RESEARCH

Evaluation of Renal Vascular Variations with Multi-Section Computerized Tomography Angiography

Mahmut Ciner[1], Alper Karacan[2],Keziban Karacan[3]

[1] Department of Radiology, Düzce Atatürk State Hospital , Düzce, Turkey
[2] Department of Radiology, Sakarya University Faculty of Medicine , Sakarya, Turkey
[3] Department of Anatomy , Sakarya University Faculty of Medicine , Sakarya, Turkey

ORCID; 0000-0002-9092-499X, 0000-0001-8930-9546, 0000-0001-886-1647

Abstract: The aim of our study is to determine the frequency and association of renal vascular variations. A total of 610 abdominal CT examinations, which were performed in the radiology unit of our hospital were evaluated retrospectively in terms of renal artery and renal vein variations. 60 patients were excluded from the study due to technical factors or situations related to the patient which complicated or completely prevented the examination of renal vascular structures. 550 patients (301 men, 249 women) were included in the study. The frequency of renal vascular variation was 44.2%. Renal artery variation is seen with a frequency of 28.3%, while renal vein variations are seen with a frequency of 26.5%. The most common renal artery variation is the right hilar accessory renal artery (35/550, 6.3%), while the most common renal veins variation is the right multiple renal veins (39/550, 7.1%). The coexistence of renal artery and vein variations was found to be 10.7%. The most common coexistence of renal artery and vein variation was found to be right hilar accessory renal artery-right multiple renal veins, right hilar accessory renal artery-left circumaortic renal vein (5/550, 0.09%). There was a statistically significant relationship between renal artery variation and renal vein variation (p<0,001). It was found that the rate of right hilar accessory renal artery, left polar accessory renal artery and late junction of left renal vein was significantly higher in men than in women (p: 0,003, p: 0,006, p:0,014). Renal vascular variations are seen in 44.2% of the population. In addition, the arterial and venous variations show a substantial coexistence, such as 10.7%. It should be known that its presence is extremely important before endovascular interventional procedures and surgical procedures and during the investigation of renovascular hypertension, pelvic varices, and varicocele etiology.

INTRODUCTION

Kidneys settle in the pelvis in the embryological period. Renal vascular structures originate from the level where the kidneys are. While the kidneys are in the pelvis, the renal vascular structures originate from the main iliac vascular at first. As the kidneys ascend, they first get their nourishment from the distal aorta, and when they reach their final position, from the permanent renal vascular that develops from the aorta. Previously developed renal vascular structures undergo involution. The development of many variations in renal vascular structures is due to this embryological development[1].

Knowing the variations and frequency of renal vascular structures is extremely important in terms of diagnosis and treatment approaches. In renal transplantation donors, partial nephrectomy, endovascular renal artery stenosis treatment before the procedure, revealing the renal vascular anatomic variations is critical in terms of the management of the procedure to be performed and its complications [2]. Laparoscopic or open methods can be used in renal transplantation. Laparoscopy has advantages such as short hospitalization time, fast recovery, and lower morbidity. However, the duration of the surgery is longer and open surgery method is used in individuals with bilateral complex vascular structure or obese individuals [3]. Horseshoe kidney, multiple renal arteries, renal ectopia, retroperitoneal varices, urolithiasis, complex venous variations (retroaortic or circumaortic renal vein), renal neoplasm, cortical atrophy, and hydronephrosis are factors that prevent laparoscopic donor nephrectomy [4].

Due to the length of the left renal vein, the left kidney is usually used for transplantations because of the easier anastomosis. However, if complex variations are detected in the left kidney anatomy, the right kidney is used for transplantation. It is necessary to know the presence of retroaortic, circumaortic or multiple renal veins to prevent renal vein incision during surgery[5]. According to studies in the literature, the incidence of renal vein variation is between 9.6% and 14.2%[6].

