Original Article

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Demographic Features and Variations of Blood Vessels in Voluntary Kidney Donors at A North Indian Hospital

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ABSTRACT

Background: Living kidney donation remains the preferred source of renal grafts, making careful evaluation of donor demographics and renal vascular anatomy essential for safe transplantation. Preoperative identification of renal arterial and venous variations helps optimize surgical planning and reduce intraoperative complications.

Objective: To study the demographic characteristics (gender ratio, age range, blood group, and relation of donor to recipient) and vascular variations in number and branching pattern of voluntary kidney donors (VKD) over seven years of renal transplantation done by a single surgical team at two hospitals consecutively.

Methods: Computed Tomography Angiography (CTA) images of 179 donors were retrospectively studied. Transplants were done from May 2012 to Sept 2024 by the same surgical team at two centers in sequence. Demographic profiles of voluntary kidney donors were analyzed.

Results: Amongst the 179 donors, 76.5% were females, and 23.5% were males. The mean age of female donors was 46.9 ± 10.4 years, and that of male donors was 46.8 ± 12 years. Blood group 'O' was the most common blood group in kidney donors in both genders. One hundred and forty-nine (149) donors had a single left renal artery (RA), while one hundred fifty-seven (157) had a single right RA. The venous anatomy revealed that one hundred and seventy-four donors (174) had a single right renal vein (RV), while one hundred and seventy donors (170) had a single left RV. The remaining patients had variations in blood vessels, and none were statistically different between the two genders.

Conclusion: The anatomical variations of the arterial and venous network in the renal donors are not uncommon and should be better documented preoperatively to avoid panic during surgery. The vascular variations documented in our study are well corroborated by those reported in previous studies. Although many factors contribute, females of the family comprise the majority of the VKD pool.

KEYWORDS: Kidney donors; Renal transplantation; Vascular anomalies

INTRODUCTION

For end-stage renal disease (ESRD), renal transplantation patients fare significantly better in longevity and quality of life parameters as compared to those put on lifelong dialysis. For any renal transplant surgeon, single-donor RA and RV of good caliber, length, and character are optimal for anastomosis and initial graft function. Preoperative knowledge of these vascular abnormalities, variations, or diversities of origin protects both the patient and the surgeon from unexpected surgical complications. In this observational study, we determined the prevalence of all vascular variations in kidney donors. The various demographic features of the donor population were also evaluated.

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MATERIALS AND METHODS

We routinely perform CTAs of all VKDs during the preoperative workup. One or two days

