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ARAŞTIRMA / RESEARCH

Evaluation of the incidence of renal vein anomalies and their relationship with renal stone disease and renal tumors by abdominal multidetector computed tomography

Renal ven anomalilerinin insidansının ve renal taş hastalığı ve renal tümörlerle ilişkisinin abdominal multidedektör bilgisayarlı tomografi ile değerlendirilmesi

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Abstract

Purpose: This study aimed to evaluate the types and incidence of renal vein anomaly (RVA) and their relationship with renal stone disease and renal tumors with multidetector computed tomography (MDCT).

Materials and Methods: We evaluated retrospectively 10124 patients abdominal MDCT images. After the exclusion criteria, the final study population consisted of 9294 patients. The demographic characteristics of the patients, the presence of RVA, the presence of renal stone disease and renal tumor were recorded. RVAs were separated into three subgroups: retroaortic left renal vein (RLRV), circumaortic left renal vein (CLRV), and double right renal vein (DRRV). The presence of renal stone disease and renal tumors were recorded in patients with RVAs.

Results: 1389 cases had RVA (14.9%). RVA was higher in males than females. The prevalence of DRRV, RLRV, and CLRV were 9.5%, 3.9%, and 1.9%, respectively. Renal tumors was detected in 20, and renal stone disease was detected in 243 of 1389 RVA cases, there was no statistically significant correlation. However, a statistically significant correlation was found between left renal stone disease with RLRV and CRLV.

Conclusion: Contrary to popular belief, RVAs are not uncommon. It is very important to know the presence of RVA before retroperitoneal surgery to prevent possible complications. In addition, RLRV and CLRV are thought to be factors that predispose to the development of left renal stone disease.

Keywords:. Renal vein, anomaly, X-ray computed tomography, renal stone disease, renal tumor

Öz

Amaç: Bu çalışmada renal ven anomali (RVA) tiplerinin insidansı ile böbrek taş hastalığı ve böbrek tümörleri ile ilişkisinin çok kesitli bilgisayarlı tomografi (ÇKBT) ile değerlendirilmesi amaçlanmıştır.

Gereç ve Yöntem: 10124 hastanın abdominal ÇKBT görüntüleri retrospektif olarak değerlendirdi. Dışlama kriterleri sonrasında son çalışma popülasyonu 9294 hastadan oluşuyordu. Hastaların demografik özellikleri, RVA varlığı, böbrek taşı hastalığı ve böbrek tümörü varlığı kaydedildi. RVA'lar üç alt gruba ayrıldı: retroaortik sol renal ven (RSRV), sirkumaortik sol renal ven (SSRV) ve çift sağ renal ven (ÇSRV). RVA'lı hastalarda böbrek taşı hastalığı ve böbrek tümörlerinin varlığı kaydedildi.

Bulgular: 1389 olguda RVA (%14.9) vardı. Erkeklerde RVA kadınlara göre daha yüksekti. RSRV, SSRV ve ÇSRV prevalansı sırasıyla %9.5, %3.9 ve %1.9 idi. 1389 RVA vakasının 20'sinde böbrek tümörü ve 243'ünde böbrek taşı hastalığı tespit edildi, istatistiksel olarak anlamlı bir korelasyon yoktu. Ancak sol böbrek taşı hastalığı ile RSRV ve SSRV arasında istatistiksel olarak anlamlı bir ilişki bulundu.

Sonuç: Popüler inanışın aksine, RVA'lar nadir değildir. Olası komplikasyonları önlemek için retroperitoneal cerrahi öncesi RVA varlığının bilinmesi çok önemlidir. Ayrıca RSRV ve SSRV 'nin sol böbrek taşı hastalığının gelişimine zemin hazırlayan faktörler olduğu düşünülmektedir.