Renal artery variations are common. In cadaver studies, 23% of double renal arteries are detected[7]. Since there will be a partial loss of blood supply in the kidney after an operation in which the accessory renal artery is ignored, it should be investigated carefully before the procedure. Early renal artery branching is defined as branching within the first 2 cm from the lateral wall of the aorta. Generally, a renal artery incision is made 2 cm distal to the exit point to control bleeding and make

Received :09.05.2021
Received in revised form :18.06.2021
Accepted :30.06.2021
Available online :15.09.2021

Keywords:

Renal vascular variation,
Renal artery,
Renal vein,
CT angiography

Corresponding Author:
Alper Karacan
E-mail; alperkaracan@sakarya.edu.tr
http://dx.doi.org/10.29228/jamp.51334

Int J Acad Med Pharm,
2021; 3 (3); 229-233

anastomosis easier. Therefore, it is important to know early-branching [8]. Post-transplantation complications are more common in kidneys with renal artery variation than those with a single renal artery [6].

Secondary hypertension is seen in 5-10% of the population. It is important to identify the underlying cause because it can be treatable. The most common cause of this picture is renal artery stenosis. Another less well-known cause is the presence of accessory renal artery. Since the accessory renal artery is narrower than the main artery, renin production is higher in the parenchyma fed by this accessory artery. In patients with treatment-resistant secondary hypertension, when the main renal artery is found to be normal, the presence of accessory renal artery should be evaluated [9].

In the evaluation of renal vascular structures; Digital subtraction angiography (DSA), doppler ultrasonography (US), computed tomography angiography (CTA), and magnetic resonance angiography (MRA) are used. Although DSA is the gold standard for evaluating vascular structures, its clinical use is limited due to it is an invasive method and technological advances in non-invasive methods. Although Doppler US provides information about flow velocities and flow patterns and is a dynamic method, it may be inadequate since accessory arteries can be overlooked due to obesity and gas artifacts, and the accessory arteries may be in very small calibration even in suitable patients. MRA is a non-invasive method that can be used in cases such as those with iodine contrast material allergy, pediatric age group, and pregnancy. In addition, it enables the evaluation of vascular structures in patients with renal dysfunction with sequences that do not contain contrast agents such as time of flight (TOF) angiography. CTA is the most commonly used method in the evaluation of renal vascular variations. It has many advantages such as fast acquisition time, high spatial resolution, multiplanar reformat (MPR), three-dimensional reformat, maximum intensity projection (MIP), such as methods that provide a better understanding of vascular anatomy[10].

MATERIALS and METHODS

In this study, a total of 610 abdominal CT examinations registered in the PACS system of our hospital were retrospectively evaluated in terms of renal artery and vein variations. Sixty patients were excluded from the study due to technical factors (inappropriate contrast phase, insufficient contrast enhancement) or conditions that complicated or completely prevented the examination of renal vascular structures (such as solitary kidney, horseshoe kidney, tumor invasion, renal transplant).

All examinations were performed with a 64-slice multidetector CT device (Aquilion; Toshiba Medical Systems, Tokyo, Japan). During the procedure, 80-100 ml of iodinated contrast material was administered at a rate of 4-5 ml/sec with an automatic injector. Scanning was started automatically when the aortic lumen density was 180 HU in the arterial phase. Automatic tube flow modulation and adaptive iterative dose-reducing reconstruction were used to reduce the radiation dose received by the patients. MSCT scanning parameters were set as follows; tube voltage: 120 kV, tube current: 200-440 mAs, collimation: 64x0.5 mm, gantry rotation time: 400 ms, section thickness: 1 mm, cross-section: 1 mm.

The images obtained were transferred to the workstation for further examination and analysis (Aquarius; Tera Recon, Durham, England).

Single renal artery (RA) on both sides was accepted as normal. In the case of more than one RA, it was named "accessory RA" or "multiple RA". In the presence of more than one RA separated by ostia discrete from the aorta, the largest diameter main RA was considered as accessory RA. Accessory arteries were categorized as "hilar" and "polar". Entering the kidney through the hilus was evaluated as the hilar accessory artery, and entering the kidney through the kidney capsule from the non-hilus areas was considered as a polar accessory artery. Branching within the first 2 cm from the aorta wall on the left side and those branching in the retrocaval region on the right were named as "early-branching RA".

Renal vein (RV) anatomy was evaluated in terms of numerical and anastomotic patterns. One RV was evaluated as normal on both sides. The presence of more than one RV was named as "accessory RV" or "multiple RV". The normal course was for the left renal vein to pass in front of the aorta and connects to the inferior vena cava. Passing behind the aorta and engage the inferior vena cava was named "retroaortic left RV". Dividing the left renal vein into two parts, dorsal and ventral, wrapping the aorta anteriorly and posteriorly, and draining it into the inferior vena cava was named as "circumaortic left RV". The presence of RV branches converging within 2 cm of the abdominal aortic wall on the left side and 2 cm of the vena cava inferior on the right side was evaluated as "late merging RV".

