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Prevalence of accessory renal artery and other renal artery variants in south Indian population by CT-Angiography

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Abstract
The most frequent anatomical variations of the renal arterial system are accessory renal arteries (supernumerary renal arteries) and aberrant renal arteries, which occur in varying numbers among various ethnic and racial groups. Prior to surgery, understanding these variations is crucial because it affects the decision to use donor kidneys, the planning of partial nephrectomy, and other urological procedures. Along with the main renal artery on the same side, there is also an accessory renal artery. The aberrant artery supplies the kidney without passing through the hilum, whereas the main renal artery enters the kidney through the hilum to do so.
Aim: This tertiary care hospital-based study aims to know the prevalence of variations of the renal arterial system including accessory renal artery, their distribution pattern, and association with gender, age, and side predilection in population of Kancheepuram and West Chennai district of Tamil Nadu.
Methodology: One hundred adults (62 males, 38 females; mean age: 45 +/- 25 years) inclusive of prospective live renal donors undergoing pre-operative CT renal angiogram for operative planning and other patients undergoing CECT Abdomen for various abdomino-pelvic pathologies were selected for the study.
Research Design: It is a cross-sectional descriptive study conducted in the Department of Radiology, of a tertiary care hospital in Kancheepuram district of Tamil Nadu, India.
Results: Renal artery variants (including Accessory renal and aberrant renal arteries) are present in 23% of kidneys. The prevalence of renal artery variants in males – is 30%, and in females – 11%. On the right side the prevalence is 60% and on the left side is 26%. The prevalence of bilateral renal artery variants is 11%.

Keywords: Accessory renal artery, Supernumerary renal artery, CT Renal angiogram, aberrant renal artery, renal donor

Introduction
The superior mesenteric artery and the renal arteries are two arteries that emerge as lateral branches from the abdominal aorta at the upper lumbar level (L1-L3). Organs that make up less than one hundredth of the total body weight are supplied by the paired renal arteries using about 20% of the cardiac output. Because the abdominal aorta is situated to the left of the midline, the right renal artery has a longer course. At or very near the kidney's hilum, each renal artery divides into anterior and posterior branches. Additionally, it separates into segmental arteries to supply the individual kidney segments, which are end arteries themselves.
There are many anatomical variations in the kidney's arterial supply. A single renal artery that emerges from the lateral wall of the aorta, just above the origin of the superior mesenteric artery at the level of the intervertebral discs of the L1 and L2 [1] vertebra, supplies each kidney in the majority of cases. The number, level, location of origin, and branching pattern of the arterial supply are related to these anatomical variations [2, 3]. The most frequent and clinically significant variation is the existence of a supernumerary renal artery. The term "accessory renal arteries" refers to these extra arteries.
These accessory renal arteries originate from the aorta above or below the primary renal artery and travel with it to the renal hilum.

They may enter the superior renal polar artery and inferior renal polar artery directly, which are referred to as aberrant renal arteries.

Nowadays, the preferred surgical method for performing renal surgical interventions such as collecting donor kidneys, performing partial nephrectomy for a variety of clinical indications, and managing renal artery stenosis is laparoscopy. Due to the lower risk of surgical complications and renal artery thrombosis, surgeons prefer to operate on donor kidneys with single renal arteries. The presence of inferior polar arteries in patients is linked to a risk of pyelo-urethral damage. Aortic aneurysm endovascular repair is complicated by the presence of an accessory renal artery. Therefore, it is crucial to understand the variations in renal arterial supply before surgery in order to prevent serious surgical complications or even life-threatening situations [4, 5].

Therefore, this study is done with the objective to know the prevalence of accessory renal arteries and to know the variations in accessory renal arteries in population of Kancheepuram and West Chennai district of Tamil Nadu.