Anahtar kelimeler: Renal ven, anomali, X-ray bilgisayarlı tomografi, böbrek taşı hastalığı, böbrek tümörü

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INTRODUCTION

Renal vein anomalies (RVAs) are common and result from errors at the vessels' embryogenesis stage. Although there are various classifications in the literature, RVAs separated into three main subgroups: retroaortic left renal vein (RLRV), circumaortic left renal vein (CLRV), and multiple renal veins (MRV)[1]. Within the main MRV group, the double right renal vein (DRRV) is the most commonly[2]. Although it varies considerably in the literature, the prevalence of RVAs is reported to be between 10% and 15%[3]. The most common RVA, which also varies is reported to be DRRV, (approximately between 2% - 25%)[4].

The embryogenesis of the bilateral renal veins is closely related with the development of the inferior vena cava (IVC) and, it onsets between the 4th and 8th weeks in the in-utero period. In the embryological period, IVC development occurs with the regression or persistence of 3 interrelated parallel veins: posterior cardinal, subcardinal, and supracardinal veins[5]. The renal veins are constituted as a result of the persistence of the anastomosis of the subcardinal and supracardinal veins. While the persistence of the dorsal arch of the renal collar and intersupracardinal anastomosis causes CLRV, the persistence of the intersubcardinal anatomosis and regression of the intersubcardinal anastomosis and ventral arch causes RLRV[5].

It is vitally important to know about the presence of RVA in retroperitoneal operations, donor nephrectomy, and vascular interventions. Especially in laparoscopic retroperitoneal surgeries, this situation becomes more crucial, because the repair of vascular injuries is more onerous than open surgery[3,6]. Awareness of the presence of RVA is also important in the staging of renal tumors.

RVAs are often silent and are detected incidentally in retroperitoneal surgery, interventional procedures, or radiological examinations. Multidetector computed tomography (MDCT) is the most commonly used imaging method in RVA assessment because it has improved spatial-temporal resolution and better z-axis resolution. It has been reported in the literature that some RVAs may be associated with varicocele, nutcracker syndrome, hematuria, and renal ectopia[7,8]. The study investigating the relationship between RVA and renal stone disease and / or renal tumor is not available in the literature as far as we know.

In this study, we aimed to investigate the frequency and type of RVAs and its relationship with renal stone disease and renal tumors in patients examined with MDCT. As far as we know, our study has the largest patient group in the literature. In addition, our study is the initial study to evaluate the relationship between renal stone disease and renal tumors and RVAs.

MATERIALS AND METHODS

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. This retrospective study was conducted in the Radiology Department of Giresun University Training and Research Hospital. Approval for the study was granted by the Clinical Research Ethics Committee of Giresun University (KAEK:2020/95). As a retrospective analysis, informed consent in this study was waived.

In the power analysis performed with reference to the results of the Ozgul et al.[2] study, which evaluated the frequency of RVA, with a test power to be 0.99 by accepting the error as 0.05 required the inclusion of at least 616 patients.

Study population

We evaluated retrospectively 10142 patients images who underwent abdominal MDCT scan due to various abdominal problems between January 2019 and December 2020. Exclusion criteria were those under the age of 18 (n = 252), image artifacts that distort the assessment (n = 189), congenital diseases of the kidneys (n = 161), metabolic disease (n = 109), a history of renal surgery (n = 89), renal anomalies (n = 39) and, situs inversus viscerum (n = 9). The final study population consisted of 9294 patients. This group consisted of 5203 male (M) and 4091 female (F) with an age range of 18–106 years (mean age ± standard deviation [SD], 53.1 ± 19.2 years).

Computed tomography imaging protocol

MDCT examinations were performed while supine with 128-slice dual-energy computed tomography (Revolution EVO, GE Healthcare, Milwaukee, WI). 2084 of 9294 MDCT were obtained without using

contrast material (CM) due to prediagnosis renal stone disease. 7210 of 9294 MDCT were obtained in the venous phase after intravenous CM injection. 80 to 100 mL of non-ionic CM (Gadovist, 370 mg / ml, Bayer Schering, Berlin, Germany) with 0.5 g of iodine per kilogram of body weight was administered at a rate of 4 ml / s, followed by 30 ml of saline solution. The scanning parameters were as follows: tube voltage, 120 kV; tube current, 200 mAs; detector collimation, 64 x 0.625 mm, pitch, 1.0–1.2, gantry rotation time, 0.75 s; and field of view, 350 mm. The multiplanar reconstruction images were obtained from axial MDCT images.