Statistical analysis was uploaded to the computer environment via SPSS (Statistical Package For Social Sciences for Windows v.25.0, SPSS Inc. Chicago, IL) and evaluated.

Descriptive statistics are presented as mean (±) standard deviation, median (min-max), frequency distribution, and percentage. In addition to descriptive statistics, the chi-square test and Fisher's exact test were used in the comparison of categorical variables. When a significant difference was detected in the comparisons with more than 2 categories of at least one variable (except 2x2), the groups were compared in pairs to determine the source of the difference, and the significance level was determined according to the Bonferroni correction. Groups that differed after Bonferroni correction were accepted as the source of the difference. McNemar chi-square test was used to compare categorical variables independent groups. Statistical significance level was accepted as $p < 0.05$.

RESULTS

A total of 550 patients who underwent abdominal computed tomography in the radiology unit of our hospital were examined within the scope of the study. 54.7% (n = 301) of the patients were male, while 45.3% (n = 249) were female. The average age of the participants is 57.7 ± 14.3, and the median is 59.0 (min19-max86).

In 28.3% (n = 156) of 550 cases, there was unilateral or bilateral renal artery variation. The most common artery variations were the right hilar accessory artery (22.4%) and the left hilar accessory artery (21.2%).

Right accessory hilar artery was observed in 11.2% (n=62) of the cases (one in 58, two in 3, and four in 1 of them). Right accessory polar artery rate was 4.7% (n = 26) of the cases(one in 25, two in 1 of them). Early-branching in the right renal artery was present in 3.8% (n = 21) of the cases. The precaval renal artery was observed in 0.6% (n = 3) of the patients (one in 2, three in 1 of them). Left accessory hilar artery was observed in 9.6% of the cases (n = 53) of the cases (one in 50, two in 3 of them). The incidence of left accessory polar artery was 3.7% (n = 20, one in 19, two in 1 of them). Early-branching in the left renal artery was 4.4% (n = 24) and early-branching in the right renal artery was 3.8% (n = 21).

26.5% (n = 146) of 550 cases have unilateral or bilateral renal vein variation. The most common vein variations were the right multiple renal veins (26.7%) and right gonadal vein opening to the right renal vein (15.1%).

A significant difference was found between the right hilar accessory renal artery, the left polar accessory renal artery, and the late fusion of the left renal vein according to gender ($p < 0.05$). Right hilar accessory renal artery was seen with a frequency of 15.0% in men and 6.8% in women, and it was significantly higher in men ($p = 0.003$). Left polar accessory renal artery was seen with a frequency of 5.6% in men and 1.2% in women and significantly higher in men ($p = 0.006$). Late fusion in the left renal vein was seen with a frequency of 6.3% in men and 2.0% in women and significantly higher in men ($p = 0.014$). No significant difference was found in other comparisons ($p > 0.05$).

While 37.8% of those with artery variation have at least one vein variation, 40.4% of those with vein variation have at least one artery variation. A statistically significant correlation was found between the presence of vein variation according to the presence of artery variation and the state of artery variation according to the presence of vein variation ($p < 0.001$).

DISCUSSION

It has great importance to reveal the renal vascular anatomy and determine the variations before the procedures such as renal transplantation, endovascular procedures such as stent placement, abdominal aortic aneurysm reconstruction surgeries, and in investigating the etiology of renovascular hypertension [11]. In addition, it is known that rejection rates after transplantation are lower in kidneys without accessory arteries [12].

It was found that 243 (44.2%) of 550 patients evaluated in our study had at least one artery or vein variation. Of these, only arterial variation was observed in 97 of them, only vein variation in 87 of them, and both artery and vein variation were detected in 59 of them.