Materials and Methods

This is a tertiary care hospital-based cross-sectional study. This cross-sectional study was done in 100 patients who presented over two year period from June 2020 - July 2022. This study was approved by the Institutional ethical committee of Saveetha University. Our study population were selected from patients who were referred to Saveetha Medical College and Hospital in Kancheepuram District of Tamil Nadu, predominantly consisting of prospective renal donors in order to perform renal angiography or abdominal multiple detectors computed tomography (MDCT) to rule out other abdominopelvic pathologies, age more than 18 years and also signing the informed consent were our other inclusion criteria. Our exclusion criteria were having a prior surgery on kidneys and patient non-willingness. Apart from these exclusion criteria, most of our patients were prospective renal donors which by itself excluded/ precluded pre-existing medical illnesses by extensive screening by clinical methods and relevant laboratory investigations. Their CT images were studied for variations in renal arterial anatomy including the presence of accessory renal artery (ARA) and aberrant renal artery, number of accessory arteries, location and characteristics of these arteries. Age, Gender and side predilections of these variations and Apart from these, the branching pattern of the renal arteries, its variations All images were reviewed by expert radiologists and data regarding to both renal arteries were documented. Data were then analyzed using SPSS software. Our sample size was a convenient sampleof 100 owing to the relatively lower CT Renal angiogram referrals and reduced prevalence of live donor nephrectomies when compared to other surgeries. The data was entered into MS Excel and analyzed using SPSS 21 software. Descriptive statistics were used to present the data and the Chi-square and Fischer exact tests were used wherever applicable to see the associations.

CT Protocol

The donors and patients were subjected to CT Angiogram/ CECT/ MDCT Abdomen after ascertaining reno-protection and radiological safety as per the radiological guidelines of the institute and expert opinions (nephrologists wherever applicable). Computed Tomography evaluation was performed using Philips Ingenuity 128 Slice CT scanner. Automatic exposure control was activated, and the acquisition was done in the axial section. Reconstruction with 1 mm slice thickness and Multi-planar reformation was done as per institution radiological protocols.

Serial axial sections were acquired before and after intravenous injection of 100 ml of non-ionic contrast media in dual phase (arterial and venous). Volume rendered and MIP reformatted images were acquired in coronal and sagittal planes. No adverse reactions were noted.

Post-processing and image analysis

The radiologist independently and in random order examined each image that was obtained. Maximum intensity projections (MIP), volume-rendered images (VRI), and axial multi-planar reformatted images (MPR) were examined. Various thicknesses were used to obtain the maximum intensity projection (MIP) (5-10mm)

For analysis, the kidneys were located in both axial and volume-rendered images, and their arteries were checked for entry and exit points. On each side of the kidney, the number of renal arteries is counted. In a kidney with two or more additional arteries, each with a distinct origin, the vessel with the largest diameter is thought to be the main renal artery, and the other vessels are thought to be accessory renal arteries.

Normal renal vascular anatomy

Most people only have one renal artery that branches off of the abdominal aorta to supply each kidney [6-9]. The renal vein is located in front of the renal artery, which typically arises from the aorta at the level of L2 just below the origin of the superior mesenteric artery.

Prior to the medial aspect of the renal hilum, the renal arteries run anterior to the renal pelvis. The right renal artery frequently travels behind the inferior vena cava on a long downward course to the relatively inferior right kidney. The left renal artery, which, in contrast, emerges below the right renal artery and has a more horizontal orientation, travels rather directly upward to the left kidney, which is situated superiorly. Because of the way the kidneys are arranged, both renal arteries typically run in a direction that is slightly to the posterior.

An accessory renal artery is one that travels alongside the main artery as it moves in the direction of the kidney's hilum and enters the kidney through the hilum to supply it, whereas an aberrant artery does not enter the kidney's hilum but instead supplies the kidney.

Near the renal hilum, segmental arteries branch off of the main renal artery [6-9]. The posterior branch, which emerges just before the renal hilum and travels posterior to the renal pelvis to supply a significant portion of the blood flow to the posterior portion of the kidney, is the first division. The apical, upper, middle, and lower anterior segmental arteries are the four anterior branches that the main renal artery divides into at the renal hilum.

The upper and lower renal poles' anterior and posterior surfaces are provided by the apical and lower anterior segmental arteries, respectively, while the remaining anterior surface is supplied by the upper and middle segmental arteries. After passing through the renal sinus, the segmental arteries split into the lobar arteries. The interlobar, arcuate, and interlobular arteries are additional

branches. A clean incision can be made toward the renal pelvis at this location during surgery, so it is crucial for the surgeon to depict the relatively avascular plane between the anterior and posterior arterial divisions of the kidney (6). A third of the distance between the posterior and anterior kidney surfaces is where the site is typically found posteriorly.
The posterior renal segment and the polar renal segments share a common avascular plane.

