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Original Article

Variations of renal arteries on 64 slice Multidetector Computed Tomography

Anu Dogra[a], R.S. Chauhan[a], Sanjiv Sharma[b], Anju Partap[a], Yogesh Diwan[a,*], Kunal Chawla[a], Kavita Negi[a], Susheela Rana[a], Deepa Diwan[a]

[a] Department of Anatomy, Indira Gandhi Medical College, Pin code: 171001, Shimla, Himachal Pradesh, India
[b] Department of Radio-Diagnosis, Indira Gandhi Medical College, Shimla, India

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ABSTRACT

Introduction: The incidence of accessory renal arteries is very high. Multidetector Computed Tomography (MDCT) is a minimally invasive alternative to conventional angiography in preoperative evaluation. The aim of this study was to document the incidence of accessory renal arteries and the level of origin of main renal arteries from abdominal aorta.
Methods: The study was conducted on one hundred patients in whom aortofemoropopliteal or aortic CT angiography was done for various indications at a tertiary care center in North India. CT angiography was performed on 64 slice MDCT scanner. The reconstructed images were analyzed using vessel analysis software.
Results: Accessory renal arteries were present in 36% cases with unilateral anomaly in 30% cases and bilateral in 6% cases. The dominant side of renal artery variations was the right side. All the accessory arteries took origin from the aorta and 52.8% of these supplied the inferior pole of the kidney. In 99% cases the origin of main renal artery was between upper border of L_1 vertebra and lower border of L_2 vertebra. The most common site of origin was at the level of intervertebral disc between L_1 and L_2.
Discussion: The incidence of multiple renal arteries is much higher than predicted by various studies. Comprehensive anatomic depiction of the renal arterial pattern aids in determining the technical feasibility of surgical and endourological interventions. It helps to avoid postoperative complications.

1. Introduction

Anatomic variations in the renal vasculature are common in general population. The paired renal arteries are the lateral branches of abdominal aorta at the level of superior margin of second lumbar vertebral body, slightly inferior to the origin of superior mesenteric artery. Near the renal hilum, each artery divides into an anterior and posterior division and then these divide into segmental arteries. In addition to supplying the renal parenchyma, the renal artery also perfuse the renal pelvis, the fatty capsule, upper part of the ureter and the adrenal gland. The first detailed account of the primary pattern of renal vascular segmentation was given by Graves in 1954.[1] Five arterial segments have been identified. These are apical (superior/upper pole), upper segment, middle segment, inferior segment (inferior/lower pole) and posterior segment. They are supplied by virtual end arteries, in contrast to intrarenal veins which anastomose freely.[2]

The role of in vivo study of anatomic variations of renal vasculature has expanded due to its significant clinical implications. The accessory renal arteries (ARAs) are more commonly associated with hypertension, renal artery stenosis and vascular thrombosis. In renal transplantation, the kidneys with renal arterial variations are more prone to higher failure rate, post-operative complications and poor prognosis than the kidneys with single renal artery.[3]

A comprehensive knowledge of variations is essential for radiodiagnostic procedures like renal angiography and uroradiological interventions for vascular reconstruction in renal artery stenosis, repair of abdominal a o r t i c aneurysm, exploration for direct renal trauma, arteriovenous anastomosis, renal thrombosis etc.[4,5]

Currently laparoscopic partial nephrectomy is being done for patients with renal tumors. The variations in extrarenal vascular anatomy make it challenging to achieve selective vascular control

* Corresponding author. Tel.: +91 9418477132.
E-mail address: drydiwan@gmail.com (Y. Diwan).

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in a particular renal segment. With extensive magnification, experience and excellent illumination of the operative field, accessory renal arteries can be identified with ease and nephron sparing excision has become feasible. There is a constant need for reviewing this anatomy due to the advent of minimally invasive laparoscopic partial nephrectomy with very limited field of vision.[6] Pre surgical evaluation of renal vascular anatomy prior to laparoscopic nephrectomy and renal transplantation helps to determine the number, location and branching pattern of renal arteries. If the branching of right renal artery occurs behind or near the lateral edge of inferior vena cava, these are treated as multiple renal arteries and interfere with the dissection of donor kidney.[7] There is a high incidence of urinary tract obstruction due to the arteries running anterior or posterior to uretropelvic junction.[8]