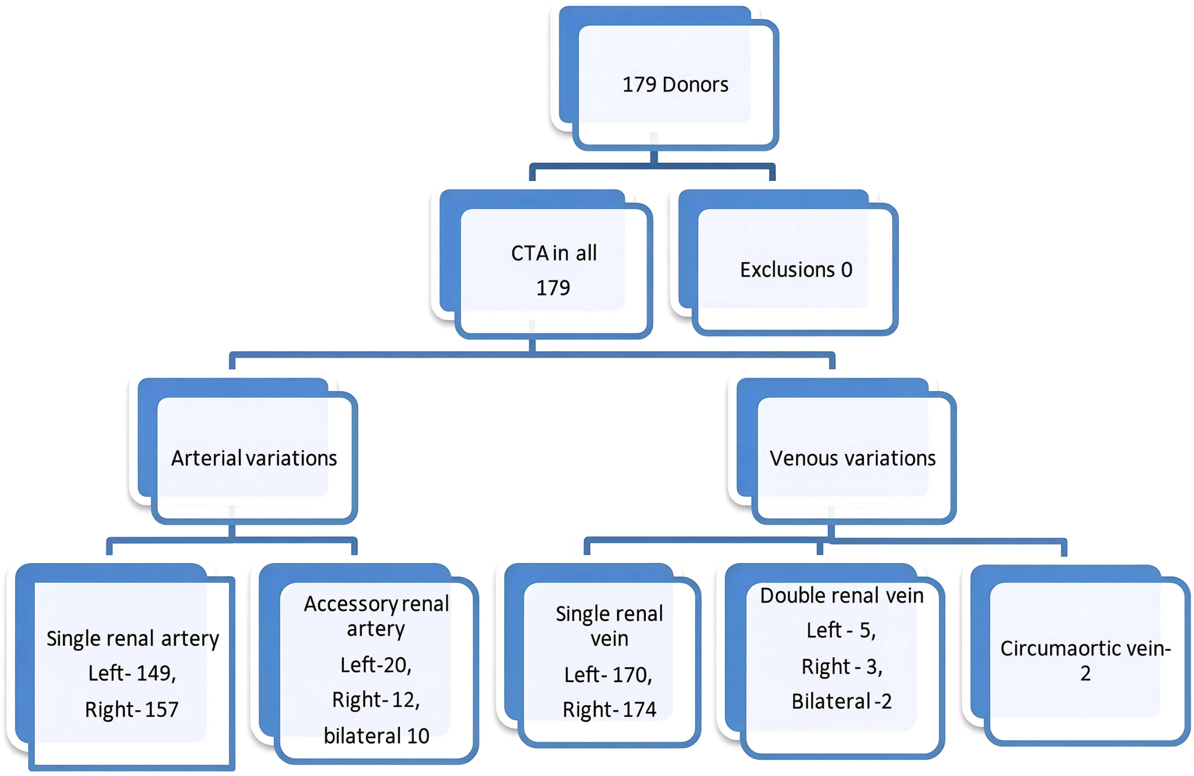


Figure 1: STROBE diagram of the study.

before the transplant, the surgical, nephrology, and anesthesia teams discuss the patient's parameters and the surgical plan. CTA images of 179 donors were retrospectively studied. Transplants were done from May 2012 to Sept 2024 by the same surgical team at two centers in sequence. All the donor nephrectomies were done by open technique. Demographic profiles of kidney donors, including family relationship between donor and recipient, age, sex, and vascular variation (number of vessels and branching pattern), were analyzed (Fig. 1).

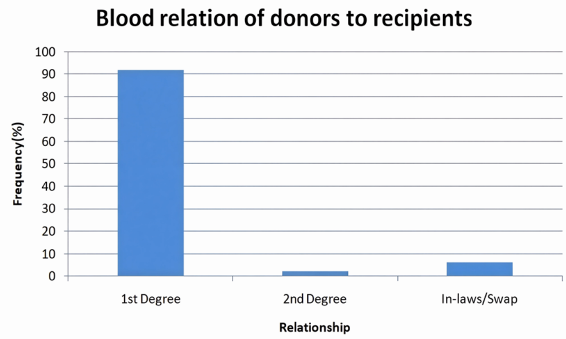
For CTA, a nonionic, water-soluble contrast medium was injected intravenously (1 mL/kg) at a rate of 4–5 mL/s with an automatic pressure injector. CTA was performed on a 384-slice computed tomography (CT) scanner [Siemens Somatom Force (Dual energy), Germany]. The scans were obtained with tube current auto modulation (80–250 mAs) and adaptive statistical iterative reconstruction, tube voltage 120 kVp, gantry rotation time 0.6s, detector coverage 40mm, slice thickness 1.25mm and 0.625mm, and pitch 1.375 and 1.1. Acquired contiguous axial 1.25 mm and 0.625 mm slice CT images were reformatted in the coronal and sagittal plane as well, and all images were transferred to picture archiving and communication systems for further analysis.

Ethical Considerations

This retrospective observational study was conducted using data obtained from hospital records. The Institutional Ethics Committee of SPS Hospitals, Ludhiana, India, granted an ethical waiver and had no objection to the conduct of the study. Patient information was handled confidentially, and all records and consent documents, where applicable, were securely maintained in accordance with institutional requirements.

Statistical Analysis

Baseline categorical variables were described as absolute frequencies and percentages. To apply the appropriate statistical test, we first checked whether the data were normally dis



Relation	Frequency	Percentage
1st degree	164	91.62
2nd degree	04	2.23
In- laws/Swap	11	6.15

Figure 2: Bar Chart to show degree of blood relation of donor to recipients.

