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Evaluation of left renal vein and IVC variations in MDCT examinations performed in patients with a preliminary diagnosis of renal calculi

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Ethics Committee Approval
The study was approved by the Ethical Committee of Haseki Research and Training Hospital, 14.12.2022, 208-2022.
All procedures in this study involving human participants were performed in accordance with the 1964 Helsinki Declaration and its later amendments.

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No conflict of interest was declared by the authors.

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Abstract

Background/Aim: Left renal vein (LRV) and inferior vena cava (IVC) variations are not rare, an observation that is extremely important to understanding the presence of these structures before performing surgery. This study aimed to evaluate the type and frequency of IVC and LRV variations with multi-detector computer tomography (MDCT) in patients admitted with a preliminary diagnosis of renal calculi and to evaluate the relationship of these variations with renal calculi, renal cysts, and horseshoe kidneys.

Methods: We retrospectively analyzed 1640 patients who underwent abdominal CT for suspicious renal calculi between January 2018 and December 2019. This retrospective cohort study consisted of 1604 patients after the exclusion criteria. Renal surgery and/or renal agenesis examinations without enough diagnostic quality due to motion artifacts were considered the exclusion criteria. Age, gender, presence and types of IVC and renal variations, and presence of renal calculi, renal cysts, and horseshoe kidney were recorded. The relationship between variation types and presence of renal calculi, renal cysts, and horseshoe kidneys was evaluated.

Results: IVC and LRV variations were detected in 107 patients (6.7%). The prevalence of circumaortic LRV (CLRV) and retroaortic LRV (RLRV), left IVC, and double IVC in 65 patients was 4.1%, 2.4%, 0.1%, and 0.1%, respectively. Male gender predominance in both total and RLRV were found in the variations (P=0.033 and P=0.033, respectively). Urinary calculi were found in 1016 (63.3%) of the patients, kidney cysts in 247 (15.4%), and horseshoe kidneys in 10 (0.6%). No correlation between the presence of renal calculi, kidney cysts, and horseshoe kidney and the presence of variations in patients with LRV was found (P=0.433, P=0.215, and P=0.500, respectively).

Conclusions: LRV and IVC variations are not uncommon. It is necessary to be informed about these variations before performing retroperitoneal surgery to prevent possible complications. LRV and IVC variations can be easily recognized in pre-diagnosed renal calculi on MDCT without the use of an intravenous contrast agent.

Keywords: inferior vena cava, left renal vein, renal stone disease, computed tomography, retroaortic, circumaortic

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Introduction

Embryonic development of the bilateral renal vein (RV) and inferior vena cava (IVC) occurs between the fourth and eight weeks of the intrauterine period, and development of each structure is closely related [1]. Variations in the anastomoses of the supracardinal, subcardinal, and cardinal veins during embryonic development cause RV and IVC variations [2]. The most common left RV (LRV) variations are circumaortic LRV (CLRV) and retroaortic LRV (RLRV), and their incidence is reported as 10.2% in the literature. The most common IVC variations are IVC duplication and left-sided IVC with a rate of 0.5% as reported in the literature [3,4].

Prior to performing retroperitoneal surgery, interventional vascular procedures, and donor nephrectomies for transplantation, it is vital to identify RV and IVC variations. Moreover, this situation becomes even more critical in laparoscopic surgeries in which vascular repair is more challenging compared to open surgeries [3,5,6]. Therefore, the surgeon performing the laparoscopy should be aware of possible vascular variations in this region to avoid unnecessary blood loss or transition to conventional surgery [7,8]. RV variations are usually asymptomatic and are detected incidentally during radiological examinations, retroperitoneal surgery, or interventional procedures [5]. Multi-detector computed tomography (MDCT) evaluation of the RV and its variations is a fast, easy-to-apply, and preferred imaging method.

This study aimed to evaluate the type and frequency of LRV and IVC variations with MDCT in patients who received a preliminary diagnosis of renal calculi and to investigate the possible relationship of these variations with gender differences and other accompanying kidney pathologies and variations (renal calculi, renal cyst, horseshoe kidney). As far as we know, our study is the first in the literature to evaluate the frequency of renal variations in all patients presenting with a preliminary diagnosis of renal calculi.

