ANATOMICAL VARIATIONS OF RENAL ARTERIES WITH ALTERED HILAR PATTERN: A CADAVERIC STUDY

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Abstract : Renal artery variations are common anatomical deviations with significant clinical relevance in surgical, radiological, and interventional procedures. Normally, each kidney is supplied by a single renal artery arising from the abdominal aorta; however, variations such as accessory renal arteries, early branching, polar arteries, segmental artery and aberrant origins are commonly observed along with altered VAP pattern. These arise due to complex embryological development, where persistence of transient arteries leads to multiple vessels. Such variations are important in renal transplantation, partial nephrectomy, and angioplasty. Accessory arteries, particularly to the lower pole, may compress the ureter and cause hydronephrosis, while early branching complicates vascular control. CT angiography is essential for preoperative assessment. In this study, multiple accessory arteries and altered vascular patterns were observed bilaterally.

Index Terms - Renal artery, accessory renal artery, early division, hilar pattern, cadaveric study, renal vascular variation.

INTRODUCTION

The renal arteries are paired lateral branches of the abdominal aorta, arising at the level of L1–L2. Each renal artery courses laterally toward the renal hilum, supplying the kidneys, suprarenal glands, and upper ureter. Typically, each kidney receives a single renal artery and the structures typically follow the VAP pattern, arranged from anterior to posterior as Vein–Artery–Pelvis. Based on previous studies, a single renal artery is present in approximately 75% of cases (range 70–85%), more commonly on the right side. Anatomical variations are frequent. Two renal arteries are found in about 20% of cases (14–23%), while three renal arteries occur in around 3.5% of cases (1–4%). Four renal arteries are rare, seen in less than 1% of individuals. These additional vessels may arise directly from the abdominal aorta and may enter the kidney at the hilum or at the superior or inferior poles.

MATERIALS AND METHODS

The present study was conducted during routine undergraduate dissection classes in the Department of Rachana Sharir, Sri Dharmasthala Manjunatheshwara College of Ayurveda and Hospital, Hassan, Karnataka, India. The abdominal cavity of a formalin-fixed 75-year-old male cadaver was carefully dissected according to standard anatomical dissection procedures.

The abdominal aorta, renal arteries, renal veins, and hilar structures of both kidneys were exposed and examined in detail. The origin, course, branching pattern, and hilar arrangement of the renal vessels were observed and documented. Photographic documentation of the variations was performed for academic and research purposes. The observed findings were compared with standard anatomical descriptions and previously published literature.

ANATOMICAL VARIATIONS OF RENAL ARTERY

Accessory Renal Arteries: Extra arteries supplying the kidney; most common variation.
Polar Arteries: Accessory arteries entering directly at the upper or lower pole instead of the hilum.
Early Branching: Renal artery divides into segmental branches before entering the hilum.
Aberrant Arteries: Any renal artery that has an unusual origin or course.
Multiple Renal Arteries: More than one artery on either side, often arising

EMBRYOLOGICAL ORIGIN

When the kidney develops, it starts low in the pelvis. As the embryo grows, the kidneys slowly move upward to reach their final position in the lumbar region. During this upward movement, the kidneys need a blood supply at every level. So, the aorta gives new arteries at each step of the ascent, and the old arteries below should disappear.If all lower arteries disappear normally, the kidney ends up with one renal artery. If some of the lower arteries do not disappear, they remain as accessory renal arteries, multiple renal arteries or polar arteries. These persistent arteries are normal variations but are important surgically because they are true end arteries and supply specific segments.

