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Renal vascular and ureteral variations in patients with kidney transplantation

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Abstract

Objectives: To investigate the renal vascular and ureteral variations in patients subjected to kidney transplantation.

Methods: This retrospective study was conducted between January 2018 and December 2021. A total of 233 donors who underwent cadaveric harvesting were included in the study. By using the operation records, the numbers of the participants' right and left renal arteries, right and left renal veins and right and left ureters were evaluated.

Results: The mean age of participants was 54.41±17.76 years, and 58.8% were males. Multiple renal vessels were detected in 77 (33%) donors, and ureter duplication was detected in 3 (1.2%) donors. No significant difference was observed between the right and left kidneys and between sexes regarding the incidence of supernumerary renal vessels and ureters. There was a substantial relationship between the supernumerary renal artery and vein count on the right side (p=0.024 when dichotomized for artery count, p=0.004 when dichotomized for vein count).

Conclusion: Anatomical differences in vascular structures and ureters may create risks that will affect the outcome of kidney surgeries and transplants. During kidney transplantation, interventional radiological procedures or other retroperitoneal surgeries, surgeons and radiologists are advised to remember that supernumerary renal arteries and veins are likely to be concurrent, especially on the right side.

Keywords: kidney surgery; supernumerary renal vessels; transplantation; ureter duplication; harvesting

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Introduction

Morphological kidney variations can be seen frequently, although frequency varies according to ethnic and racial differences.[1,2] These variations may be related to the kidney itself, such the presence of ectopic kidney[3] or horseshoe kidney,[4] and may also be directly associated with variations in the renal artery, renal vein and ureters.[1] The most common variations related to the renal artery are supernumerary renal artery (SRA) and early bifurcation of renal artery.[1,5] Supernumerary renal vein (SRV),[6] retroaortic left renal vein,[7] plexiform renal vein[8] and late confluence of renal vein[9] can be counted among the well-known variations of the renal vein. Ureteral duplication and dilatation are anatomical variations of the ureter.[10]

Anatomical variations in arteries, veins and ureters can create extra risks for the donor, recipient and graft during kidney transplantation. Additionally, missing such structural differences during intra-abdominal operations and radiological interventions may cause bleeding, pyeloureteral necrosis, increased complications, and may even necessitate conversion of laparoscopic operations to open surgery.[1,8,11] Moreover, especially SRV presence has been associated with increased spread of cancer cells throughout the body and these vessels are critical for the placement of caval filters.[8,12] It is also known that multiple ureter complicates renal transplantation surgeries and increase the risk of complications after transplantation.[13] The prevalence of SRA is estimated to be 2–56% and 2–67% in the right and left sides, respectively.[14,15] SRV frequency on the right and left sides has been reported between 7–38% and 0–9%, respectively.[12,16,17] Finally, multiple ureter has been detected in 0.1–1.1% of individuals.[10,18,19] The incidence of these variations may show ethnic and racial dif-

ferences.[1,20] Therefore, knowing population- and sex-specific frequencies and type of multiplicity on the right and left sides (arteries, veins and ureters) can provide important advantages in diagnostic imaging, interventional radiological procedures, retroperitoneal surgical procedures and renal transplantation.[1,12,21,22] There are many studies in the literature which have examined renal vessel variations.[1,9,11] However, the number of studies in which both renal vessels and ureters are evaluated with respect to sex and side are limited.[18]

In this study, we aimed to investigate the renal vascular and ureteral variations in patients subjected to kidney transplantation harvesting.

Materials and Methods

This study is a retrospective study evaluating the operations performed by Bursa Regional Organ and Tissue Transplant Coordination Center between January 2018 and December 2021 in Turkey. A total of 233 donors who underwent kidney harvesting for donor kidney vessels assessment before renal transplantation were included in the study. All samples and information were recorded anonymously. Donors whose anatomy of the artery, vein, and ureter of both kidneys could not be clearly evaluated by any reason, and donors who did not have one and have ectopic kidney were excluded from the study (n=18).

The primary outcome was to evaluate whether there were significant differences in the number of renal arteries, renal veins and ureters between the right and left kidneys. The secondary outcomes were to investigate whether there were significant differences in the numbers of right and left kidney renal arteries, renal veins and ureters between males and females and to ascertain whether there was a significant relationship between the number of SRA and SRV in the right and left kidneys, separately.