BOX I

The VKD with SMA was a female who wanted to donate a kidney to her husband. She had no abdominal complaints and was incidentally detected to have chronic SMA stenosis leading to a massively dilated collateral vessel from the inferior mesenteric artery impinging on the renal hilum. As no other donor was available, this donor was taken up for surgery after thorough counseling and by keeping the gastrosurgeon and vascular surgeon colleagues on hold. Left open donor nephrectomy through a flank incision was done with meticulous retroperitoneal dissection. The thick collateral vessel was dissected away from the renal hilum, and the renal vessels were managed. The patient was fully informed in detail that in the event of injury to collateral, she may be at risk of gut ischemia, and may thus need microscopic vascular surgery for revascularization of gut. The donor and recipient both did well in the postoperative period. She was on regular follow-up for a few years and was specifically asked to report to hospital in case of abdominal pain, however trivial it may appear.

tributed; for this, we used the Kolmogorov-Smirnov or Shapiro-Wilk test. The characteristics of the study subjects were summarized by computing univariate analyses. To assess the association between categorical variables, the chi-square ($\chi 2$) test was used (the Fisher exact test if any expected frequency was less than 5). The results were considered statistically significant when the two-tailed p-value was less than 0.05. All statistical calculations were performed using the Statistical Package for the Social Sciences (SPSS) version 26 (SPSS Inc., Chicago, IL, USA) on Microsoft Windows.

RESULTS

Demographic Characteristics of Donors

Amongst the 179 donors, one hundred and thirty-seven (76.5%) were females, and forty-two (23.5%) were males. The mean age of the donors was 46.9 ± 10.8 years, with females of 46.9 ± 10.4 years and males of 46.8 ± 12 years (Table 1). Blood group O was the most common in donors of both genders (54.8% in males and 48.9% in females), followed by B, A, and AB, respectively, in decreasing order (Table 2).

One hundred and sixty-four (91.62%) donors were first-degree relatives to the recipients, while donors from In-laws were 5, and for swap transplants were 6 (in India, swap transplants are permitted for first-degree relatives only) (Fig. 2). Only four (2.23%) donors were second-degree relatives (Table 3). One hundred nine (approx. 61%) donations were made by wives and mothers, with wife-to-husband transplants in 33.5% and mother-to-child transplants in 27.4% (Fig 2).

CTA Findings

CTA findings were shown in Table 4. On preoperative vascular assessment of donors with CTA, it was found that one hundred and forty-nine (149) donors had a single left RA, while one hundred fifty-seven (157) had a single right RA. Forty-two donors had accessory (acc.) arteries; ten had bilateral acc., and twenty had left acc. RA. (Fig. 3) and twelve had right acc. RA. In five cases, left polar RA was found but was too insignificant to be considered for anastomosis. None of the arterial variations showed statistically significant gender differences.

The venous anatomy showed that one hundred and seventy-four donors (174) had single right

Figure 3: Image showing left accessory renal artery.

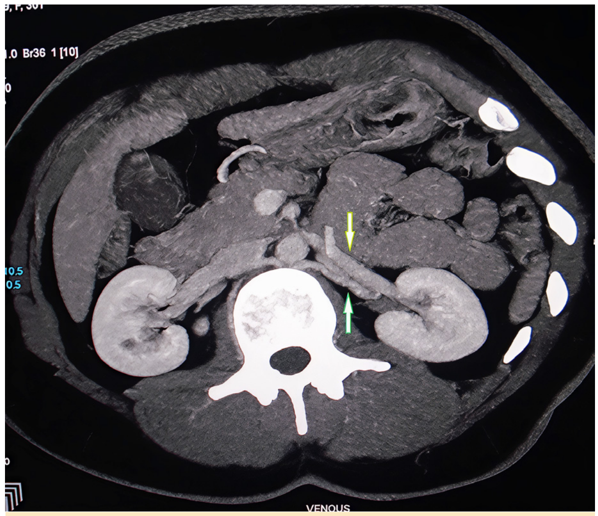


Figure 4: Image showing left circumaortic vein.

RV while one hundred and seventy donors (170) had single left RV. Three donors had double RV on the right, five on the left, and two had these on both sides. In two donors, circumaortic RV was detected (Fig. 4). In recipient surgery for these donors, a pantaloon was made for a common stump in one donor, and two venous anastomoses were performed in the other (Table 5). Four donors had retroaortic RV (Fig. 5). As with arterial variations, no statistically significant differences in the frequency of venous variations were found between the two genders.