The frequency of accessory renal artery varies between 9% and 76% in the literature, and it has been reported to be between 28% and 30% in anatomical and cadaver studies 13-15. This rate was found to be 24% in the study conducted by Özkan et al, and 31.3% in the study by Çınar C. and Türkvatan A. [14, 16.] We found the frequency of accessory renal artery to be 29.3% (Table 1). The prevalence was within the ranges reported in the literature. Accessory arteries originate most frequently from the aorta [17]. All of the accessory arteries in our study originate from the abdominal aorta. Accessory renal artery was detected in 88/550 (16%) on the right side and 73/550 (13.2%) on the left side (Table 2). As in the studies conducted by Özkan U. et al, Holden et al, Uğurel et al, it was found that the variation of the accessory renal artery was higher on the right side[14,18,19].

The hilar artery was observed in 115 (71.4%) of our 161 patients with accessory renal artery, and 46 (28.6%) polar artery. In the study by Çınar C. and Türkvatan A., the hilar artery ratio was 84.5%, and the polar artery ratio was 15.5% [16]. The hilar accessory artery was found in 115 patients (one in 108, two in 6, and four in 1 of them). Polar accessory artery was observed in 46 patients (one in 44, two in 2 of them)(table 1). In our study, the hilar artery was observed bilaterally at a frequency of 12.2% (14/115) and the polar artery at a frequency of 15.2% (7/46)(Table 2).

In renal transplantation operations, renal arterial dissection is performed 1.5-2cm distal to the aorta to control hemorrhage more easily and to create a more suitable anastomosis line for the recipient. In order to avoid complications during this procedure, the presence of early branching in the renal arteries should be known. In the literature, the frequency of early branching in the renal artery varies between 4.3 -13% [4, 18, 20]. In our study, the prevalence was found to be 8.2% (Table 1). In the study of Raman et al, it was stated to be 15% on the right and 21% on the left, while in our study it was found to be 3.8% on the right and 4.4% on the left [21]. The rates in our study are lower than those in the studies conducted by Holden et al, Raman et al and Özkan et al. The reason for this was accepted as early-branching in our study, within the first 2 cm after separation of the renal artery from the aorta; In these studies, early-branching may be considered as the onset of branching at any point before the renal artery enters the hilus[14, 18, 21]. In the study of Çınar C. and Türkvatan A., in which early-branching is accepted as the branching of the renal artery within the first 2 cm of the aortic origin, as in our study; Early branching rate in the renal artery was found to be 6.5% (2.6% on the right and 3.7% on the left) [16]. These values are in parallel with those in our study. Of our 43 patients with early-branching in the renal artery, 41 (95.3%) were unilateral, and 2 (4.7%) were bilateral (Table 2). This rate was found to be 97% (32/33) unilateral and 3% (1/33) bilateral in the study of Çınar C. and Türkvatan A[16].

Table 1. Distribution of renal artery variation states

(n=550)		n	%
Right accessory hilar artery			
	None	488	88,7
	1	58	10,5
	2	3	0,5
	4	1	0,2
Right accessory polar artery			
	None	524	95,3
	1	25	4,5
	2	1	0,2
Right early-branching renal artery			
	None	529	96,2
	1	21	3,8
Right precaval artery			
	None	547	99,5
	1	2	0,4
	3	1	0,2
Left accessory hilar artery			
	None	497	90,4
	1	50	9,1
	2	3	0,5
Left accessory polar artery			
	None	530	96,4
	1	19	3,5
	2	1	0,2
Left early-branching renal artery			
	None	526	95,6
	1	24	4,4

Table 2. Laterality distribution of renal artery variations

(n=186)		Unilateral		Bilateral	
		n	%	n	%
	Hilar artery	87	86,1	14	13,9
	Polar artery	32	82,0	7	18,0
	Early-branching	41	95,3	2	4,7
	Precaval	3	100,0	-	

The normal right renal artery passes posterior to the IVC. However, precaval renal artery variation can also be seen and its prevalence has been reported between 0.8-5% [22, 23]. Its frequency in our study is 0.6% (3/550). While one precaval renal artery was observed in two of these patients, there were three precaval renal arteries in one patient (Table 1). In the study conducted by Maxwell et al, it has been reported that precaval renal artery variation is accompanied by increased kidney size, double collecting system, "crossed-fused" renal ectopia, and other renal artery variations [24]. In our study, in three patients with precaval renal artery variation, one had an accompanying right hilar accessory artery, and the other two had an accompanying bilateral hilar accessory artery variation.