All analyses were performed on IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA), and with a statistical significance threshold of $p<0.05$. Mean±standard deviation was used to summarize continuous variables, while absolute and relative frequency were used for categorical variables. Age was analyzed with the independent samples t-test. Analyses between right and left side were performed with the McNemar test or marginal homogeneity test depending on number of categories. For the analysis of relationships between artery and vein counts, variables were dichotomized for both artery and vein count ($n=1$ vs. $n\geq2$) with relative assessment according to exact numbers ($n=1$, $n=2$, $n=3$). Between-groups analysis of categorical variables was performed with the Fisher's exact test or the Fisher-Freeman-Halton test.

Results

Overall mean age was 54.41±17.76 years and 58.8% of the participants were males. Multiple renal vessels were detected in 77 (33%) donors and ureter duplication was detected in 3 (1.2%) donors (**Figure 1**). SRA anomalies were present in 68 (29.1%) donors and 8 (3.4%) of them had concomitant SRV. Right-sided SRA was detected in 40 donors (17.1%), left-sided in 40 donors (17.1%), and bilateral SRA in 12 (5.1%) donors. SRV was present in 17 (7.3%) donors, of which 11 (4.7%) were on the right, 6 (2.6%) were on the left, while none of the participants had bilateral SRV anomalies. Bilateral ureteral duplication was not detected in any donor. No significant difference was observed between the right and left kidneys in terms of the number of renal arteries ($p=0.808$), the number of renal veins ($p=0.180$), and the number of ureters ($p=1.000$) (**Table 1**) and (**Figure 2**).

The mean age of females was significantly higher than male ($p=0.005$). There was no significant difference between the sexes in terms of the numbers of right and left renal arteries ($p=0.179$ and 0.247, respectively), renal veins ($p=0.603$ and 1.000, respectively) and ureters ($p=1.000$ for both sides) (**Table 2**). There was a significant relationship between SRA count and SRV count on the right side ($p=0.024$ when dichotomized for artery count, $p=0.004$ when dichotomized for vein count) (**Table 3**).

Figure 1. Double artery kidney. **Black arrows:** arteries.

Table 1
Summary of the numbers of arteries, veins and ureters with regard to side.

		Right (n=233)	Left (n=233)	p-value
Number of arteries	1	193 (82.8%)	193 (82.8%)	
	2	39 (16.7%)	37 (15.9%)	0.808
	3	1 (0.4%)	3 (1.3%)	
Number of veins	1	222 (95.3%)	227 (97.4%)	
	2	10 (4.3%)	6 (2.6%)	0.180
	3	1 (0.4%)	0 (0.0%)	
Number of ureters	1	232 (99.6%)	231 (99.1%)	1.000
	2	1 (0.4%)	2 (0.9%)	h

Data are given as frequency (percentage).

Discussion

Morphological variations of renal vessels and ureter are mostly asymptomatic and diagnosed incidentally. The importance of these clinically silent conditions emerges especially in retroperitoneal surgeries, renal transplantations and interventional radiological procedures.[8] Since the prevalence of these variations may show ethnic differences[1,2] and considering that the most common variations are additional vessel(s) or ureter(s), we aimed to determine the frequencies of multiple-renal vessels and ureters with respect to the right and left kidneys and sexes in a population from Turkey. There was no significant difference between the right and left kidneys and between males and females in terms of supernumerary vessels and ureters. It was observed that there was a significant positive correlation between the number of SRA and the number of SRV on the right side.

The importance of accessory arteries is evident in many clinical situations.[1] It is especially important to detect SRAs in kidney transplant, since these variations