Apart from renal vascular anomalies, in one of the female donors, chronic stenosis of the superior mesenteric artery (SMA) leading to a massively dilated collateral vessel from the inferior mesenteric artery was found (Fig. 6).

DISCUSSION

Nearly 20% of cardiac output (approx. 1 liter/minute) is supplied to both kidneys via the renal arteries. Usually, the renal arteries arise as lateral branches of the abdominal aorta at the level of L1/L2 vertebrae. At variable distances from the origin, the renal arteries divide into anterior and posterior divisions, which further divide into segmental vessels. Approximately 71-85% of kidneys are supplied by a single RA, which supplies the entire renal parenchyma, with a slight predominance on the right. One RV, which routes anterior to the RA (and the aorta on the left), is found in the majority of cases [1]. The right RV has a shorter route measuring 2–3 cm, which joins the lateral edge of the inferior vena cava. The left RV has a more extended course, measuring 6–10 cm, and joins the medial side of the inferior vena cava [2]. However, the renal vascular variations are common and have been reported in many studies. For uniformity in the literature, the terms multiple, accessory, aberrant, or anomalous renal arteries, prehilar branching, and venous variations have specific definitions.

Prehilar branching is pivotal for the donor nephrectomy procedure because most transplant surgeons prefer at least 1.0 cm of main arterial length on the left side for good anastomosis after retrieval [3].

The arterial and venous variations of the kidneys can be understood by emphasizing their embryological development. The kidneys are derived from the intermediate mesodermal urogenital ridge, which is supplied by a net

Table 1: Gender wise mean age of donors (n=179).

Gender	n (%)	Mean ± SD (years)	95% CI
Male	137 (76.5)	46.9 ± 10.4	-3.80, 3.74
Female	42 (23.5)	46.8 ± 12.0	

work of capillaries called the "rete arteriosum urogenitale," which arises from the abdominal aorta and later gives rise to the segmental lateral splanchnic arteries [4]. As Keibel and Mall [5] documented in an 18 mm fetus, the developing mesonephros, metanephros, suprarenal glands, and gonads are supplied by nine pairs of lateral mesonephric arteries arising from the dorsal aorta. These arteries are divided into three groups: the 1st and 2nd arteries as the cranial group, the 3^{rd} to 5^{th} arteries as the middle group, and the 6th to 9th arteries as the caudal group. Initially, the metanephric kidney lies in the sacral region and subsequently, as the abdominal wall grows, 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 [6]. The failure of regression of these arteries, otherwise to be degenerated, results in accessory or polar renal arteries.

In our observational study, no statistically significant differences in frequency of arterial or venous variations were found in the two genders. Among the 179 donors, 137 (76.5%) were females, and 109 (nearly 61%) donations were made by wives and mothers, with wife-to-husband transplants in 33.5% and mother-to-child transplants in 27.4%. The reasons for more females presenting as VKD are multifactorial. The contextual hypothesis could be that, in the North Indian scenario, with predominantly male financial responsibility, cultural norms and social and family networks warrant wives and mothers coming forward as VKD. Another factor is the predominance of males as ESRD patients undergoing dialysis. In our two hospitals, the crude male-to-female ratio among dialysis patients was 65/35 and 80/20, respectively.

The prevalence of various renal vascular variations has been assessed in various studies (Table 6). In a Polish population, Sośnik and Sośnik [7] studied formalin-fixed renovascular samples removed from deceased bodies, "en bloc" after postmortem aortonephrography or cavonephrography. Variations in the renal venous system were observed in 33.8% of cases. Deviations in the structure of the renal arteries were observed significantly more often in patients with renal venous system anomalies than otherwise (46.8% v/s 34.9%).

BOX II (Fig. 7)

Accessory renal artery denotes two or more arteries supplying the same renal segment.
Multiple renal arteries denote more than one vessel supplying the kidney and originating from the aorta.
Aberrant or Anomalous arteries are the vessels supplying the kidney but not arising from the aorta or main renal artery.
Polar renal artery is a renal artery that enters the kidney directly at its upper (superior) or lower (inferior) pole, bypassing the main renal hilum.
Prehilar branching of the renal artery is when the main renal artery divides into anterior and posterior divisions or even more segmental arteries before reaching the renal hilum, rather than at or within the hilum.
Circumaortic left renal vein, also known as a **circumaortic renal collar**, is an anomaly of the left renal vein when an accessory left renal vein passes posterior to the aorta, apart from the normal renal vein passing anterior to the aorta.
Retroaortic left renal vein is a normal anatomical variant where the left renal vein is located between the aorta and the vertebra and drains into the inferior vena cava.
Preaortic left renal vein is a normal anatomical variant where the left renal vein is positioned in front of the aorta.
Double renal vein is a rare anatomical variation where a kidney has two veins, instead of the usual one, that drain into the inferior vena cava.