Materials and methods

Study population and study design

All patients admitted for renal calculi in our hospital's Radiology Department between January 2018 and December 2019 and referred for non-contrast abdominal CT were included in this study. The study was conducted based on the ethical standards stated in the Declaration of Helsinki, and the study was approved by the ethics committee of Haseki Training and Training hospital (Decision Number: 208-2022). Informed consent was waived from the participants due to the retrospective design of the study.

A total of 1640 patients were included in the study. Exclusion criteria were a history of renal operation (right n=12, left n=8), renal agenesis (left n=1, right n=1), examinations without enough diagnostic quality due to motion artifacts (n=14). The final study population consisted of 1604 patients.

Computed tomography imaging protocol

Abdominal CT examination was performed using a 128-detector CT device in standard calculi protocol (PHILIPS Ingenuity). Oral and intravenous (IV) contrast material was not used since the examination was performed with a preliminary diagnosis of renal calculi and based on the calculi protocol. Specific scanning parameters were used: (1) tube voltage was 100 Kv, (2) tube current 150 mAs, (3) pitch was 1.441, and (4) gantry rotation time was 0.4 sec. The evaluation was based on axial images or sagittal and coronal multi-planar reformat (MPR) images from axial images in necessary cases. Images were analyzed by two radiologists with 16 years of CT experience.

Image analysis

The LRV crosses the aorta anteriorly and extends to the IVC and was evaluated as a normal preaortic LRV. The LRV passing behind the aorta and draining into the IVC was defined as RLRV and CLRV when the LRV drained into the IVC by forming a loop both behind and in front of the aorta. The placement of the IVC on the right side of the aorta in the axial images was considered to be structurally normal. If the IVC had one branch on each side of the aorta, it was defined as a double IVC. The demographic characteristics of the patients, the presence of renal, ureteral, and bladder calculi, renal cysts, and horseshoe kidneys were noted.

Statistical analysis

The SPSS 15.0 for Windows (SSPS Inc. Chicago, İlinois, USA) program was used for statistical analysis. Descriptive statistics were presented as numbers and percentages for the categorical variables and as mean, standard deviation, and minimum and maximum values for numerical variables. The rates in the groups were compared with the chi-squared test. The alpha significance level was set at 0.05.

Results

A total of 1604 patients with 595 females (37.1%) and 1009 males (62.9%) were included in the study. The ages of the patients ranged from 0 to 89 years (mean age [SD], 44.7 [15.5]) as shown in Table 1.

IVC and LRV variations were detected in 107 patients (6.7%) and RLRV in 65 patients (4.1%) as shown in Figure 1, CLRV in 38 patients (2.4%) as shown in Figure 2a and b), left IVC in two patients (0.1%) as shown in Figure 3a and b, and double IVC in two patients (0.1%) as shown in Figure 4a and b. The presence of total variations in the male gender was significantly higher than in the female gender (27 females [4.5%] versus 80 males [7.9%]; *P*=0.033). When subgroups were evaluated, RLRV was higher in men than in women (16 females versus 49 males; *P*=0.033). All four IVC variations in the study were observed in males (Table 2).

Table 1: Distribution of patients by gender

		Gender		
	n	**Female**	**Male**	***P*-value**
n (%)	1604	595 (37.1)	1009 (62.9)	
Age; Mean (SD) (Min-Max)	44.7 (15.5) (0-89)	45.7 (15.5) (12-88)	44.1 (15.4) (0-89)	0.045

Table 2: Renal vein anomalies distribution of the gender

n=1604		**Gender**		
	Total	**Female**	**Male**	***P*-value**
LRV variation n (%)				
Retroaortic LRV	65 (4.1%)	16 (2.7%)	49 (4.9%)	0.033
Circumaortic LRV	38 (2.4%)	11 (1.8%)	27 (2.7%)	0.293
IVC variation n (%)				
Left IVC	2 (0.1%)	0 (0.0%)	2 (0.2%)	0.533
Double IVC	2 (0.1%)	0 (0.0%)	2 (0.2%)	0.533
Total variation n (%)	107 (6.7%)	27 (4.5%)	80 (7.9%)	0.009

IVC: inferior vena cava, LRV: Left renal vein

Figure 1: 55-year-old female patient, axial multi-detector computed tomography (MDCT) image reveals the retroaortic left renal vein (RLRV) traveling posterior to the aorta (arrows).