Results and Observations

In the present study, the mean age is 45.7 ± 25. The majority of the study population were male 62 and 38 were female.
In the present study, 23 had accessory renal artery and 77 had single renal artery supplying the kidneys. (Fig 1).

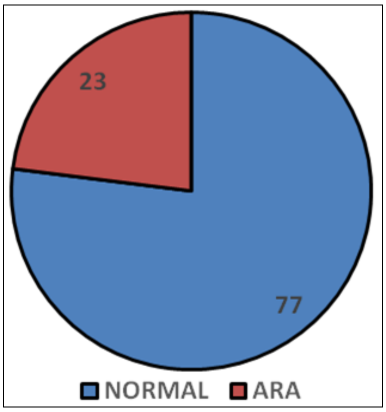

Fig 1: Frequency distribution of RA & ARA

Table 1: Frequency distribution of RA & ARA based on gender

Renal artery	Male	Female	Total	P Value
Normal	43	34	77	0.02
Ara	19	4	23	
Total	62	38	100	

Table 2: Frequency distribution based on laterality of ARA

ARA	Left	Right	Total
Unilateral	6	13	19
Bilateral	4		4
Total	23		

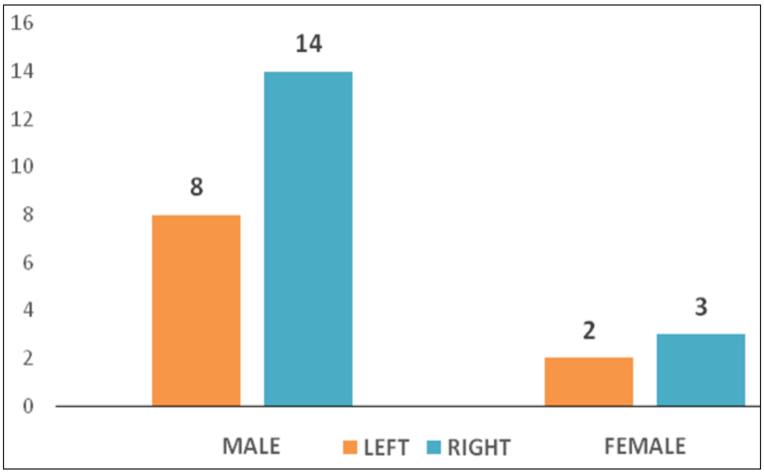

Fig 2: Frequency distribution based on laterality of ARA and gender.

Table 3: Frequency distribution based on laterality of ARA and gender

Ara		Male	Female	Total	P Value
Left	Yes	8	2	10	0.21
	No	54	36	90	
Right	Yes	14	3	17	0.014
	No	48	35	83	

The frequency of the accessory artery in males was higher (19) than in females (4). The prevalence of bilateral accessory renal artery was 4% (n=4). The left side accessory renal artery was present in 6% (n=6) and the right side in 13% (n=13). Males had accessory renal arteries on the right side in 14 kidneys and on the left side in 8 kidneys while females had left accessory renal arteries in 2 kidneys and on the right side in 3 kidneys. The overall prevalence of left renal accessory arteries was 17% and 10% on the right side. (Table 1, 2, 3; Fig 2). Table 2 shows the significant association between the gender and presence of ARA. Males had a higher proportion of ARA when compared with females which was statistically significant (p-0.02). Table 3 denotes that there is statistically significant association between gender and right-sided ARA where males had higher ARA prevalence on the right side than females. Though on the left side males had higher prevalence than females, the association was not statistically significant.