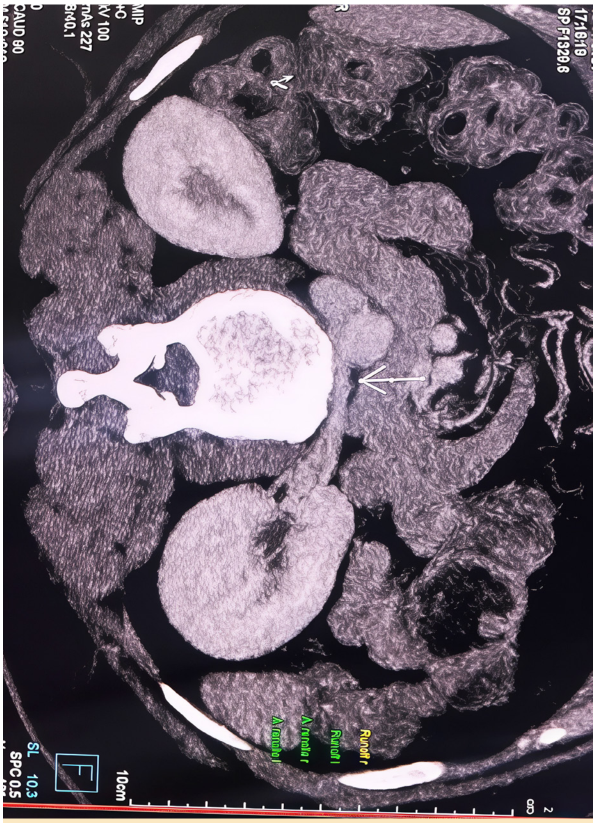


Figure 5: Image showing left retroaortic vein.

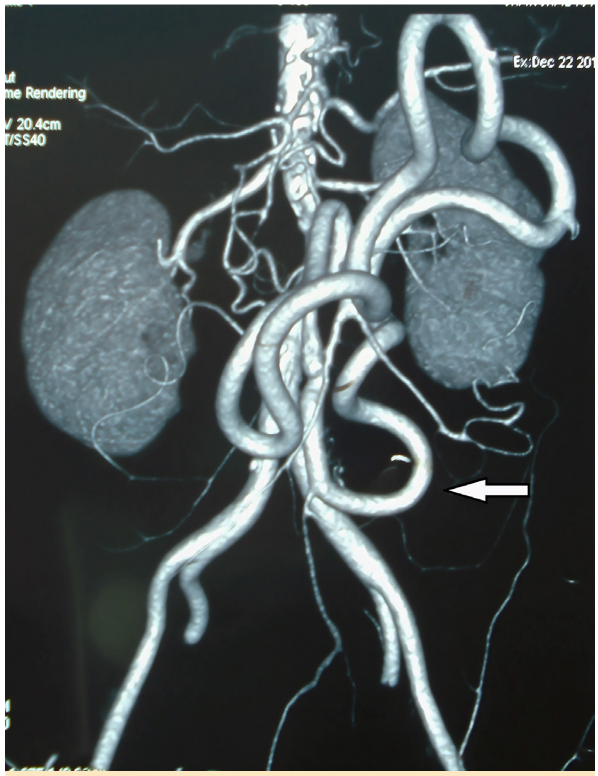


Figure 6: Image showing grossly distended collateral resulting from superior mesenteric artery stenosis.

