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Anatomical Variations of Renal Artery in Patients Undergoing Computed Tomography of Abdomen: A Hospital-based Cross-sectional Study

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ABSTRACT:

Introduction: Renal vasculature is known for presenting a wide range of variations. Knowledge of different anatomical variations helps the surgeon prevent possible intraoperative complications. Computed Tomography (CT) is an excellent imaging modality providing detailed anatomy of the renal artery. This study aimed to evaluate renal arterial variations in individuals undergoing abdominal CT examination. **Methods:** This was a hospital based cross-sectional study on 400 consecutive patients who underwent abdominal CT examination in a medical college in Nepal. The number of patients with normal and any arterial variations was noted. Accessory renal artery (hilar and polar artery) and any pre-hilar branching were evaluated. **Results:** Among 400 patients, 271 (67.75%) individuals had normal renal artery supply and 129 (32.25%) had variations. Among 129 individuals (79 males and 50 females) with artery variations, 93 (72.09%) had unilateral and 36 (27.91%) had bilateral variations.The most common unilateral variation was a single polar artery in 66 (70.97%) cases, pre-hilar branching in 18 (19.35%), accessory hilar artery in 7 (7.53%) and dual polar arteries in 2 (2.15%). In those with bilateral arterial variations, the right and left kidneys showed polar artery in 25 (69%) and 30 (83%), pre-hilar branching in 6 (17%) and 2 (6%), and accessory hilar in 5 (14%) and 4 (11%) cases respectively. **Conclusion:** Renal artery variation was observed in approximately one-third of individuals. Unilateral variation was more common than bilateral and polar artery was the most common arterial variant.

Keywords: Anatomical Variations; Computed Tomography; Renal Artery

INTRODUCTION:

Each kidney is normally supplied by a single renal artery which divides into segmental arteries near the hilum. Anatomical variations in the number and origin of the renal arteries were first reported by Bartholin (1665-1738).[1] In approximately 25-30% of individuals, more than one renal artery is present.[2]

Different origin and variations of renal artery are explained by the development of the mesonephric arteries. During embryogenesis, the kidneys ascend from the pelvis to lumbar region. During their ascent, they are supplied by several mesonephric arteries. Overtime, the preceding caudal vessels usually regress and disappear, leaving only one mesonephric artery. However, failure of regression leads to anomalous renal arteries.[3] Clinically, the identification of renal vascular variants is important especially for transplant surgeons, vascular surgeons and for intervention radiologists.[4,5]

When a kidney has two or more arteries with separate aortic ostium, the vessel with the greatest diameter is considered the main renal artery and others, accessory arteries.[6] Accessory arteries are categorized as either hilar or polar. Hilar artery enters

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the kidney through the hilum while polar artery enters the kidney through the capsule outside the hilum. Polar arteries perfuse the superior or inferior renal poles.[7] Pre-hilar or early branching arise less than 1.5-2 cm from the origin of the main renal ostium in the left kidney or in retrocaval segment at the right kidney.[8]

Although Digital Subtraction Angiography (DSA), an accepted gold standard in assessing the renal vascular anatomy, is an invasive procedure and hence not used routinely.[9] Currently, Multi-detector-row Computed Tomographic (MDCT) angiography has become a key imaging modality.[6] The sensitivity of CT angiography (CTA) for the demonstration and location of the main renal arteries approaches 100%.[10] The disadvantages of CTA include reactions to iodinated contrast material, nephrotoxicity and exposure to ionizing radiation. Typically detection of vessels smaller than 2 mm is limited in CTA.[10,11]

This study aimed to determine the prevalence of renal arterial variations in patients advised for MDCT for various indications.

METHODS:

This was a hospital based cross-sectional study on 400 consecutive patients who underwent abdominal CT for various indications between November 2018 and October 2019 in the Department of Radiology, College of Medical Sciences-Teaching Hospital, Bharatpur. Patients with history of contrast reactions, impaired renal function, images with artifacts or suboptimal post-contrast arterial opacification and presence of renal pathology (e.g., large renal mass or gross hydronephrosis) that distorted or interfered with optimum evaluation of the renal vessels were excluded from the study.