Image analysis

9294 patients MDCT images were transferred to a picture archiving communication system (PACS) and were interpreted by a board-certified radiologist with 9 years of experience in abdominal radiology. The demographic characteristics of the patients (gender and age), the presence of RVA, the presence of renal stone disease and the presence of renal tumor were recorded. RVA was separated into three subgroups: RLRV, CLRV, and DRRV. Renal tumors were divided into 8 main groups: clear type renal cell carcinoma (RCC), chromophobe type RCC, papillary type RCC, cystic RCC, transitional cell carcinoma (TCC), renal lymphoma, oncocytoma and angiomyolipoma. Presence of renal stone disease and / or the presence of renal tumor in patients on same laterality as RVA was recorded.

Statistical analysis

Statistical analyses were performed using with SPSS software (IBM SPSS Statistics for MacOS, Version 25.0. Armonk, NY: IBM Corp.). Percentages of RVA types, descriptive statistics, and frequencies were calculated. The normality of data was assessed using the Kolmogorov Smirnov test. The independent sample t test was used for the comparison of normally distributed data (Frequency of RVA, RVA subtypes, renal stone disease and renal tumor in male and female). The relationship of the categoric variables (RVA with renal stone disease, RVA with renal tumors) with each other was defined using Pearson Chi-square test. The results of quantitative data are presented as mean ± standard deviation. Qualitative data were presented as frequencies (percentage). The level of statistical significance was set as $p < 0.05$.

RESULTS

9294 patients (5203 M and 4091 F; mean age ± SD, 53.1 ± 19.2 years) were included in the study. RVA was detected in a total of 1389 cases (747 M and 642 F), the overall prevalence was 14.9%. RLRV in 361 cases (3.9%) (Figure 1a, b), CLRV in 176 cases (1.9%) (Figure 2a - c), and DRRV in 887 cases (9.5%) (Figure 3a, b) were detected (Figure 4). Both RLRV and DRRV were detected in 19 cases (0.13%), and both CLRV and DRRV were detected in 16 cases (0.11%) (Figure 5a -d). RVA was higher in males than females, but the difference was not statistically significant (747 M, 53.7% vs. 642 F, 46.3%, respectively, $p = 0.073$). When the subgroups are evaluated; CLRV and DRRV were detected more frequently in males than females, but the difference was not statistically significant (95 M vs. 81 F, $p = 0.589$; 499 M vs. 388 F, $p = 0.862$, respectively). RLRV was seen more frequently in female than male and the difference was statistically significant (189 F vs. 172 M, respectively, $p < 0.001$) (Table 1).

Table 1. Renal vein anomalies distribution of the gender

	Male	Female	Total	p
RVA	747 (14.4%)	642 (15.7%)	1389 (14.9%)	0.227
RLRV	172 (3.3%)	189 (4.6%)	361 (3.9%)	**< 0.001**
CLRV	95 (1.8%)	81 (2%)	176 (1.9%)	0.589
DRRV	499 (9.6%)	388 (9.5%)	887 (9.5%)	0.862
RLRV + DRRV	9 (0.02%)	10 (0.03%)	19 (0.13%)	0.565
CLRV + DRRV	9 (0.02%)	7 (0.02%)	16 (0.11%)	0.623

*$p < 0.05$ were taken as statistically significant and significant p values have been highlighted in bold.
RVA = renal vein anomaly, RLRV = retroaortic left renal vein, CLRV = circumaortic left renal vein, DRRV = double right renal vein