Most of the previous studies to delineate renal vascular anatomy were done on cadavers by dissection. Earliest studies on renal blood vessels were done by Greeks by inserting flexible sticks in them. Gale injected air, Bellini and Malpighi used ink, Robert Boyle employed fluid mass of POP and gelatin, and Ruych filled the vessels with molten wax and Schiefferdecker used corrosion method.[9] Graves[1] in 1954 made angiograms by injecting solution of diodone. Later Smith et al.[7] proved that computed tomography is a minimally invasive alternative to conventional angiography in living related donors. Color Doppler ultrasonography, computed tomography angiography, magnetic resonance angiography and renal arteriography have been used for in vivo studies. During the past decade Multidetector Computed Tomography (MDCT) has become a standard non invasive key imaging investigation for assessment of renal vasculature particularly for detection of additional renal arteries, their origin and course.[10]

Therefore, to elucidate the importance of anatomic variations in renal vasculature extending geographical regions and associated clinical implications, a study was carried out in North Indian population on 64-slice MDCT and available literature has been reviewed to bring out the renal artery variations.

2. Materials and method

The study was conducted on one hundred adult patients on whom aortofemoropopliteal or aortic CT angiography was done for various indications like aortic aneurysm, aortic stenosis, peripheral vascular disease, mesenteric ischemia etc., at a tertiary care center in North India, after approval from the hospital's ethics committee. Only those cases in which the images were free from artifacts i.e. arterial phase was clearly visualized and an adequate and comprehensive evaluation of renal arteries was possible, were analyzed.

Nonionic and water soluble radiographic contrast medium (omnipaque) was injected intravenously (1.5 ml/kg) at the rate of 4–5 ml/s with automatic pressure injector. CT angiography was performed on GE light speed VCT Xte 64 slice MDCT scanner. The scans were taken by tube current automodulation (100–550 mAs) with ASIR, tube voltage 120 kVp, gantry rotation time 0.6 s, detector collimation 40 mm, slice thickness 0.625 mm, helical thickness 5.0 mm, threshold 200 HU, pitch 0.984:1, gantry tilt 0 and diagnostic delay 8.0 s. After completion of CT contiguous 5 mm slices were reconstructed and transferred to real time interactive 3D workstation Advantage Window version 4.5 GE healthcare, for further analysis using specialized vessel analysis software.

The level of origin of renal arteries supplying each kidney was evaluated by viewing the images in axial and labeled coronal or sagittal plane simultaneously. The number of renal arteries was evaluated on 2D axial and maximum intensity projection (MIP) images. Renal artery variations were divided into two groups: I. *Early division/prehilar branching* – It is the division of renal arteries into segmental branches at more proximal level than hilum. II. *Accessory renal arteries/supernumerary arteries* – They are present in addition to the main renal artery. Most commonly they originate from abdominal aorta. When the origin is lower, it may arise from iliac arteries or aortic bifurcation. Rarely, they can arise from the celiac, mesenteric, lumbar, middle colic or middle sacral artery. They were categorized according to the mode by which they terminate in the kidney as: (i) *Polar* – piercing the upper or lower pole of the kidney directly. (ii) *Hilar* – entering the kidney at the hilum.[11] The accessory arteries were visualized by generating oblique, coronal, axial and sagittal MIP and volume rendered (VR) images. The observations were tabulated and analyzed using SPSS version 21 software.

3. Results

The study was done on one hundred randomly selected patients and 200 vessels were analyzed. There were 86 male and 14 female patients in the age group of 18–80 years, attending the outpatient department or were admitted at a tertiary care center in North India.