Staśkiewicz *et al.* [8] observed that the incidence of single RA was 73%, with single RV in 95%. Our study showed single left RA in 83.2% of donors, single right RA in 87.7% of donors, and single left (preaortic) and right RV in 94.9% and 97.2% of donors, respectively. Circumaortic or retroaortic courses of left RV were observed in 10% of cases by Staśkiewicz *et al.*, which is quite different from the finding from our study group, where retroaortic vein was detected in four donors and circumaortic vein in two, for which bench surgery for pantaloon was done in one case and an additional anastomosis in the other. Similar to our results, Saldarriaga *et al.* [9] and Staśkiewicz et al. [8] did not observe gender differences in frequency of supernumerary arteries.

Similarly, prevalence of single RA in studies of cadaveric models was reported as 86% by Kumar and Prabha [10] and 87.7% by Weld

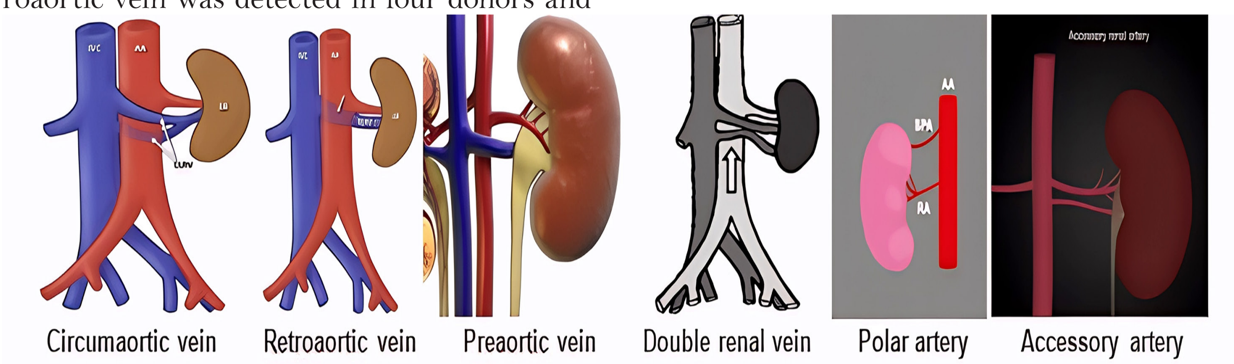


Figure 7: Schematic images of various vascular variations.

Table 2: Gender wise blood group distribution of donors (n=179).

Blood Group	Gender		Total	Chi-square value p-value
	Male	Female		
O	23 (54.8)	67 (48.9)	90 (50.3)	$\chi 2$= 1.39 p= 0.4979 Non-Significant
B	11 (26.2)	47 (34.3)	58 (32.4)	
A	8 (19.0)	19 (13.9)	27 (15.1)	
AB	0 (0.0)	4 (2.9)	04 (2.2)	

Table 3: Blood relation of donors to recipients.

Relation	Frequency	Percent
Wife to Husband	60	33.5
Mother to Son	36	20.1
Sister to Brother	13	7.3
Mother to Daughter	13	7.3
Brother to Brother	12	6.7
Father to Son	11	6.1
Swap Unrelated	6	3.4
Brother to Sister	5	2.8
Son to Father	4	2.2
Husband to Wife	3	1.7
Sister to Sister	3	1.7
Father to Daughter	3	1.7
Daughter to Father	1	0.6
Paternal Uncle to Nephew	2	1.1
Paternal Aunt to Nephew	1	0.6
Maternal Aunt to Nephew	1	0.6
Mother-In-Law to Daughter-In- Law	1	0.6
Father-In-Law to Daughter-In-Law	1	0.6
Brother-In-Law to Sister-In-Law	1	0.6
Mother-In-Law to Son-In-Law	1	0.6
Brother-in-law to Brother-in-law	1	0.6
Total	179	100

et al. [11] The presence of vascular variations is though not deterrent for transplant surgeons to proceed for good transplant anastomosis, but with preoperative detailed assessment, the chances of unplanned additional vascular maneuvers during transplant and thus the additional ischemia time can be reduced. This necessitates improved communication between the radiologist and transplant surgeon.

In conclusion, anatomical variations of the arterial and venous networks in renal donors are not uncommon. They are of utmost significance to be well documented on preoperative CTA for transplant surgeons. There is no statistically significant difference in prevalence of vascular variations between the genders. Any new transplant surgeon, including our team in the initial phase, is somewhat skeptical of surgical success in cases with vascular variations evident on preoperative CTA and more so about finding vascular anomalies peroperatively, undetected on preoperative CTA. Although the prevalence of ESRD is higher in males, and thus females of the family would be expected to volunteer as VKD, in our society, as evident in our study, the reasons for females forming the majority of VKD population are multifactorial and include cultural, societal, and family norms along with financial responsibilities of males.