Case Report :

During routine gross anatomy dissection of abdominal region in a 75-year-old male cadaver at Department of Rachana Sharir, Sri Dharmasthala Manjunatheshwara College of Ayurveda and Hospital, Hassan, Karnataka, India. It was observed that, the **left renal artery** displayed a clear pattern of early division rather than true accessory or aberrant arteries. The vessel bifurcated approximately 1 cm from its origin into three early-division branches, two coursing anteriorly **(In Fig 01)** and one posteriorly to the hilum **(In Fig 04).** Additionally, a segmental artery arose from the second anterior branch and entered the renal hilum **(as shown in Fig 01)** . Importantly, none of these branches fulfilled the criteria for hilar or polar (aberrant) arteries, further supporting their classification as early division arteries. The altered hilar arrangement, with the artery positioned anteriorly followed by the vein and pelvis, underscores the anatomical variability encountered in this case.

On the right side, two renal arteries originated directly from the abdominal aorta, both entering the renal hilum **(Fig 02 & Fig 04).** These vessels represent early division arteries, as they arise separately but supply the kidney through the hilum without demonstrating the course typical of aberrant/polar arteries.

Overall, the findings reinforce the complexity of renal vascular anatomy and highlight the predominance of early division patterns in both kidneys in this case. Accurate preoperative identification of such variations is essential to minimise vascular complications and ensure optimal surgical & interventional outcomes.

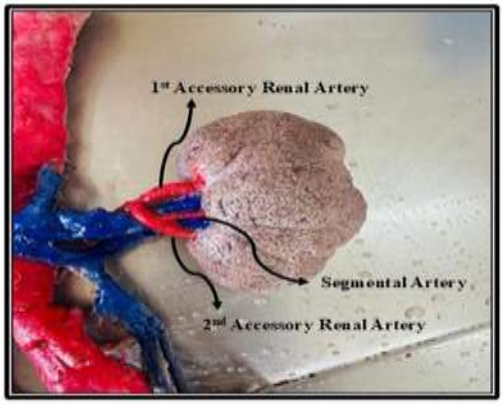

Figure 1. Anterior view of left renal branches

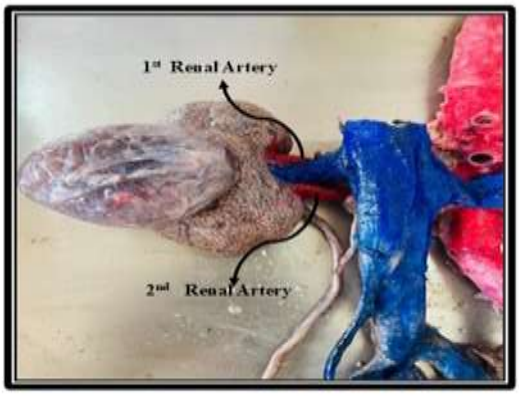

Figure 2. Anterior view of right renal branches

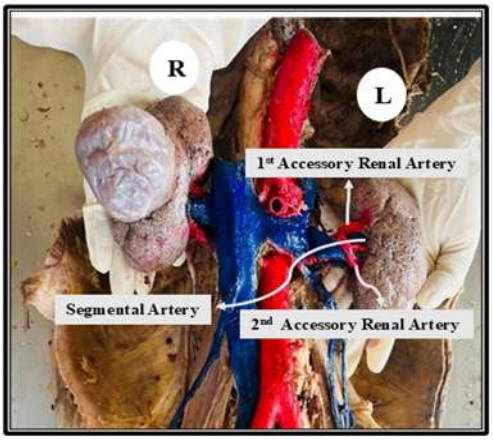

Figure 3. Anterior view of both renal branches

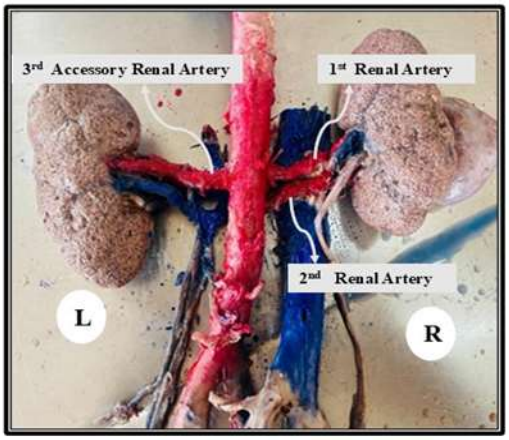

Figure 4. Posterior view of both renal branches

CLINICAL ANATOMY OF RENAL ARTERY VARIATION

The presence of early division of the renal arteries has important clinical and surgical implications. Since the renal arteries divide close to their origin, the segmental branches become functionally end arteries, meaning there is minimal collateral circulation. Any injury or ligation of these branches can lead to segmental ischemia or infarction of the kidney.