3.1. Accessory renal arteries/Supernumerary arteries:

In our study the accessory renal arteries were observed in 36% cases (44% kidneys) and all of them originated directly from aorta. Out of these 12% were hilar arteries, they entered the hilum with the main renal artery and 11% were polar arteries which entered the renal parenchyma directly through the capsule. The superior polar arteries were seen in 12% and inferior polar arteries in 14% kidneys. Triple renal arteries i.e.: two accessory arteries in addition to one normal renal artery (Fig. 1), were seen in two cases on left side (2%). Unilateral accessory arteries were present in 30% cases (Fig. 2), and bilateral in 6% cases (Fig. 3). On the right side, single main renal artery was present in 75% and accessory renal artery in

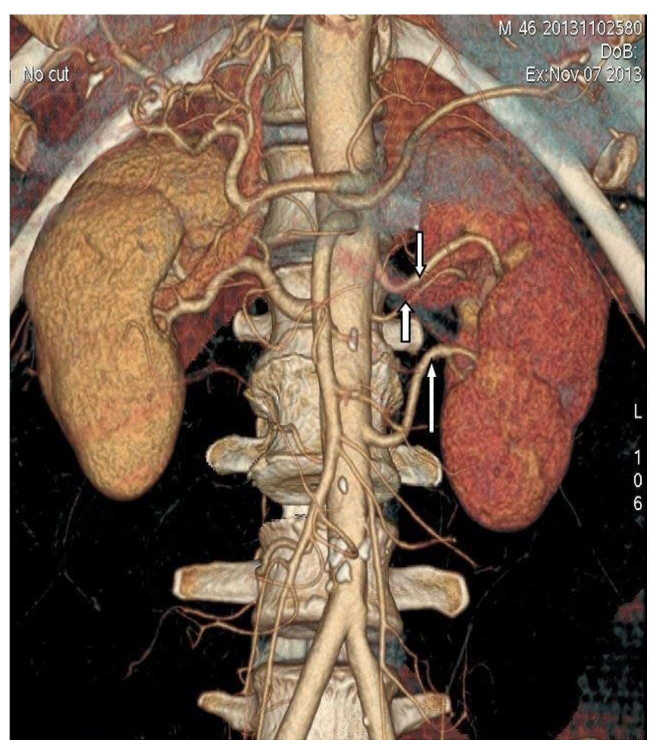

Fig. 1. Volume rendered coronal image for triple renal arteries on left side.

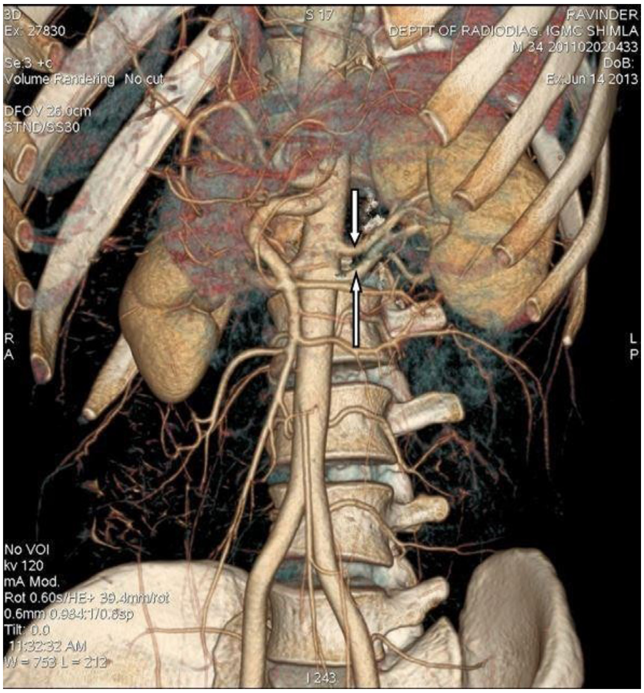

Fig. 2. VR coronal image for unilateral accessory renal artery on left side.

25% cases, whereas on the left side there was single main renal artery in 83% and accessory renal artery in 17% cases. Out of 36 cases with accessory renal arteries, inferior polar segment was supplied by them in 19 cases (52.8%), superior polar segment in 7 cases (19.44%), middle segment in 2 cases (5.56%), superior and inferior segments in 2 cases (5.56%), superior and middle segments in 4 cases (11.11%), inferior and middle segments in 1 case (2.78%) and superior, middle and inferior segments in 1 case (2.78%). The origin of accessory renal arteries was inferior to main renal artery in 20 cases (55.56%) and superior to main renal artery in 16 cases (44.45%).