Figure 2: Sixty-one -year-old male patient, axial MDCT images reveal the preaortic and retroaortic segments of the circumaortic left renal (CLRV) (arrows). The right kidney is atrophic, and a calculi image is revealed in the left renal pelvis.

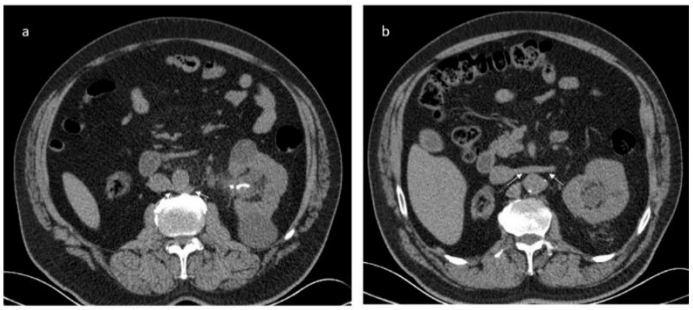


Figure 3: Sixty-seven-year-old male patient, right and left inferior vena cava (IVC) are revealed on a) coronal multi-planar reformat (MPR) b) axial MDCT images (arrows).

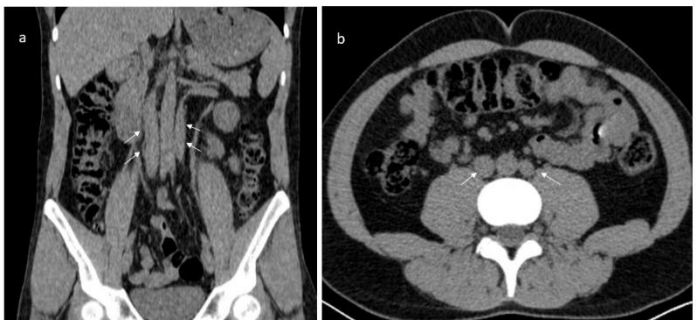
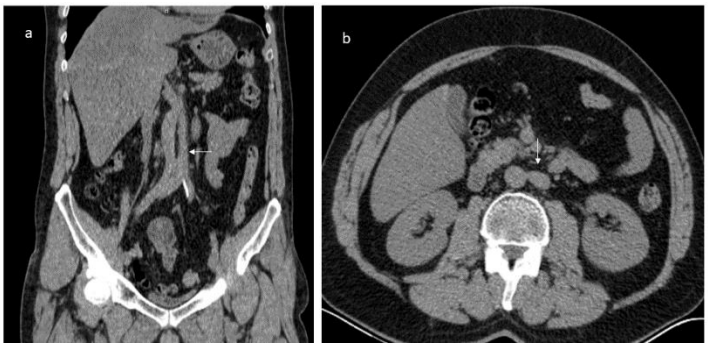


Figure 4: Forty-nine--year-old female patient with left transpositioned IVC (arrows) on a) coronal and b) axial MPR MDCT images.



Calculi were detected in the urinary system in 1016 (63.3%) patients. Of these, 839 (52.3%) had kidney calculi, 415 (25.9%) had ureteral calculi, and 51 (3.2%) had bladder calculi. Renal cysts were detected in 247 (15.4%) patients and horseshoe kidneys in 10 patients (0.6%). The incidence of calculi and cysts in males was significantly higher than in females (P<0.001 and P=0.017, respectively) as shown in Table 3.

No correlation was found between the presence of renal calculi, kidney cysts, and horseshoe kidneys with the presence of variation in patients with left renal variation (P=0.433, P=0.215, and P=0.500, respectively) as shown in Table 4. When the left RV variations were evaluated according to subgroup classifications as RLRV and CLRV, no significant correlation was found between the presence of kidney calculi and the presence of variation (P=0.179 and P=0.345, respectively) as shown in Table 5.