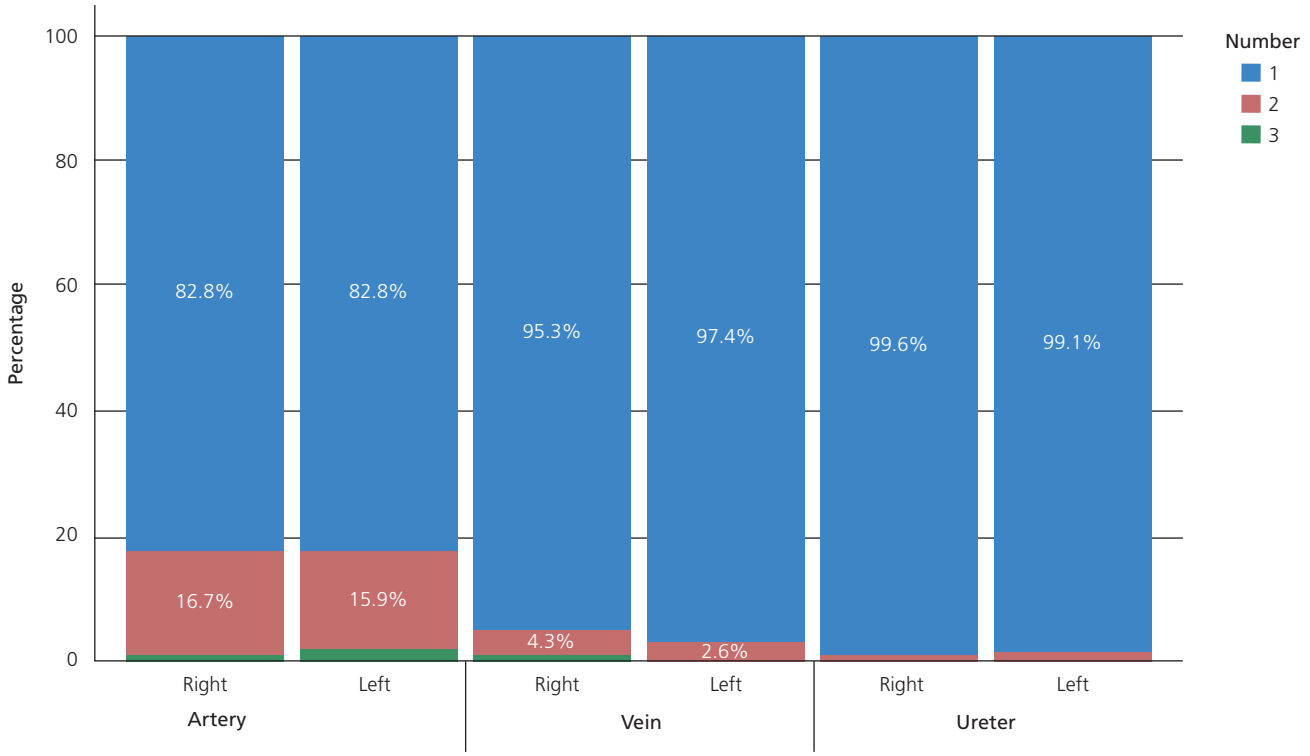

Figure 2. Distribution of the numbers of arteries, veins and ureters.

Table 2
Summary of the numbers of arteries, veins and ureters with regard to sex.

		Female (n=96)	Male (n=137)	p-value
Number of arteries, right	1	84 (87.5%)	109 (79.6%)	
	2	12 (12.5%)	27 (19.7%)	0.179
	3	0 (0.0%)	1 (0.7%)	
Number of arteries, left	1	78 (81.3%)	115 (83.9%)	
	2	18 (18.8%)	19 (13.9%)	0.247
	3	0 (0.0%)	3 (2.2%)	
Number of veins, right	1	91 (94.8%)	131 (95.6%)	
	2	4 (4.2%)	6 (4.4%)	0.603
	3	1 (1.0%)	0 (0.0%)	
Number of veins, left	1	94 (97.9%)	133 (97.1%)	
	2	2 (2.1%)	4 (2.9%)	1.000
	3	0 (0.0%)	0 (0.0%)	
Number of ureters, right	1	96 (100.0%)	136 (99.3%)	1.000
	2	0 (0.0%)	1 (0.7%)	
Number of ureters, left	1	95 (99.0%)	136 (99.3%)	1.000
	2	1 (1.0%)	1 (0.7%)	

Data are given as mean±standard deviation for continuous variables and as frequency (percentage) for categorical variables.

Table 3
Relationships between numbers of arteries and veins.

		Number of arteries, right		
		1 (n=193)	≥2 (n=40)	p-value
Number of veins, right	1	187 (96.9%)	35 (87.5%)	
	2	5 (2.6%)	5 (12.5%)	**0.024**
	3	1 (0.5%)	0 (0.0%)	
		Number of arteries, left		
		1 (n=193)	**≥2 (n=40)**	**p-value**
Number of veins, left	1	188 (97.4%)	39 (97.5%)	
	2	5 (2.6%)	1 (2.5%)	1.000
	3	0 (0.0%)	0 (0.0%)	
		Number of veins, right		
		1 (n=222)	**≥2 (n=11)**	**p-value**
Number of arteries, right	1	187 (84.2%)	6 (54.5%)	
	2	35 (15.8%)	4 (36.4%)	**0.004**
	3	0 (0.0%)	1 (9.1%)	
		Number of veins, left		
		1 (n=227)	**≥2 (n=6)**	**p-value**
Number of arteries, right	1	188 (82.8%)	5 (83.3%)	
	2	36 (15.9%)	1 (16.7%)	1.000
	3	3 (1.3%)	0 (0.0%)	