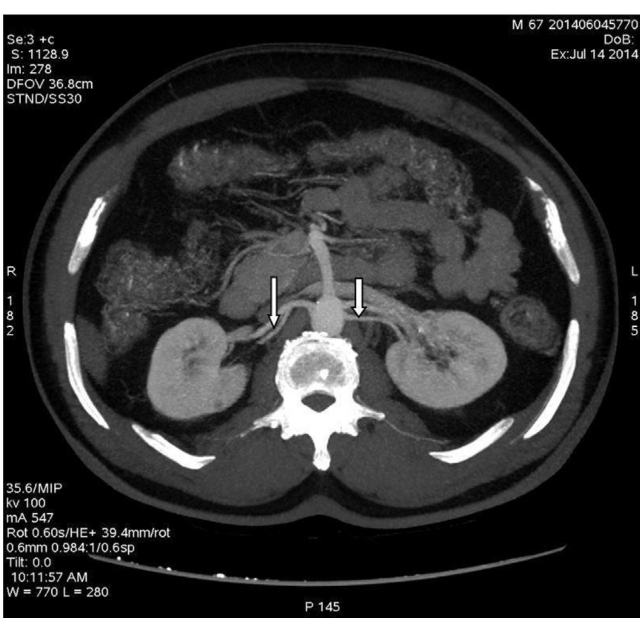

Fig. 3. Axial image for origin of bilateral accessory arteries from aorta.

3.2. Early renal artery branching

Any branch arising from the main renal artery within 2.0 cm from aorta was classified as prehilar or early branching.[12] In our study prehilar branching was observed in 27% of right main renal arteries and 23% of left main renal arteries (Fig. 4). They were unilateral in 22% and bilateral in 14% of patients. In 200 analyzed vessels, early branching was seen in 25% arteries.

3.3. Origin of renal arteries

In 99% cases the main renal artery took origin between the upper border of L_1 vertebra and lower border of L_2 vertebra. In 1% cases, it originated at the level of intervertebral disc between L_2 and L_3. The right main renal artery took origin from the upper border of L_1 vertebra in 3%, body of L_1 vertebra in 19%, lower border of L_1 vertebra in 10%, disc between L_1 and L_2 vertebra in 39%, upper border of L_2 vertebra in 17%, body of L_2 vertebra in 9% and lower border of L_2 vertebra in 3% cases. The left main renal artery took origin from upper border of L_1 vertebra in 0%, body of L_1 vertebra in 14%, intervertebral disc between L_1 and L_2 vertebrae in 36%, upper border of L_2 vertebra in 23%, body of L_2 vertebra in 10%, lower