Patients were advised 4-6 hours of fasting prior to CT. They were placed in supine position and advised quiet breathing. An 18-gauze peripheral line was inserted into the antecubital vein. 2 ml/kg of non-ionic iodinated contrast agent (iohexol) with a concentration of 300 mg/ml was injected using the bolus tracking technique with an automatic injector at a flow rate of 4-5 ml/sec. The scan area was taken from the diaphragm to the mid-sacrum as per routine CT abdominal protocol. A voltage of 120 kVp, current of 220 mA, slice thickness of 0.5 and pitch ratio of one was taken. Patients were advised breath-hold technique during the scan. The arterial phase scanning was done with the bolus tracking method. Scanning commenced following peak enhancement of 150 HU at the region of interest placed within the abdominal aorta at the level of the diaphragm. After scanning, images were analyzed via Vitrea® Advanced Visualisation Software. Image reconstruction and interpretation were done using multi-planar reconstruction (MPR), maximum intensity projection (MIP) and volume rendering (VR) technique.

Data were analyzed using Statistical Package for Social Sciences (SPSS) version 20. The descriptive results were presented in terms of mean, standard deviation, frequency and percentage.

Ethical clearance was obtained from the ethical review committee of the institute (Ref. No. 2018-038).

RESULTS:

A total of 400 consecutive patients (219 males and 181 females) undergoing abdominal CT examination were included in this study. The mean age (±SD) of the patients were 48.51 (+/-20.47) years (range: 3-92 years).

Normal renal arterial supply to both the kidneys was noted in 271 (67.75%) individuals (Figure 1). Remaining 129 (32.25%) individuals had variations in either kidney or both the kidneys. Among those with renal arterial variations, 79 (61%) were males and 50 (39%) were females. However no statistically significant association was found between the existence of renal arterial variations and gender (p=0.4).

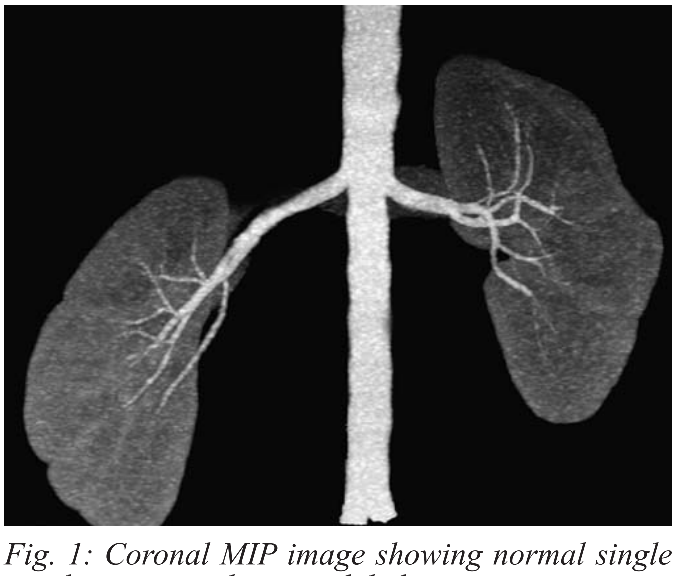

Fig. 1: Coronal MIP image showing normal single renal artery supplying each kidney.

We found unilateral renal artery anomaly (n=93) was more common than bilateral renal artery anomaly (n=36). Ninety-one (70.54%) patients had arterial variation limited to one kidney, two (1.55%) had double renal artery involving the left kidney and 36 (27.91%) had variations involving both the kidneys. In unilateral variations, the most common anomaly noted was polar artery (n=66) (Figure 2) followed by pre-hilar branching (n=18) (Figure 3). The right kidney was affected in 51 (54.84 %) and left kidney in 42 (45.16 %) individuals (Table 1).