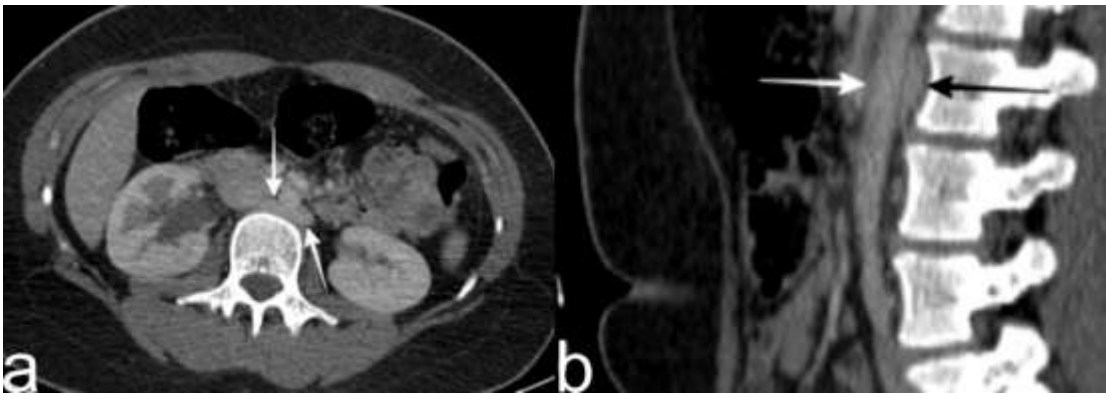

Figure 1. A 37-year-old female patient. a. Axial multidedector computed tomography (MDCT) images demonstrate retroaortic left renal vein (RLRV) (white arrows). b. Sagittal multiplanar reconstruction (MPR) images show RLRV (black arrow). Aorta is seen in front of the RLRV (white arrow).

Figure 2. A 43-year-old male patient. a, b. Axial MDCT and c. sagittal multiplanar reconstruction (MPR) images demonstrate anterior and retroaortic segments of circumaortic left renal vein (CLRV) (white arrows) around the aorta.

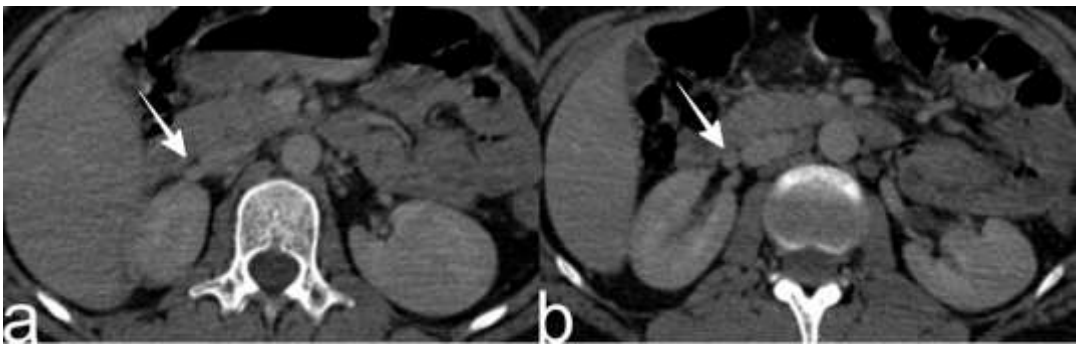

Figure 3. A 32-year-old female patient. a, b. Axial MDCT images show double right renal vein (DRRV) (white arrows).