FINANCIAL SUPPORT: None.

CONFLICTS OF INTEREST: None declared.

Table 4: Distribution of arterial and venous variations according to gender.

Vascular variation	Gender		Total (n=179)	OR (95%CI)	P-value
	Female (n=137)	Male (n=42)			
Single left RA	115 (83.9)	34 (81.0)	149 (83.2)	1.23 (0.5,3.01)	0.650†
Single right RA	122 (89.1)	35 (83.3)	157 (87.7)	1.63 (0.61,4.3)	0.323†
Bilateral acc. RA	7 (5.1)	3 (7.1)	10 (5.6)	0.67 (0.17,2.73)	0.701‡
Left acc. RA	15 (10.9)	5 (11.9)	20 (11.2)	0.93 (0.32,2.72)	0.787‡
Right acc. RA	8 (5.8)	4 (9.5)	12 (6.7)	0.57 (0.16,1.99)	0.480‡
Left polar RA	4 (2.9)	1 (2.4)	5 (2.8)	1.19 (0.13,10.93)	1.000‡
Single right RV	132 (96.4)	42 (100)	174 (97.2)	——	0.593‡
Single (preaortic) left RV	129 (94.2)	41 (97.6)	170 (95.0)	0.24 (0.03,1.91)	0.688‡
Bilateral double RV	2 (1.5)	0 (0.0)	2 (1.1)	——	1.000‡
Right double RV	3 (2.2)	0 (0.0)	3 (1.7)	——	1.000‡
Left double RV	4 (2.9)	1 (2.4)	5 (2.8)	1.19 (0.13,10.93)	1.000‡
Circumaortic RV	2 (1.5)	0 (0.0)	2 (1.1)	——	1.000‡
Retroaortic RV	4 (2.9)	0 (0.0)	4 (2.2)	——	0.574‡

Values are presented as n (%). † Pearson's chi-square test; ‡ Fisher's exact test. RA, renal artery; RV, renal vein.

Table 5: Outcome linkage and operative strategy to various vascular variations.

CTA finding	No. of patients	Preoperative assessment	Operative strategy	Change in WIT/ CIT Any DGF
Bilateral acc. RA	10	Concomitant double left renal vein in 3 patients	Left nephrectomy - 7 (pantaloon in 5, double anastomosis in 2) Right nephrectomy – 3 (pantaloon in 2 and double anastomosis in 1)	Minimal, None
Left acc. RA	20	Right kidney optimal in 12	Right nephrectomy – 12 Left nephrectomy – 8 (pantaloon in 6, double anastomosis in 2)	Minimal, None
Right acc. RA	12	Left kidney optimal	Left nephrectomy - 12	None, None
Left polar RA	5	Upper polar, too small for optimal anastomosis	Left nephrectomy -5 (polar artery sacrificed)	None, None
Circumaortic RV	2	Left kidney otherwise optimal	Left nephrectomy – 2 (pantaloons in 1 and double anastomosis in 1)	Minimal, None
Left double RV	5	Right kidney optimal	Right nephrectomy - 5	None, None
Right double RV	3	Left kidney optimal	Left nephrectomy - 3	None, None
Bilateral double RV	2	Both had close insertions in the vena cava on right side	Right nephrectomy with longer IVC cuff - 2	None, None

Table 6: Comparison with cited literature series.

Author	No. of patients/ kidneys	Technique of study	Prevalence of single renal artery (%)
Sośnik *et al.*	1100 kidneys	Cadaveric retrieval, postmortal aortonephrography and cavonephrography	76.7
Staśkiewicz *et al.*	996 patients	Live patients, abdominopelvic CT scan	73
Kumar *et al.*	84 kidneys	Cadaveric retrieval, bench dissection	86
Weld *et al.*	73 kidneys	Cadaveric retrieval, bench dissection	87.7
Present Study	179 patients	Live patients, CT angiography	Left side – 83.2, Right side – 87.7

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