Table 4: Frequency distribution based on the diameter of ARA and gender

Ara	Diameter	Male	Female	Total
Right	Smaller	9 (81.8%)	2 (100%)	11 (84.6%)
	Same	2 (18.2%)	0	2 (15.4%)
Left	Smaller	8 (100%)	2 (100%)	10 (100%)
	Same	0	0	0

On the right side, 81.8% of the males had smaller accessory renal arteries than the main renal artery and 100% in females were smaller than the main renal artery. On the left side, 100% of the accessory renal arteries were smaller than the main renal artery in both males and females. (Table 4)

Table 5: Frequency distribution based on the location of ARA and gender

Ara	Location	Male	Female	Total
Right	Low level	4 (36.3%)	0	4 (30.7%)
	Same level	0	0	0
	Upper level	7 (63.7%)	2 (100%)	9 (69.2%)
Left	Low level	3 (37.5%)	1 (50%)	4 (40%)
	Same level	0	0	0
	Upper level	5 (62.5%)	1 (50%)	6 (60%)

The accessory renal arteries are present at upper level on right side in 100% of the females, whereas in males 36.3% were at lower level and 63.7% were at upper level. On the left side, the accessory renal arteries in females were 50% each in upper and lower levels and in males 37.5% were at lower level and 62.5% were at upper level. (Table 5).

Fig 1: Accessory renal arteries in a 27-year-old male, 3D VRT images shows two renal arteries supplying the right kidney. The inferior artery was not appreciated on initial axial source Images

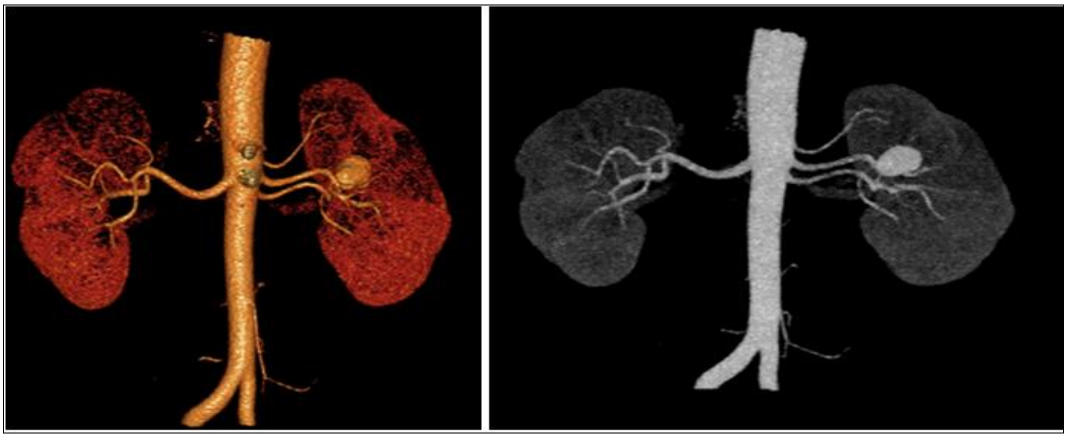

Fig (2A) and (2B): 3D VRT (2A) and 3D MIP (2B) images of Left upper segmental renal artery saccular aneurysm / pseudo-aneurysm (arising from aberrant artery)

Fig 3: Bilateral accessory renal arteries in a 49-year-old male, 3D VRT image shows two renal arteries supplying each kidney.

Fig 4: 3D VRT image of 41 yr female shows two renal arteries supplying right kidney

Fig 5: Axial Post contrast arterial phase image in a 21 year old male, shows two renal arteries supplying left kidney with adjacent prominent retroperitoneal lymph nodes (black arrows).

Fig 6: 3D VRT image of 60 yr female shows Aberrant right renal artery supplying the inferior pole of right kidney is noted