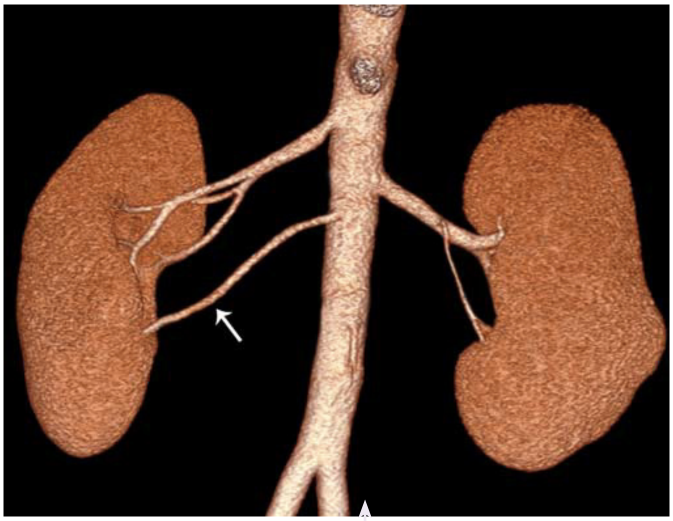

Fig. 2: Coronal volume rendering image showing a polar artery (arrow) supplying inferior pole of the right kidney.

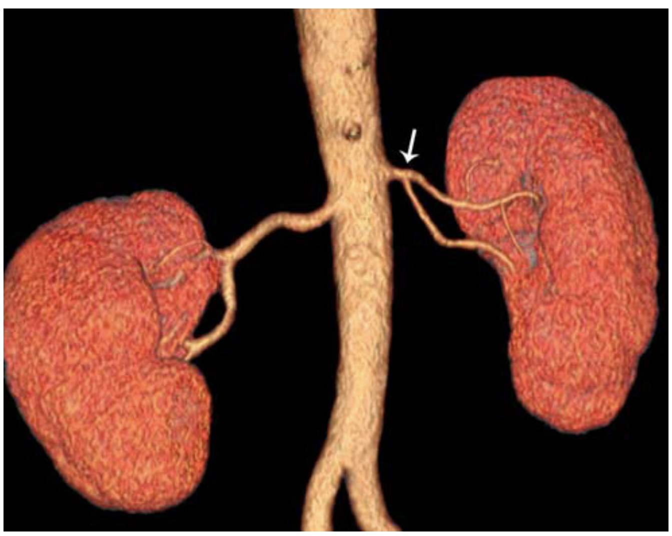

Fig. 3: Coronal volume rendering image showing pre-hilar branching of the left renal artery (arrow) near the origin from the aorta.

In 36 patients, both kidneys showed variation in the arterial supply. Table 2 shows the various frequencies and the combinations affecting each kidney. The most common combination was an inferior polar artery supplying both kidneys (n=12) followed by superior polar artery supplying both kidneys (n=6). Pre-hilar branching in both kidneys was seen in two and hilar artery in both kidneys was reported in one individual. The rest of the patients showed various combinations as shown in Table 2.

Table 1. Frequency of unilateral renal arterial variants (n=93).

Renal artery variant	Right kidney	Left kidney	Total
Superior renal polar artery	26	10	36 (38.71%)
Inferior renal polar artery	13	17	30 (32.26%)
Pre-hilar branching	8	10	18 (19.35%)
Hilar artery	4	3	7 (7.53%)
Both superior and inferior polar artery	0	2	2 (%)
Total	51 (54.84%)	42 (45.16%)	93 (100%)

Table 2. Frequency of combination of bilateral renal artery variations (n=36).

Right Kidney	Left kidney	N (%)
Inferior polar artery, and	Inferior polar artery	12 (33.3%)
	Superior polar artery	1 (2.8%)
Superior polar artery, and	Superior polar artery	6 (16.7%)
	Accessory hilar artery	3 (8.3%)
	Inferior polar artery	3 (8.3%)
Pre-hilar branching, and	Inferior polar artery	4 (11.1%)
	Pre-hilar branching	2 (5.6%)
Accessory hilar artery, and	Inferior polar artery	3 (8.3%)
	Accessory hilar artery	1 (2.8%)
	Superior polar artery	1 (2.8%)

Also among the 36 individuals with bilateral renal anomalies, the right kidney showed polar artery in 25 (inferior polar artery in 13 and superior polar artery in 12), pre-hilar branching in six, hilar in five and the left kidney showed polar artery in 30 (inferior polar artery in 22 and superior polar artery in 8), hilar artery in four and pre-hilar branching in two. Thus polar artery was the most common anomaly seen in 55 kidneys (inferior polar artery in 35 and superior polar artery in 20 kidneys), followed by accessory hilar artery in nine kidneys (Figure 4) and pre-hilar branching in eight kidneys.