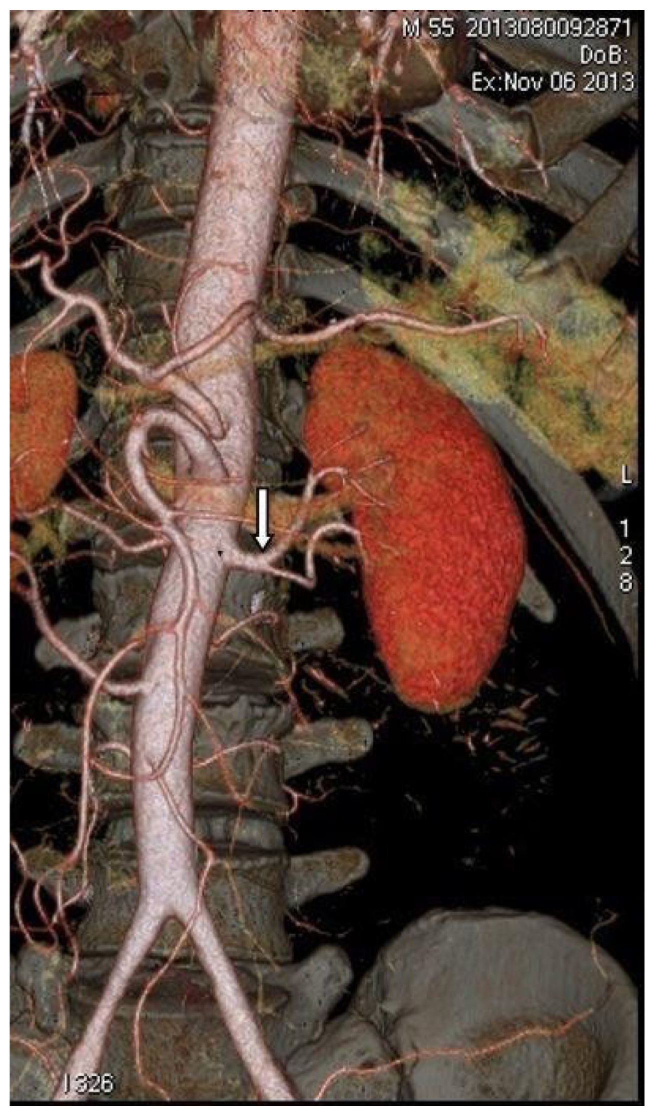

Fig. 4. VR coronal image for prehilar division of left main renal artery.

border of L_2 vertebra in 2% and disc between L_2 and L_3 vertebrae in 1% cases (Figs. 5 and 6).

4. Discussion

Great variability in the vasculature of the abdominal organs makes the preoperative evaluation of arterial anatomical conditions extremely important and helpful. The incidence of variations in renal arteries as seen in previous studies is shown in Table 1. The high incidence of variations in the older studies done by Rupert[13] and Gellaspie et al.[14] could be due to small sample size. The results of the present study are close to that of Kornafel O et al.[22] as the method of study is same 64 slice MDCT. It allows imaging of the arterial phase of contrast enhancement for visualization of vascular wall, lumen, adjacent tissues and the possibility of presenting the anatomy of the vessels from every angle using data from single acquisition only.

The embryological development of the kidney forms the basis for understanding accessory renal arteries. The kidneys are derived from intermediate mesodermal urogenital ridge which is supplied by a network of capillaries called “rete arteriosum urogenitale” arising from abdominal aorta and later named the segmental lateral splanchnic arteries.[3] As discussed by Keibel and Mall,[25] in an 18 mm fetus, the developing mesonephros, metanephros, suprarenal glands and gonads are supplied by nine pairs of lateral mesonephric arteries arising from dorsal aorta and these arteries were divided into three groups as follows- the 1st and 2nd arteries as the cranial group, the 3rd to 5th arteries as the middle group and 6th to 9th arteries as the caudal group. Initially the metanephric kidney lies in the sacral region and subsequently with the differential growth of the abdominal wall it ascends via the iliac fossa to its final destination in the lumbar region. The caudal arteries degenerate and the more proximal vessels which are closer to the final position of the kidney persist as a single renal artery on either side.[26] The failure of regression of these arteries result in accessory renal arteries.

It is important to know the vertebral level of origin of the renal arteries as it helps to identify these vessels on contrast MRI and CT images. Also it is essential to be aware of them for correct interpretation of renal angiograms performed during interventional radiological procedures for various conditions like renal vessel thrombosis, stenosis, aneurysm etc. According to Aubert and Koumare[17] the origin of renal arteries varies between the upper border of lumbar vertebra L1 and lower border of L2 in 95.8% (604/630 specimens). Out of this 14.49% on right side and 13.37% on left side took origin at the level of intervertebral disc between L1 and L2 vertebrae. Beregi et al.[27] found that 88% right and 87% left renal arteries originated between lower 1/3rd of L1 vertebra and lower border of L2. Ozkan et al.[28] found that right and left renal arteries originated between upper margin of L1 and lower margin of L2 in 98% and 97% of patients respectively. Only 23% on the right side and 22% on left side originated at the level of intervertebral disc between L1 and L2. In our study 99% renal arteries took origin between upper border of L1 and lower border of L2 and 39% on the right side and 36% on the left side originated at the level of disc between L1 and L2. Incidental case reports show higher origin of right renal artery from thoracic aorta at the level of body of T11,[29] disc between T11 and T12.[30] In our study one case with low origin was seen i.e. intervertebral disc between L2 and L3. To sum up all the studies including mine, right and left renal arteries took origin from abdominal aorta below the superior mesenteric artery between the upper margin of L1 and lower border of L2.