Data are given as frequency (percentage).

may create special conditions for both the donor and the recipient. Their potential effects include the transplant decision, nephrectomy method, operation side, selection of donor, graft ischemia duration, and greater risk of complications.[1,11] In addition to kidney transplant, these variations or anomalies should be considered during other intraabdominal operations.[1,22,23] SRVs may cause undesirable consequences and difficulties for both the donor/recipient and surgeons during kidney transplant and other surgeries.[23] In the presented study, we determined the rate of supernumerary renal vessels as 33%, SRA rate as 29.1% (17.1% on the right and left), and SRV rate as 7.3% (4.7% on the right, 2.6% on the left). Bilateral SRA ratio was 5.1%, and bilateral SRV was not detected in any donor. There was no significant difference between the right and left sides in terms of the incidence of SRA and SRV. In the computed tomography angiography (CTA) study of Gupta et al.,[1] renal vessel variations were investigated and the frequency of overall SRA was found to be 43.5% (28.70% on the right side, 29.62% on the left side, 14.81% bilateral). The frequency of SRV was 8.3%, and interestingly, all of these variations were right-sided. In another study conducted in Turkey, the renal vessels of 70 kidney donors were evaluated by CTA. SRA was detected in 40 (29.6%) of the 140 kidneys and SRV was identified in 3 (2.1%). In this study, no significant difference was found between the right and left kidneys in terms of SRA.[11] In another study from Turkey, the incidence of SRV and SRA on the right and left sides also was found to be similar.[24] Our findings in this study were similar to the data reported in the Turkish population.[11,24] SRV anomaly was reported at higher rates in our study. This difference may have arisen because the data evaluated in our study was higher and the venous anatomy was more variable.[11,24]

Although many studies on the subject report varying frequencies, it can be said that the frequency of SRA is higher than that of SRV in the majority of literature,[11,25] and that SRVs are seen more frequently on the right side.[8,12,17] The literature concerning the comparison of SRA and SRV frequencies on the right and left sides is inconsistent. While there are those who argue that the frequency is similar.[11,26–28] there are also studies that argue that these variations are more common on the right[24,29] or on the left.[1,30] The fact that SRV is more common on the right side is thought to be due to the different embryological origins and developmental processes of the right and left renal veins.[1,8,12,31] There are also studies that do not conform to this generalization.[5,26,27] But, whatever the reason for these differences, with regard to the reasons outlined above, surgeons and radiologists need to consider the risk and frequency of abnormalities in right and left renal vessels in their population. For instance, the presence of the inferior vena cava on the right causes the left renal vein to be longer, making the left kidney a better transplant candidate than the right due to ease of anastomosis. However, if there are multiple arteries in the left kidney, this may result in preference of the right kidney (even though the vein is shorter) in order to reduce the risk of vascular injury and to shorten ischemia duration.[11,23]

In the current study, we also evaluated the relationship between the number of SRA and the number of SRV for the right and left kidneys separately. According to our results, there was a significant relationship between the number of SRA and the number of SRV on the right side, but no such relationship on the left side. In addition, we also observed that the donor who had 3 renal veins on the right side had 1 renal vein on the left and 1 renal artery on each side. In the observational study of Ikidag et al.,[11] it was reported that a patient with 3 renal veins on the right had 1 renal artery on the right, 2 renal arteries and 2 polar arteries on the left. Deshpande et al.[32] published a case report presenting a patient with 3 renal arteries on the right, 2 renal arteries on the left, and 2 renal veins on the right. We did not come across any other study in which this relationship was investigated. Although CTA scan performed before renal transplantation can accurately detect renal vessel abnormalities with a highly-respectable sensitivity, it should be kept in mind that the sensitivity is not 100%, especially if such variations are not suspected.[5,24] In one study, CTA findings were found to be correlated well with the intraoperative findings in only 72.7% of patients.[5] Therefore, we recommend that when SRA or SRV anomaly is encountered both during renal transplantation and other intra-abdominal operations as well as during interventional radiological procedures, it should be considered that there may be other accompanying supernumerary opposite vessels, especially on the right side. The limitations of imaging methods in radiological studies increase the importance of surgical and cadaver studies. Anomalies of position, rotation, and duplication of the collection system are rarely encountered compared to renal vessel variations. They are caused by anomalies in the morphogenesis of the urinary system.[10] Ureter duplication frequency has been reported to be around 1%.[18,19] Depending on the type and severity of duplication, it may be asymptomatic, or it may be a cause of vesicoureteral reflux, incontinence, ureterocele, obstructive uropathy, renal parenchymal scarring, dysplasia and decreased renal function.[33] In this study, we detected ureteral duplication in only 3 donors (1.2%). None of these had bilateral duplications. One of the donors also had 2 renal arteries on