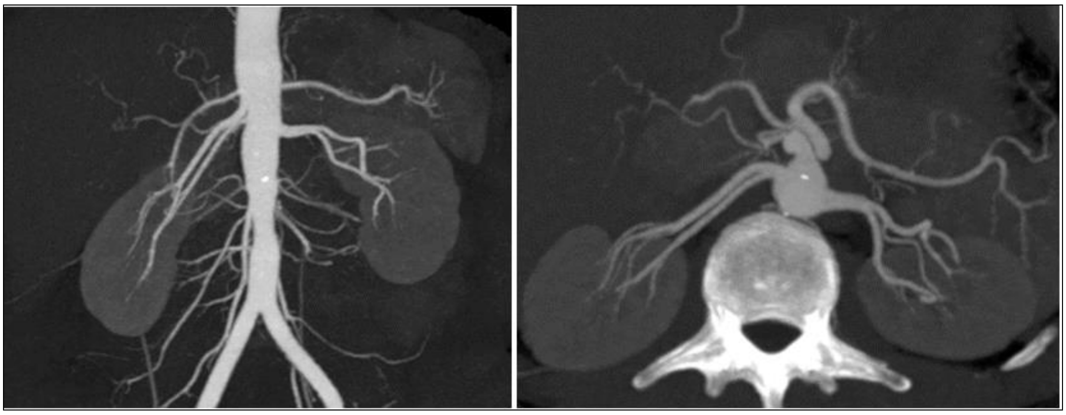

Fig 7: 3D MIP image of 42 yr male shows bilateral pre hilar branching of renal arteries.

Discussion

The existence of aberrant and accessory renal arteries must be taken into account when evaluating a donor kidney for potential renal transplantation because they may unintentionally be damaged during renal surgery. However, the persistence of some cephalic mesonephros vessels may cause vascular abnormalities [10].

During development, these mesonephric arteries stretch from C6 to L3. The majority of cranial vessels disappear, but a network of caudal arteries known as the rete arteriosum urogenitale, which will eventually supply the metanephros, remains. The lowest suprarenal artery, which releases a permanent renal artery, supplies the metanephros, which later develops into an adult kidney. These segmental arteries of the adult kidney are formed by persistent roots of the network that vary where they originate. Following the ligation of the polar arteries, the kidney donor grafts with multiple arteries caused post-transplant morbidity and graft loss. Technically speaking, transplanting a kidney with a single renal artery is simpler than transplanting a kidney with multiple arteries [11].

The term "aberrant or accessory arteries" has been used to refer to a vessel entering the kidney at either pole or an additional artery in the renal pedicle, regardless of whether it originates from the main renal artery, the aorta, or a branch of the aorta [12].

Renal arteries that are malformed are typical in fused kidneys. Instead of supplying the kidney's hilum, abnormal arteries perforate its parenchyma. These arteries may have their origins as high as the internal iliac arteries or as low as the inferior phrenic artery. The aorta, as well as the gonadal, common iliac, middle sacral, external or internal iliac, or superior or inferior mesenteric arteries, may give rise to the unusual vessels. Typically, there is only one superior renal polar renal artery. They can develop independently from the aorta or as branches of the inferior suprarenal, inferior phrenic, or superior mesenteric arteries, as well as the renal artery. The aorta or the renal artery give rise to inferior renal polar arteries, which are typically single. In some cases, it has also been claimed that they come from the suprarenal, common iliac, or superior mesenteric arteries. Sometimes there are two inferior polar arteries, one coming from the aorta and the other from the renal artery, or both coming from either source. A form of hydronephrosis that can be surgically treated has been linked to the inferior polar arteries [13].

The perihilar branching pattern of the main renal artery shows high individual variability in clinical practice, but there are only a few cases of it in this study. The most frequent perihilar branching pattern, according to the study by Weld *et al.* [14], consisted solely of segmental arteries without any pre-segmental arteries. (Fig - 7).

One case of higher (thoracic) origin of the renal artery is also found in the study (at D10 vertebral level), [15].

In the current study, 77% of kidneys have a single renal artery, and 23% of kidneys have renal artery variants. In males and on the right side, renal artery variants are more common. Only a few studies claimed to have found no gender or side preference. On the left side, however, renal artery variants are more common, according to other studies.

Conclusion

In the current study, 77% of the kidneys have a single renal artery. The current study's 23% prevalence of renal artery variants is comparable to other studies' findings. Males (16, 17) and right-sided individuals (18, 19) are more likely than females to have renal artery variants. Renal artery variations are 11% common.

Abbreviations

ARA: Accessory renal artery.
CECT: Contrast-enhanced computed tomography.
CTA: CT Angiography.
MDCT: Multi-detector computed tomography.
MPR: Multi-planar reformatted image.
VRI: Volume rendered images.
MIP: Maximum intensity projection.

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Declarations

Ethics approval and consent to participate – Institutional ethics committee approval obtained and patient data anonymized and written informed consent of the patient for participation in the study wherever applicable obtained.

Consent for publication

All radiological images used in the study have been anonymized by removing patient identifiers.

Competing interest
The authors declare that they have no competing interests.

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