As in many studies in the literature, the most common renal vein variation in our study was found to be the right multiple renal veins[8,18,21, 25]. In their studies, Koc et al 14.3%, Raman et al 24%, Çınar C. and Türkvatan A. 21.6% reported right multiple renal veins [21, 25]. In our study, this rate was found to be significantly lower than the literature, and it was 9.8%. Of the 54 patients with multiple right renal veins, 51 (94.4%) had 2 renal veins, and 3 (5.6%) had 3 renal veins (Table 3). In the study conducted by Çınar C. and Türkvatan A., 2 renal veins were observed in 88.8%, 3 in 10.2%, and 4 in 1% [16].

Table 3. Right and left renal vein variations

(n=550)		n	%
Multiple right renal vein			
	None	496	90,2
	1	51	9,3
	2	3	0,5
Involvement of the gonadal vein in the right renal vein			
	None	523	95,1
	1	27	4,9
Late fusion of the right renal vein			
	None	540	98,2
	1	10	1,8
Multiple left renal vein			
	None	546	99,3
	1	4	0,7
Retroaortic left renal vein			
	None	525	99,4
	1	25	4,6
Circumaortic left renal vein			
	None	527	95,8
	1	23	4,2
Late fusion of the left renal vein			
	None	526	95,6
	1	24	4,4

In our study, the retroaortic renal vein was observed with a rate of 4.6% (25/550), and the circumaortic renal vein was 4.2% (23/550) (Table 4). The retroaortic renal vein was observed with a rate of 4.6% and the circumaortic renal vein was 5.5% in a study conducted by Koc et al [25]. In the study conducted by Raman et al with 126 renal donors, the retroaortic renal vein was observed at a rate of 2% and the circumaortic renal vein at 8% [21]. The rates in our study are found to be similar to the literature. While the most common venous variation on the right is multiple renal veins, the most common venous variation on the left is the circumaortic renal vein [8, 18, 21, 25]. In our study, although with a very small difference, the most common renal venous variation on the left was detected as the retroaortic renal vein, and the second most common renal venous variation was circumaortic vein.

Late fusion of renal veins has not been identified in many studies on variations in renal vascular structures. In two studies in the literature, the late union rate in the right renal vein was 4-10%, and the late union rate in the left renal vein was 3.2-17% [16, 21]. In our study, this rate was found to be 1.8% on the right and 4.4% on the left. It is observed that 31 (96.9%) of 32 patients with late fusion in the renal vein were unilateral and 1 (3.1%) was bilateral (Table 3).

No significant difference was found in the prevalence of renal artery and vein variation by gender in the studies in the literature [8, 14, 16, 25]. Generally, when looking at all renal vascular variations by gender, no significant difference was found in the frequency of renal artery and vein variations in our study (artery; p = 0.1, vein; p = 0.237). In the literature, it has been observed that each renal vascular variation has not been compared specifically by gender. In our study, when we evaluated the variations one by one, we found that the incidence of right hilar accessory renal artery, left polar accessory renal artery, and late fusion in the left renal vein was statistically significantly higher in males compared to females (respectively, p values; p = 0.003, p = 0.006, p = 0.014). The data we have obtained has the feature of being the first in this regard in the literature (Table 4).

Table 4. Comparison of the renal artery and renal vein variations by gen-

		Gender				p*
		Man		Woman		
		n	%	n	%	
Right Renal Hilar Artery						
	None	256	85,0	232	93,2	0,003
	Exist	45	15,0	17	6,8	
Right Renal Polar Artery						
	None	285	94,7	239	96,0	0,475
	Exist	16	5,3	10	4,0	
Right Early-Branching Renal Artery						
	None	288	95,7	241	96,8	0,500
	Exist	13	4,3	8	3,2	
Right Precaval Renal Artery						
	None	300	99,7	247	99,2	0,455
	Exist	1	0,3	2	0,8	
Left Renal Hilar Artery						
	None	267	88,7	230	92,4	0,147
	Exist	34	11,3	19	7,6	
Left Renal Polar Artery						
	None	284	94,4	246	98,8	0,006
	Exist	17	5,6	3	1,2	
Left Early-Branching Renal Artery						
	None	285	94,7	241	96,8	0,230
	Exist	16	5,3	8	3,2	
Right Multiple Renal Veins						
	None	271	90,0	225	90,4	0,898
	Exist	30	10,0	24	9,6	
Involvement of the gonadal vein in the right renal vein						
	None	283	94,0	240	96,4	0,201
	Exist	18	6,0	9	3,6	
Right Renal Vein Late Fusion						
	None	294	98,0	246	98,8	0,465
	Exist	6	2,0	3	1,2	
Left Multiple Renal Veins						
	None	299	99,3	247	99,2	1,000 ¶
	Exist	2	0,7	2	0,8	
Left Retroaortic Renal Vein						
	None	291	96,7	233	94,0	0,127
	Exist	10	3,3	15	6,0	
Left Circumaortic Renal Vein						
	None	285	94,7	242	97,2	0,144
	Exist	16	5,3	7	2,8	
Left Renal Vein Late Fusion						
	None	282	93,7	244	98,0	0,014
	Exist	19	6,3	5	2,0	