both sides. In a study of 254 deceased donors, ureteral duplication was found in 3 subjects (2 left- and 1 right-sided).[18] Ureteral duplication may also accompany renal vascular anomalies. Other studies have also presented cases with ureteral duplication concurrent with multiple renal vessel anomalies.[19,34] Therefore, when radiologists and surgeons detect ureteral duplication, they should make extra evaluations and be more careful for other accompanying collector system or vessel anomalies. Additionally, when incidental accessory vessels are detected preoperatively or intraoperatively, it should be taken into account that undetected ureteral duplication may be present. This will allow the surgeon to approach the pedicle more carefully, especially during renal graft removal. In addition, since presence of multiple ureter may also be effective in donor selection, its detection is of particular importance. Indeed, high complication rates have been reported in kidney transplants with multiple ureters.[13]

Our investigation did not reveal any difference between a significant difference between males and females in terms of the number of renal arteries, renal veins and ureters on either the right or left side. The studies by Ferhatoglu et al.[24] and Ikidag et al.[11] also found no significant differences between the sexes in terms of SRA and SRV frequencies. These findings are also supported by other literature.[27,28,35] However, in a retrospective evaluation of CTA images of 820 patients, Gumus et al.[36] found the incidence of SRA to be significantly higher in males on both sides. Another retrospective study reported that the overall rate of renal vascular variation was significantly higher in male.[37] In the same study, it was reported that the percentage of males with SRA was higher than females (31.1% vs 15.2%), and the percentage of females with SRV was higher than male (10.2% vs 8.2%), but the significance of these differences was not given.[37] It is also important to note that urinary tract duplication is encountered more frequently in females.[33]

In our study, no significant effect of sex on the frequency of ureteral duplication was observed, but this may be due to the low number of cases. Sex does not seem to have a clear effect on numerical anomalies of the renal vessels; however, more studies that are comprehensive are required to reach a definite conclusion.

This study has considerable advantages over others, including the fact that SRA, SRV and multiple ureters were evaluated together. Additionally, cross-sectional analysis of these abnormalities between the right and left sides and between the sexes was performed. The numerical relationship between SRA and SRV was also investigated. The number of cases included is higher than in many similar studies conducted in Turkey. However, some critical limitations should be noted. It is a single-center study, so its results cannot be generalized to the entire population. The retrospective design prevented the inclusion of prospective data, which may have been valuable in cases where additional imaging may have been required. Also, other anomalies that may be important in radiological interventions and surgeries such as polar vessels, vessel and ureter diameters, early branching arteries, complete or incomplete ureteral duplication[1,5] were not investigated. Evaluation was made only on CTA data, and although CTA and visual detection are usually consistent,[11,24] some studies have reported that there may be differences in the rates of radiologically-detected variations and intraoperatively-detected variations.[5,24] Finally, despite high patient count, multicenter studies with more cases are needed to provide data on a national scale.

Conclusion

The incidence of SRA, SRV, and duplicated ureter did not differ significantly between the right and left sides and between males and females. There was a significant positive correlation between the incidence of SRA and SRV on the right side. We also found that SRA was more frequent compared to SRV and ureter duplication. During interventional radiological procedures, kidney transplantation or other retroperitoneal surgeries, both surgeons and radiologists are advised to keep in mind that SRA and SRV are likely to be concurrent, especially on the right side.

Conflict of Interest

There is no competing interest.

Author Contributions

AS: protocol/project development, data collection or management, literature review, manuscript writing/editing; MYY: protocol/project development, data collection or management, literature review manuscript writing/editing; MÖ: protocol/project development, literature review, supervision; EŞ: protocol/project development, literature review, supervision; HD: protocol/project development, literature review, supervision.

Ethics Approval

The protocol of this study was approved by the Ethics Committee of the Health Sciences Bursa Yüksek İhtisas Training and Research Hospital, with the date: May 12, 2021, no: 2011-KAEK-25 and conducted by the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments. Since the study is retrospective, the Medical Ethics Committee did not require written

informed consent from donors. All samples and information were recorded anonymously.

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