidental ligation can potentially result in lower-pole infarction or compromise ureteral perfusion. This may increase the risk of ureteral ischemia, necrosis, urinary leakage, or stricture. Therefore, the decision to sacrifice a small accessory artery should consider the anatomical territory it supplies rather than vessel diameter alone.

The same anatomical principles apply to partial nephrectomy. Nephron-sparing surgery aims to remove a renal lesion while preserving maximum functional renal parenchyma. Detailed knowledge of segmental arterial anatomy enables selective clamping of tumor-feeding vessels while maintaining perfusion to uninvolved renal tissue. This may reduce the amount of kidney exposed to ischemia and contribute to better postoperative renal function.Conversely, failure to identify an accessory or early branching artery before surgery may result in incomplete vascular control. Continued arterial inflow through an unidentified branch may cause unexpected bleeding and increase operative difficulty. This emphasizes the practical importance of detailed vascular imaging before both partial and radical nephrectomy.

Early branching also deserves particular surgical consideration. Although it may not cause a physiological abnormality, early division of the renal artery reduces the length of the main arterial trunk available for clamping or transplantation anastomosis. Thus, a kidney with a single but very early branching renal artery may present surgical difficulties similar to those associated with multiple separate arteries.Renal arterial anatomy is also important in interventional radiology. Selective embolization is used in the management of renal tumors, vascular malformations, trauma, and active renal hemorrhage. Precise identification of the arterial branch supplying the pathological region

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enables targeted treatment while minimizing unnecessary ischemia of healthy renal parenchyma. Accessory vessels may need to be catheterized separately to achieve complete treatment.

Renal denervation provides another example of the clinical significance of renal artery variants. Sympathetic nerve fibers surrounding the renal arteries contribute to blood pressure regulation, and catheter-based renal denervation has been developed for selected hypertensive patients. If accessory arteries are not recognized or cannot be effectively treated, residual sympathetic innervation may theoretically reduce procedural effectiveness. Therefore, renal arterial anatomy may influence both patient selection and technical strategy for this procedure.The embryological origin of these variations also has practical relevance. Accessory arteries represent persistent embryonic vessels that normally regress during renal ascent. Because persistence can occur at different developmental levels, renal arteries may arise from different portions of the aorta or, less commonly, from neighboring arteries. This developmental variability explains why preoperative assumptions based only on textbook anatomy can be unsafe.

Another important consideration is terminology. The term “accessory artery” may imply that the vessel is functionally unnecessary. In reality, many so-called accessory arteries are essential end arteries supplying a distinct renal segment. From a surgical perspective, the concepts of “additional” or “multiple” renal arteries may therefore more accurately reflect their functional significance.The available evidence also demonstrates considerable variation in the reported prevalence of renal arterial patterns. Differences may be related to ethnicity, population characteristics, imaging modality, definitions of accessory arteries, and study design. CTA-based studies may identify small vessels that are difficult to demonstrate in conventional cadaveric dissection, whereas anatomical studies can provide detailed information about vessel relationships that may not always be evident on imaging.

This study has several limitations. Much of the available evidence regarding the relationship between accessory renal arteries and hypertension is observational. Consequently, association does not necessarily establish causation. Hypertension is a multifactorial disorder, and patients with renal artery variations may also have obesity, diabetes, atherosclerosis, genetic predisposition, or other factors contributing to elevated blood pressure. Furthermore, definitions of accessory arteries, early branching, and clinically significant stenosis are not completely standardized between studies.Despite these limitations, the clinical significance of renal arterial anatomy is well established in surgical and interventional practice. The evidence consistently indicates that preoperative recognition of accessory arteries, polar vessels, early branching, and unusual origins can help reduce vascular injury, hemorrhage, segmental ischemia, and technical complications.

Overall, renal artery variations should be evaluated individually according to their anatomical and functional significance. In hypertension, the key question is whether a particular vessel contributes to regional hypoperfusion and activation of the renin–angiotensin–aldosterone system. In surgical practice, the major considerations are preservation of viable renal tissue, adequate vascular control, maintenance of ureteral perfusion, and technically successful reconstruction.Future research should

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focus on defining which renal arterial variants have genuine hemodynamic significance in hypertension, improving non-invasive assessment of segmental renal perfusion, and optimizing surgical reconstruction techniques for kidneys with complex vascular anatomy. Integration of high-resolution vascular imaging with functional renal assessment may allow more individualized management of both hypertensive and surgical patients.

CONCLUSION:Renal artery anatomical variations are common and have important clinical implications in both hypertension and surgical practice. Accessory renal arteries, multiple renal arteries, polar vessels, and early branching patterns can significantly alter renal perfusion and influence the technical complexity of diagnostic, surgical, and interventional procedures.Although the presence of an accessory renal artery does not automatically cause hypertension, selected variants may contribute to regional renal hypoperfusion and activation of the renin–angiotensin–aldosterone system, particularly when the vessel is narrow, stenotic, or hemodynamically unfavorable. Therefore, renal vascular anatomy should be considered in patients with resistant or unexplained hypertension, especially when standard evaluation of the main renal arteries does not reveal significant abnormalities. In surgical practice, detailed knowledge of renal artery anatomy is essential for kidney transplantation, donor nephrectomy, partial nephrectomy, and vascular reconstruction. Multiple or polar arteries may require additional anastomoses or reconstructive techniques, while unrecognized vessels can increase the risk of hemorrhage, segmental renal ischemia, ureteral complications, and prolonged operative time.Computed tomography angiography and magnetic resonance angiography are valuable tools for preoperative vascular mapping and allow accurate identification of vessel number, origin, branching pattern, and renal entry site. Recognition of these anatomical features improves surgical planning and reduces the risk of unexpected intraoperative complications.In conclusion, renal artery variations should be evaluated according to both their anatomical configuration and functional significance. Integration of detailed vascular imaging with clinical assessment is essential for accurate diagnosis of selected forms of renovascular hypertension and for safe planning of renal surgical and endovascular procedures. A comprehensive understanding of renal arterial anatomy can therefore improve diagnostic accuracy, reduce procedural complications, and contribute to better clinical outcomes.

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