Table 3: Renal stone disease, cyst, and horseshoe kidney distribution of the gender

n=1604		Gender		
	Total	Female	Male	*P*-value
Calculi n (%)	1016 (63.3%)	329 (55.3%)	687 (68.1%)	<0.001
Kidney	839 (52.3%)	284 (47.7%)	555 (55.0%)	
Ureter	415 (25.9%)	108 (18.2%)	307 (30.4%)	
Bladder	51 (3.2%)	7 (1.2%)	44 (4.4%)	
Cyst n (%)	247 (15.4%)	75 (12.6%)	172 (17.0%)	0.017
Horseshoe kidney n (%)	10 (0.6%)	3 (0.5%)	7 (0.7%)	0.753

Table 4: Relationship between renal veins variations and calculi, horseshoe kidney, and renal cysts

	Renal vein variation		
	No	Yes	
	n (%)	n (%)	*P*-value
Calculi	952 (63.6%)	64 (59.8%)	0.433
Kidney	785 (52.4%)	54 (50.5%)	
Ureter	396 (26.5%)	19 (17.8%)	
Bladder	48 (3.2%)	3 (2.8%)	
Horseshoe kidney	9 (0.6%)	1 (0.9%)	0.500
Cyst	235 (15.7%)	12 (11.2%)	0.215

Table 5: Relationship between retroaortic LRV and circumaortic LRV with calculi

	Renal vein variation				
	Retroaortic LRV	Circumaortic LRV	No		
	n (%)	n (%)	n (%)	*P*1	*P*2
Calculi	36 (55.4%)	27 (71.1%)	952 (63.6%)	0.179	0.345
Kidney	31 (47.7%)	22 (57.9%)	785 (52.4%)	0.453	0.506
Ureter	9 (13.8%)	10 (26.3%)	396 (26.5%)	0.023	0.985
Bladder	2 (3.1%)	1 (2.6%)	48 (3.2%)	1.000	1.000

*P*1: retroaortic LRV versus control, *P*2: circumaortic LRV versus control

Discussion

In our patient group consisting of 1604 patients, all had a pre-diagnosis of renal calculi, and we detected 107 RV and IVC variations in total with as RVLV in 65 patients (4.1%), CLRV in 38 patients (2.4%), double IVC in two patients (0.1%), and left IVC in two patients (0.1%). Male gender predominance in both total and RLRV in the variations was noted. We did not determine a significant relationship when the relationship between IVC and LRV variations with renal calculi, cysts, and horseshoe kidneys were evaluated.

IVC and the LRV are formed as a result of anastomoses and regressions of three pairs of precursor veins, namely the subcardinal, supracardinal, and posterior cardinal veins, that occurs between the fourth and eighth weeks of intrauterine life [9]. The anastomoses of the supracardinal and subcardinal veins form the RVs. The left part of the circumaortic venous ring has a ventral and a dorsal arm, and the dorsal arm atrophies during normal development. The development of the ventral arm forms the normal preaortic vein. If the ventral arm regresses, the dorsal arm continues to develop, RVLV occurs, and if both fail to regress, CVLV occurs. Dysfunction in left supracardinal vein regression results in double IVC formation, and right supracardinal vein regression dysfunction causes left IVC formation [1,7,10]. A wide range of LRV and IVC variations have been demonstrated in the literature. Dilli et al. [11] determined the rates of RLRV and CRLV as 2.68% and 1.66%, respectively, in their study involving 1204 patients. The computed tomography/magnetic resonance imaging (CT/MRI) study in which Şahin et al. [12] evaluated 2189 patients reported RLRV at a rate of 2% and CLRV at 0.3%. Özgül et al. [7] revealed the frequency of RLRV and CLRV to be 1.1% and 0.3%, respectively, in their study, which examined 8517 patients.

Ayaz et al. reported these rates as RLRV 5.85% and CLRV 3.15% in their positron emission tomography/computed tomography (PET/CT) study in which they evaluated 222 patients [13]. Arslan et al. examined 10,124 patients, and they determined these rates to be 3.9% and 1.9%, respectively [5]. In the general population, left IVC has been defined as 0.2% to 0.5% and double IVC as 0.2% to 3% [2]. Almost all of the aforementioned studies were performed using CT or MRI with contrast administration. Although all patients in our study presented with a specific preliminary diagnosis, such as renal colic, the percentages of IVC and RV variations in our study were close to other studies in the literature.

While studies reporting no relationship between left RV variations and gender have been published, Dilli et al. [3,11] found RLRV more frequently in women than in men [7,14]. In our study, however, the total variation and amount of RLRV were statistically higher in males than females, a result that is different from the literature in this sense. This condition may be related to characteristics of our patient population.