%: percentage of column *: Pearson Ki kare has been applied. ¶: Fisher's exact test has been used

Development of the renal arteries and veins occurs simultaneously as the kidneys exit the pelvis to their final positions. Therefore, it is predictable that the presence of arterial or venous variation on either side may lead to the development of arterial or venous variation on the same or opposite side. However, there is no study in the literature showing the association of renal arterial and venous variations. In our study, it was observed that in 59 (24.3%) of 243 patients with artery or vein variations, artery and vein variations were together. In general, the rate of occurrence of artery and vein variations together was found to be 10.7%. Among these, the most common ones are the coexistence of five (0.09%) patients with the right hilar accessory artery-right multiple renal veins, and the right hilar accessory artery-left circumaortic renal vein. The rate of these in cases where renal artery and vein variations are seen together is 17%. According to the Mcnemar chi-square test, a statistically significant correlation was found between the presence of renal vein variation according to the presence of renal artery variation and the presence of renal artery variation according to the presence of renal vein variation (p <0.001) (Table 5).

Limitations of our study;

Table 5. Comparison of the presence of vein variation according to the state of artery variation

(n=550)		Vein Variation				
		None		At least one		p*
		n	%	n	%	
	Arter variation					
	None	307	77,9	87	22,1	<0,001
	At least one	97	62,2	59	37,8	

*: Mcnemar Ki Kare has been applied

Since our study was retrospective, the effect of renal vascular variations on life expectancy could not be evaluated.

Although the number of patients is higher than similar studies in the literature, multicenter studies with more patients may provide additional information.

Conclusion

Renal vascular variations are seen in 44.2% of the population. In addition, the arterial and venous variations show a substantial coexistence, such as 10.7%. Incidence of right hilar accessory renal artery, left polar accessory renal artery, and late fusion in the left renal vein was statistically significantly higher in males compared to females. It should be known that its presence is extremely important before endovascular interventional procedures and surgical procedures and during the investigation of renovascular hypertension, pelvic varices and varicocele etiology.