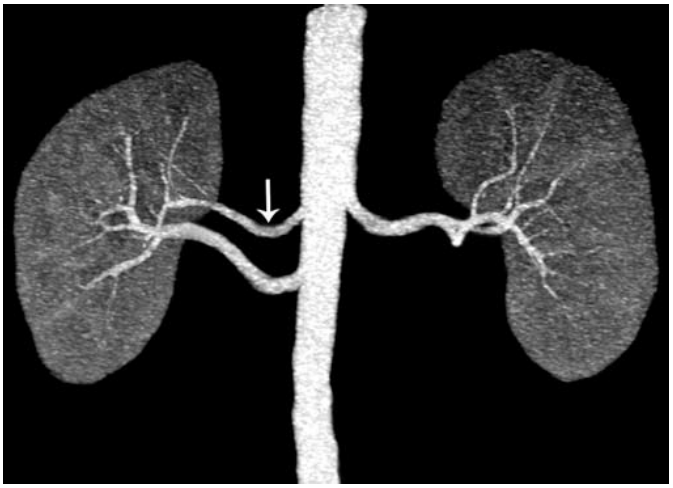

Fig.4: Coronal MIP image showing accessory hilar renal artery (arrow) supplying the right kidney.

As shown in table 3, among 400 patients studied, the most common variation was inferior polar artery seen in 65 kidneys (16.25%) followed by superior polar artery in 56 kidneys (14%), pre-hilar branching in 24 kidneys (6%), hilar artery in 16 kidneys (4%) and combined superior and inferior renal arterial supply in two kidneys (0.5%).

Table 3. Frequency of renal artery variant affecting each kidney (N=400).

Renal artery variant	Right	Left	Total
Inferior polar artery	26	39	65 (16.25%)
Superior polar artery	38	18	56 (14%)
Pre-hilar branching	14	10	24 (6%)
Hilar artery	9	7	16 (4%)
Both superior & inferior polar artery	-	2	2 (0.5%)

DISCUSSION:

Awareness of the presence of renal artery variations is important if surgical procedures are indicated in this region. MDCT being a reliable, easily applicable and non-invasive tool for visualization of abdominal organs and vascular structures [12], proves to be a supportive pre-operative investigation.

In this study, 271 (67.75%) had a normal renal arterial supply. Similar findings were reported by Reginelli A et al. (69%), Ugurel M et al. (58%) and Ozkan U et al. (76%).[13,14,15] However, Tardo et al. (87.8%) and Raman SS et al. (81%) reported higher prevalence of normal variants. This might be because the sample frame of their study consisted of kidney donors only and naturally people with grossly abnormal vasculature were not included.[16,17] On the other hand, studies by Munnusamy K et al. (49%) and Toro JCS et al. (48%) found comparatively lower prevalence.[18,19] This shows that the prevalence of normal renal artery varies widely among different population.

Our study found no statistically significant association between the existence of renal arterial variation and gender (p=0.4). Similarly, no statistically significant association was found in the studies by Toro JCS et al. (p = 0.16).[19] and Palmieri BJ et al. (p = 0.31).[20] However, in a study by Famurewa OC et al. vascular variants were present in 37 (36.3 %) females and 63 (64.3%) males and were noted to be significantly commoner in males (p<0.001).[21]

Among 129 patients with renal artery variations in this study, unilateral arterial anomaly was more common than bilateral arterial anomaly. Similarly, in a study by Toro JCS et al. 117 (77%) patients had unilateral variations and 35 (33%) had bilateral variations.[19] Sampaio and Passos found bilateral renal arterial variations in only 12 cases (4.5%).[22]

In our study, among 93 individuals with unilateral renal arterial variations, right kidney was involved in 51 (54.84 %) and left kidney in 42 (45.16 %) individuals. Similarly, Toro JCS et al. noted variation to be significantly more frequent in the right kidney than the left (58% vs 42%, p = 0.002).[19] However, Palmieri BJ et al. noted that the relationship of the presence of multiple arteries between sex and laterality was no different in right and left kidneys of males (p = 0.29) and between left and right kidneys in females (p = 0.22).[20]