Variations in IVC and LRV rarely present clinically. They are mainly detected incidentally during imaging, surgery, and/or autopsy [7]. Although such variations are mostly asymptomatic, their detection before retroperitoneal surgery is vital. Missing it prior to surgery may lead to nephrectomy, bleeding, and even death during retroperitoneal surgery [7,8]. Since the length of the LRV is longer than the right, this type of variation is preferred in left kidney transplantation. Therefore, the course of the LRV should be known precisely in such an operation [12]. Besides, differential diagnosis of RV variations from retroperitoneal tumors or possible retroperitoneal lymph nodes in patients with renal and testicular tumors is critical [15].

IVC and RV variations can be evaluated using an invasive method, such as venography, in addition to non-invasive methods, such as ultrasonography (US), color Doppler US (CDUS), MRI, and/or CT [16]. US and CDUS are preferred since they are easily accessible and cheaper than other methods, but they may be insufficient in obese patients. Today, multi-detector computed tomography (MDCT) is a non-invasive, reliable method for evaluating abdominal organs and vascular structures [2]. We used non-contrast CT scans in our study because the was performed in patients with a preliminary diagnosis of renal calculi.

Studies in the literature evaluating the relationship between variations and malignancy and renal tumors are available [5,7,8]. However, apart from our study, we could not find any studies evaluating the relationship between variations and renal cysts in the literature. The present study calculated the prevalence of renal cysts as 15.4%. However, we did not find a significant relationship between the described variations and the presence of such cysts.

Our study is the first study in the literature to evaluate the frequency of renal variation in all patients presenting with a preliminary diagnosis of renal calculi. In our study, the total calculi prevalence was calculated as 63.3%. However, when we evaluated patients with variations in both total and subgroups classified as RLRV and CLRV, no significant relationship between variations and the presence of calculi was found. Our study is the second study that investigated the relationship between variations and calculi in the literature. The study of Arslan et al. [5] determined the calculi rate to be 16.4% in a patient population who underwent CT for different indications. While no relationship was observed between renal variations and renal calculi in their study, they demonstrated a significant relationship between left renal calculi and LRV variations in the evaluation while considering subgroups. We think that the reason for the difference between our study and theirs may be related to the fact that we classified subgroups as RLRV and CLRV instead of dividing patient subgroups into right and left kidneys. However our calculi rate is quite high compared to the other study, and our study included 3.2% bladder stones, which we could not attribute to specific kidney issues of the patients.

The horseshoe kidney is the most common type of renal fusion anomaly, and its prevalence has been reported as between 0.1% and 0.3% in the literature [17,18]. In our study, 10 patients in total presented with with horseshoe kidneys, and the prevalence was determined as 0.6%, which is close to the rate stated in the literature. Very few studies evaluating the relationship between horseshoe kidneys, RV, and IVC variation in the literature can be found. Ichikawa et al. detected IVC anomalies more frequently in patients with horseshoe kidneys compared to the normal population [19]. Ichikawa et al. [20] revealed in an another study that the total venous anomaly rate was 28.6% in patients with horseshoe kidneys and evaluated it as higher than the normal population. Leblebisatan et al. [18] reported that the variation rate was 5.18 times higher in patients with horseshoe kidneys of RLRV than those without. In our study, a total of four patients had IVC variation, but these patients did not have a horseshoe kidney. Only one of the patients with horseshoe kidney had a CLRV anomaly. In our study, we did not find a significant relationship between horseshoe kidney and LRV variations unlike results reported in the literature. We thought that this difference might be related to our patient population.

Limitations

Our study has some limitations. First of all, our study is single-centered; thus, it is not community based and may not represent the general population. The retrospective nature is another limitation of the study.

Conclusion

The radiologist needs to be aware of renal and IVC variations to prevent catastrophic complications that may develop in aortic, renal, and retroperitoneal surgeries. The data indicate that the rate of renal and IVC variation in patients with a pre-diagnosis of renal calculi is close to the studies in the literature involving patient groups with miscellaneous complaints.

LRV and IVC variations can be easily recognized in patients with pre-diagnosed renal calculi using MDCT without an IV contrast agent.

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