REFERENCES

1. Moore KL, Persaud TVN. Human embryology with its clinical aspects. Nobel Medicine Bookstore. 2008;second edition.
2. Tao XF, Zhu JQ, Wu YW, et al. Dual-energy computed tomography angiography for evaluating the renal vascular variants. *Chinese medical journal.* 2013;126:650-654.
3. Hussain SM, Kock MC, JN IJ, Pattynama PM, Hunink MG, Krestin GP. MR imaging: a "one-stop shop" modality for preoperative evaluation of potential living kidney donors. *Radiographics : a review publication of the Radiological Society of North America, Inc*. 2003;23:505-520.
4. Rydberg J, Kopecky KK, Tann M, et al. Evaluation of prospective living renal donors for laparoscopic nephrectomy with multisection CT: the marriage of minimally invasive imaging with minimally invasive surgery. *Radiographics : a review publication of the Radiological Society of North America, Inc*. 2001;21 Spec No:S223-236.
5. Yesildag A, Adanir E, Koroglu M, Baykal B, Oyar O, Gulsoy UK. Prevalance of left renal vein anomalies in routine abdominal CT. *Diagnostic and Interventional Radiology*. 2004;10:140-143.
6. Vazquez R, Garcia L, Morales-Buenrostro L, Gabilondo B, Alberu J, Vilatoba M. Renal grafts with multiple arteries: a relative contraindication for a renal transplant? *Transplantation Proceedings*. 2010;42:2369-2371.
7. Hazirolan T, Oz M, Turkbey B, Karaosmanoglu AD, Oguz BS, Canyigit M. CT angiography of the renal arteries and veins: normal anatomy and variants. *Diagnostic and Interventional Radiology (Ankara, Turkey).* 2011;17:67-73.
8. Kawamoto S, Montgomery RA, Lawler LP, Horton KM, Fishman EK. Multi-detector row CT evaluation of living renal donors prior to laparoscopic nephrectomy. *Radiographics : a review publication of the Radiological Society of North America, Inc*. 2004;24:453-466.
9. Chan PL, Tan FHS. Renin dependent hypertension caused by accessory renal arteries. *Clinical Hypertension*. 2018;24:15.
10. Al-Katib S, Shetty M, Jafri SM, Jafri SZ. Radiologic Assessment of Native Renal Vasculature: A Multimodality Review. *Radiographics : a review publication of the Radiological Society of North America, Inc*. 2017;37:136-156.
11. Hänninen EL, Denecke T, Stelter L, et al. Preoperative evaluation of living kidney donors using multirow detector computed tomography: comparison with digital subtraction angiography and intraoperative findings. *Transplant international : official journal of the European Society for Organ Transplantation*. 2005;18:1134-1141.
12. Budhiraja V, Rastogi R, Asthana AK. Renal artery variations: embryological basis and surgical correlation. *Romanian journal of morphology and embryology = Revue Roumaine de Morphologie et Embryologie*. 2010;51:533-536.
13. Khamanarong K, Prachaney P, Utraravichien A, Tong-Un T, Sripaoraya K. Anatomy of renal arterial supply. *Clinical Anatomy (New York, N.Y.).* 2004;17:334-336.
14. Ozkan U, Oguzkurt L, Tercan F, Kizilkilic O, Koc Z, Koca N. Renal artery origins and variations: angiographic evaluation of 855 consecutive patients. *Diagnostic and Interventional Radiology (Ankara, Turkey).* 2006;12:183-186.
15. Satyapal KS, Haffejee AA, Singh B, Ramsaroop L, Robbs JV, Kalideen JM. Additional renal arteries: incidence and morphometry. *Surgical and Radiologic Anatomy : SRA.* 2001;23:33-38.
16. Cinar C, Turkvatan A. Prevalence of renal vascular variations: Evaluation with MDCT angiography. *Diagnostic and Interventional Imaging*. 2016;97:891-897.
17. Dhar P, Lal K. Main and accessory renal arteries--a morphological study. *Italian journal of anatomy and embryology = Archivio Italiano di Anatomia ed Embriologia*. 2005;110:101-110.
18. Holden A, Smith A, Dukes P, Pilmore H, Yasutomi M. Assessment of 100 live potential renal donors for laparoscopic nephrectomy with multi-detector row helical CT. *Radiology*. 2005;237:973-980.
19. Ugurel MS, Battal B, Bozlar U, et al. Anatomical variations of hepatic arterial system, coeliac trunk and renal arteries: an analysis with multidetector CT angiography. *The British Journal of Radiology*. 2010;83:661-667.
20. Kim JK, Park SY, Kim HJ, et al. Living donor kidneys: usefulness of multi-detector row CT for comprehensive evaluation. *Radiology*. 2003;229:869-876.
21. Raman SS, Pojchamarnwiputh S, Muangsomboon K, Schulam PG, Gritsch HA, Lu DS. Surgically relevant normal and variant renal parenchymal and vascular anatomy in preoperative 16-MDCT evaluation of potential laparoscopic renal donors. *American Journal of Roentgenology*. 2007;188:105-114.
22. Petit P, Chagnaud C, Champsaur P, Faure F. Precaval right renal artery: have you seen this? *AJR. American Journal of Roentgenology*. 1997;169:317-318.
23. Yeh BM, Coakley FV, Meng MV, Breiman RS, Stoller ML. Precaval right renal arteries: prevalence and morphologic associations at spiral CT. *Radiology*. 2004;230:429-433.
24. Meng MV, Yeh BM, Breiman RS, Schwartz BF, Coakley FV, Stoller ML. Precaval right renal artery: description and embryologic origin. *Urology*. 2002;60:402-405.
25. Koc Z, Ulusan S, Oguzkurt L. Association of left renal vein variations and pelvic varices in abdominal MDCT. *European Radiology*. 2007;17:1267-1274.