Similar to our study, Toro JCS et al. noted that among those with unilateral variations, the most commonly observed was polar artery in 66 patients (55%) but the second most common was hilar artery in 39 patients (33%).[19]

The present study found a very low prevalence (0.5%) of the presence of both the superior and inferior polar arteries involving the left kidney. Similarly, prevalence of 0.3% individuals with both superior and inferior renal polar artery was noted by Kornafel O et al.[23]

In this study, 36 (9%) patients had renal artery variations affecting both the kidneys. In the literature, the prevalence of bilateral renal arterial variations ranged between 3.1% and 12%.[23,24] Also, among 36 individuals (72 kidneys), polar artery was the most common anomaly seen in 55 kidneys (inferior polar artery in 35 and superior polar artery in 20 kidneys) followed by hilar artery in 9 kidneys. Similarly, the presence of a polar artery was the most common variation found in 61% of the 35 patients with bilateral renal artery variations by Toro JCS et at.[19]

When both unilateral and bilateral variations were considered together, inferior polar artery (16.25%) was noted more frequently than superior polar artery (14%) and hilar artery (4%) in this study. In a study by Bordei P et al., the most common variation observed was also an inferior renal polar artery (29.63%) followed by superior renal polar artery (9.26%).[24] Similarly, Kornafel O et al. found inferior renal polar artery (8.7%) to be the most common variant.[23] It is important for the surgeons to know if the accessory artery is supplying the upper or lower pole because their accidental injury during surgery can lead to necrosis. Hence any disease confined to the upper or lower poles of the kidney will need special care in case of accessory vessels supplying these regions. Moreover, inferior polar renal arteries are more important clinically because they can lead to obstruction of the pelvi-ureteric junction.[25]

However, Swarna et al., noted that among patients with right renal accessory arteries on MDCT angiography, 72 (58.5%) were hilar and 51 (41.5%) were polar arteries and on the left, 94 (61.8%) were hilar and 58 (38.2%) were polar arteries. Thus hilar accessory was more common than polar artery in their study.[26] Likewise, among 24% of kidneys with accessory renal artery, Uflacker noted that 12% had two hilar arteries and 12% had one hilar and one polar artery.[27] Presence of accessory renal arteries is a relative contraindication to transplant surgery.Since these are end-arteries, these must be re-implanted and require several anastomoses with a prolonged ischemic time leading to a theoretically higher incidence of renal failure, graft rejection and reduced graft function.[28]

In our study, pre-hilar branching was seen in 24 (6%) individuals. Similarly, Reginelli A et al. and Ozkan U et al. reported pre-hilar branching in 6% and 8% patients respectively.[13,15] However, pre-hilar branching was not observed in a study by Bordei P et al.[24] Although an infrequent anomaly, it is important to detect any pre-hilar branching because most transplant surgeons require at least 2 cm length of renal artery before hilar branching in order to clamp and properly anastomose the artery in the recipient.[8]

In a study to determine the site of anomaly, Raman SS et al. noted that pre-hilar branching was more common on the left (21%) than on the right side (15%).[17] In a renal MDCT angiographic study by Clnar C and Turkavatan A, the rate of pre-hilar branching was 2.6% on the right, 3.7% on the left and 0.2% bilateral.[29] These findings were quite similar to our study where 14 (3.5%) of pre-hilar branching was on right, 10 (2.5%) on the left and 2 (0.5%) on both sides.

One limitation of this study was that images from CECT of the abdomen with optimal enhancement of the aorta and renal vessels were evaluated rather than CTA of the aorta and its branches which is potentially more suitable. Another limitation is that a larger study is needed to further explore the prevalence of renal arterial variations in our population.

CONCLUSION:

This study aimed to evaluate renal arterial variations in patients undergoing CT abdomen. Renal arterial variations were not uncommon. They were observed in approximately one-third of the patients; unilateral renal arterial variation being more common than bilateral variations. Polar arterial supply was the most common arterial variant in this study. However, larger multicentric studies are needed to verify and generalize the results of this study.

Conflict of Interest: The authors declare that no competing interests exist.

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