On the left side, the early trifurcation and altered hilar arrangement (artery lying anterior to the vein and pelvis) increase the risk during renal surgeries, nephrectomy, and kidney transplantation. Surgeons must be cautious, as unexpected anterior positioning of the artery may lead to accidental vascular injury or bleeding. It can also complicate hilar dissection and vascular clamping.

On the right side, the presence of two renal arteries entering the hilum (early division pattern) is clinically significant during renal transplantation and vascular procedures. Multiple arteries require separate anastomoses, increasing surgical complexity and operative time. If not properly identified, one of the branches may be missed, leading to partial renal ischemia.

Radiologically, these variations are important in CT angiography and renal Doppler studies, where early branching or multiple arteries may be misinterpreted if not carefully evaluated. Proper identification helps in preoperative planning and avoids intraoperative surprises.

COMPARISON TABLE: NORMAL VS OBSERVED KIDNEYS

Feature	Normal Kidney	Left Kidney	Right Kidney
Number of Renal Arteries	Single	Single	Two
Origin	Abdominal aorta	Abdominal aorta	Both from abdominal aorta (separate origins)
Branching Pattern	Division at hilum	Early division (~1 cm before hilum)	Two trunks (early division pattern)
Branches	Anterior & posterior	2 anterior + 1 posterior	Two main arteries
Segmental Artery	Near hilum	From second anterior branch	Not noted
Entry into Kidney	Through hilum	All branches through hilum	Both arteries through hilum
Hilar Arrangement	Vein → Artery → Pelvis	Artery → Vein → Pelvis (altered)	Likely normal
Key Variation	—	Early division + altered hilum	Double origin with hilar entry

DISCUSSION

Typically, single renal arteries branch off from both sides of the aorta and then bifurcate, near the renal hilum, into the anterior and posterior branches, which divide further into segmental arteries supplying different renal segments. It is common to see more than 1 renal artery supplying a single kidney, and previous investigators described cases with renal arteries of varying numbers and courses
[18, 22, 26–29]. The frequency of multiple renal arteries is determined by the feature of population. For example, in Caucasian and African populations a high incidence of multiple renal arteries is observed (30–40%), compared to Indian population (13.5%) [22, 27]. The frequency of presence of multiple renal arteries varies widely with ethnicity. According to Gulas et al. [7], range of the frequency of multiple renal arteries depending on ethnicity is between 4% (Malaysians) and 61.5% (Indians). In Polish population, the variability of multiple renal arteries seems to be between 11.2% and 38.3% [7, 25]. The classification of additional renal arteries is ambiguous, and different investigators use different terms to describe additional renal arteries, which hinders research on the subject. For example, Merklin and Michels [14] distinguish “supernumerary” arteries, whereas Graves [6] describes each additional