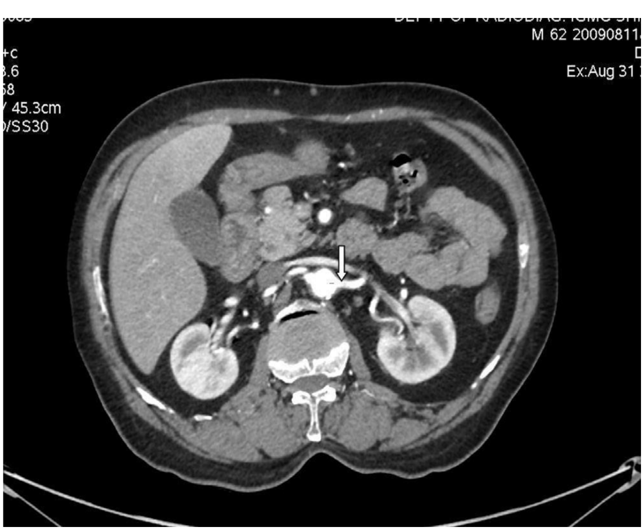

Fig. 5. Axial image for origin of left renal arteries.

Fig. 6. Sagittal image for corresponding origin of left renal arteries.

It is clinically important to determine the significantly dominant side of the renal artery variations because the left kidney is technically easier to collect laparoscopically for transplantation purposes.[19] According to my study anomalies were more frequent on right side (25%) than on the left (17%). However, studies by Dhar and Lal,[20] Pollak et al.[31] and Patil et al.[32] showed that left side shows more variations than right. Saldarriaga et al.[21] found no difference on left and right side. Other authors Cicekcibasi et al.[33] and Ayuso et al.[34] described an opposite laterality of anomalies. Tarzamni et al.[35] observed 32.47% of right sided anomalies and 17.09% of left sided anomalies. The result of the present study is in accordance with these studies.

Accessory arteries to the inferior pole are not only of academic interest but also important to help radiologists for correct interpretation of images and for surgeons because of the part that these may play in the causation of hydronephrosis by obstructing the flow of urine at pelviureteric junction.[36] An inferior polar artery running anterior to the renal pelvis or ureter can compress it and lead to hydronephrosis.[15] This subsequently causes secondary renal infection.[37] Polar arteries can be accidentally injured during surgical procedures and renal transplantation. Earlier polar arteries were considered additional arteries and were

Table 1
Incidence of variations in renal arteries.

S.no.	Studies	No. of cases	Method	Incidence (%)
1	Rupert[13]	50	Dissection	68
2	Gellaspie[14]	33	Dissection	73
3	Pick and Anson[15]	430	Dissection	32.25
4	Anson and Daseler[16]	100	Dissection	25
5	Aubert and Koumare[17]	630	Aortography	12.1
6	Coen and Raftery[18]	403	Donor population	31
7	Satyapal et al.[5]	440	Clinical, Cadaveric	27.7
8	Kawamoto et al.[19]	74	MDCT	25
9	Dhar and Lal[20]	40	Dissection	20
10	Saldarriaga et al.[21]	196	Injection corrosion technique	22.3
11	Kornafel et al.[22]	201	64 slice MDCT	32.3
12	Xiao-Feng et al.[23]	378	Dual energy CT angiography	16.3
13	Uday Kumar et al.[24]	84	Dissection	14.3
14	*Present study*	100	64 slice MDCT	36

ligated or clamped to treat hydronephrosis. This resulted in ischemia and necrosis of ureter. To overcome this Wolters et al.[38] anastomosed the inferior polar artery to inferior epigastric artery successfully. Most commonly the accessory renal arteries originate from abdominal aorta and supply the inferior pole of the kidney. Weld et al.[6] reported the incidence of inferior polar arteries as 15.1% and that of superior polar as 9.6%. Uday Kumar et al.[24] observed superior polar arteries in 13.09% and inferior polar in 5.95% cases on their study on South Indian population. In our study all the accessory arteries took origin from the lateral aspect of aorta and majority of them; 52.8% supplied the inferior pole compared to 19.44% that supplied the superior pole. The superior polar artery supplies the capsule and perinephric fat. Surgeons should be careful in dissecting the fat to avoid accidental injury to this artery. In renal transplantation polar vessels can increase the failure rate due to thrombosis of renal vessels and urinary leakage.[39]