renal artery arising from the abdominal aorta as "accessory" and those arteries not arising from the aorta as "aberrant". Herein, we used the classification of additional renal arteries put forward by Satyapal et al. [23] and Özkan et al. [18]. In this classification, additional renal arteries fall into two categories: (1) early division arteries, i.e., those branching off from the main renal arteries into segmental branches more proximally than the renal hilum; and (2) extra renal arteries, which are further classified as hilar (accessory) arteries and polar (aberrant) arteries. Hilar arteries, along with the main renal artery, enter the kidney through the renal hilum, whereas the aberrant arteries run directly towards the renal capsule and do not enter the renal hilum. Based on these criteria, the LRA4 artery described herein can be classified as an aberrant artery. Kidneys supplied by more than one artery can have other anatomical variations, such as more than one vein or ureter [24]. We, however, did not find such anatomical variants in the presented case. The anatomical variations of renal arteries are much more common than the variations of renal veins [11]. According to Bordei et al. [2], the former occur 8 times as often as the latter. Rossi etal. [21] put forward that the common occurrence of vascular changes in the kidneys may be due to the disturbances of kidney migration early in the development of blood vessels, which may lead to the formation of additional renal arteries. Moreover, Satyapal et al. [23] propose that an abnormal spatial arrangement of the kidney promotes the development of abnormal blood vessels. Our description of four renal arteries supplying one kidney is very rare among the existing reports on the variations of renal arterial supply; it is not, however, the only such description [5, 19, 20, 25,29]. Previous investigators reported many interesting variants of the renal arterial supply. Kinnunenet al. [12] described one of the most interesting cases, in which ten arteries supplied one kidney. Miclaus and Matusz [15] described a 58-year-old man with 4 renal arteries supplying each kidney. Rossi et al. [21] described a 23-year-old male living donor candidate with 4 arteries supplying the left kidney and 3 arteries supplying the right kidney. Koplay et al. [13] presented a case of a 36-year-old patient with 7 renal arteries: 3 arteries on the right and 2 arteries on the left branched off from the abdominal aorta; 1 artery on the left branched off from the lower mesenteric artery; and 1 artery on the right, from the common iliac artery. Orlando etal. [17] described a kidney transplant recipient with 6 arteries — the first instance of successful transplantation of a kidney with more than 4 arteries [1]. Mishra et al. [16] found 5 renal arteries in an 18-year-old woman undergoing CT (3 right and 2 left arteries). In a post-mortem examination of a 61-year-old man, Jeon et al. [10] observed 3 right and 2 left renal arteries with asymmetric origin. Other studies support these observations [5]. Other authors [19, 20], however, indicate that renal arteries show greater variability on the left side compared with the right side. Saldarriaga et al. [22] and Satyapal et al. [23] found additional renal arteries more often on the left than on the right side. In our case, the additional renal vessels occurred on the left side as well. In the study by Jeon et al. [10], the distance from the origin of additional renal arteries to the aortic bifurcation ranged between 30 and 118 mm, and the external diameter of these arteries at their origin ranged from 3 to 7 mm. In the study by Mishra et al. [16], this diameter ranged between 2.5 and 4.3 mm. Additional inferior aberrant renal arteries are rare. Vilhova et al. [30] found that superior aberrant renal arteries occurred more often than did inferior aberrant renal arteries (22% vs. 4.4%), and Budhiraja et al. [4] reported similar figures. Other studies, however, reported a more frequent occurrence of inferior aberrant renal arteries compared with that of superior aberrant renal arteries [9, 31]. Aberrant renal arteries usually have smaller diameters than do the main renal arteries entering the kidney through the renal hilum [26]. In some people, aberrant renal arteries may cause ureteral obstruction leading to hydronephrosis, which is an important clinical problem [26].

These findings highlight the clinical importance of recognizing renal artery variations for surgical planning, renal transplantation, radiological interpretation, and preventing inadvertent vascular injury.

CONCLUSION

The present cadaveric study reveals notable bilateral variations in renal arterial anatomy predominantly in the form of early division patterns. On the left side, the renal artery exhibited trifurcation approximately 1 cm from its origin, giving rise to two anterior and one posterior branches. A segmental artery arising from the second anterior branch entered the hilum. The altered hilar arrangement, with the artery positioned anterior to the vein and renal pelvis, further highlights the variability in hilar anatomy.

On the right side, two renal arteries originated separately from the abdominal aorta and entered the renal hilum. These vessels represent an early division pattern rather than true accessory arteries, as they follow a normal hilar course and do not supply the poles directly. Importantly, the hilar arrangement on this side remains normal. This variation highlights that multiple renal arteries can exist without being aberrant, emphasizing the need for careful anatomical identification during clinical and surgical procedures.

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