The anatomical knowledge of accessory arteries is essential before surgical intervention for renal transplantation, renal trauma and urological operations. They have been associated with higher rate of vascular complications including arterial thrombosis and renal stenosis. In particular, polar artery can cause infarction, infection and urologic complications such as calyceal and ureteral fistulas and necrosis. This increases morbidity and graft loss.[40] Usually a single renal artery supplies each kidney. However, the renal artery variations including their number, source and course are very common, the most common being multiple renal arteries.[3]

In our study two cases with triple renal artery were present but we did not find any case with quadruple renal arteries as observed by Pollak et al.[31] Ozkan et al.[28] studied 855 angiograms and reported an incidence of three right renal arteries in 1% and four left renal arteries in 0.2% cases. Pollak et al.[31] reported triple renal arteries in 4% and quadruple in 1% cases. In our study triple renal arteries were present in 2% cases on left side (Table 2).

Prehilar or early branching pattern is a normal variant in which the main renal artery divides into segmental branches at a more proximal level than the renal hilum. Prehilar branching was reported by Patil et al.[32] in 10%, Ayuso et al.34 in 11.8%, Kornafel O et al.[22] in 12%, Saldarriaga et al.[21] in 12.95%, Kadir et al.[43] in 15% and Kawamoto et al.[19] in 18.91%. Present study observed prehilar branches in 25% of cases. It is important for renal transplantation because most surgeons require at least 2.0 cm length for successful anastomosis. These may be erroneously interpreted as accessory arteries in diagnostic imaging studies. In surgical practice the ligation of these vessels on the ground that it is an additional artery will lead to necrosis of a segment as these segmental arteries are virtually end arteries. They supply a definite segment of the kidney and do not anastomose with adjacent arteries.[1]

The presence of bilateral accessory renal arteries makes it technically difficult to procure the donor kidney for transplantation and also results in increased subsequent complications. Their incidence has been reported, ranging from 1.66% to 10% (Table 3).

Table 3
Comparison of incidence of bilateral accessory arteries.

S.no.	Authors	Bilateral accessory arteries
1	Pollak et al.[31]	10–15%
2	Dhar et al.[20]	5%
3	Ozkan et al.[28]	5%
4	Kornafel et al.[22]	10%
5	Peria et al.[44]	1.66%
6	*Present study*	6%

Table 2
Comparison of the incidence of multiple renal arteries.

S.No.	Study	Single renal artery	Double renal artery	Triple renal artery	Quadruple renal artery
1	Pollak et al.[31]	72%	23%	4%	1%
2	Patil et al.[32]	–	–	0.98%	0.98%
3	Khamangrong et al.[41]	–	17%	1%	–
4	Bordei et al.[42]	–	20%	1.1%	–
5	Ozkan et al.[28]	83%	15%	1%,	–
	Right				
	Left	86%	12%	0.7%	0.2%
6	Saldarriaga et al.[21]	62.9%	22.3%	2.6%	–
7	Budhiraja et al.[40]	82%	15.4%	2,4%	–
8	Uday Kumar et al.[24]	85.7%	14.28%	Nil	Nil
9	*Present study*	75%	25%	Nil	–
	Right				
	Left	83%	15%	02%	–

Our findings (6%) are close to those of Dhar and Lal[20] and Ozkan et al.[28]

Meredith et al.[45] studied accessory renal arteries and blood pressure-lowering effects of renal denervation on 24 patients and observed neither presence nor treatment of accessory arteries was significantly associated with the change in systolic BP.

5. Conclusion

The incidence of multiple renal arteries is very high, the most common being the inferior polar renal arteries. The normal hilar branching of the main renal artery was more frequent compared to prehilar branching. The urologists must preserve each of the multiple arteries to prevent ischemia of the vascular segment supplied by it, as these are end arteries. Left kidney is preferred for donor nephrectomy as it is technically easier to remove. According to our study the probability of having variations on the left side is low, as the dominant side of renal variations was the right side. So, the evaluation of renal vasculature in laparoscopic nephrectomy, renal transplantation and other retroperitoneal surgeries is essential for surgical planning. It is also important for the radiologists performing interventional procedures to be aware of these for correct interpretation of angiograms. MDCT angiography with vessel analysis software can provide valuable information about anatomical variations of renal vasculature.

Ethical clearance

Required approval was taken from institutional ethical committee.

Conflict of interest

The authors declare that they have no conflict of interest. There is no financial help from the organizing research committee.

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