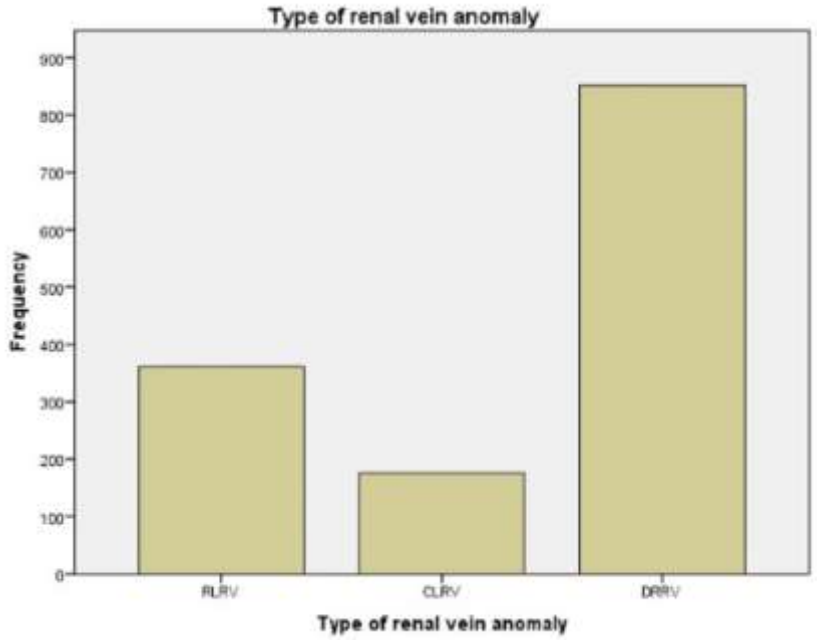

Figure 4. Frequency of renal vein anomaly (RVA) types.

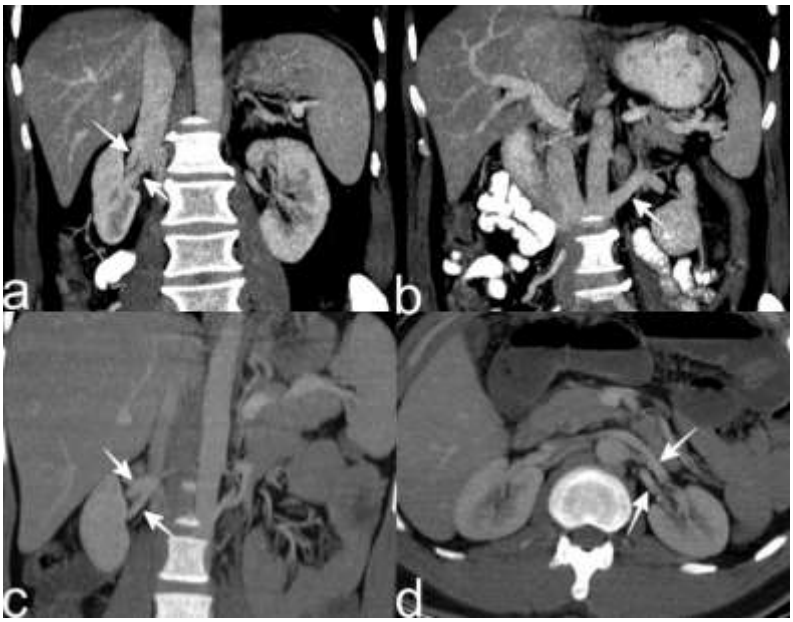

Figure 5. Case examples with both right and left RVAs. First, a 54-year-old male patient. a. b. Sagittal MPR maximum intensity projection (MIP) images show both DRRV and RLRV (white arrows). Secondly, a 43-year-old female patient. c. Sagittal MPR and d. axial MDCT images demonstrate both DRRV and CLRV (white arrows).

Of the 9294 cases, 1523 cases (16.4%) had renal stone disease. This disease was seen more frequently in male than females (957 M vs. 566 F, respectively; $p < 0.001$) (Table 2). Renal stone disease was detected in 243 of the 1389 RVA cases, but was not statistically significant ($p = 0.227$). Among these 243 cases, RLRV was found in 84 cases (34.6%), CLRV in 13 cases (5.4%), and DRRV in 146 cases (60%). While there was no statistically significant correlation between DRRV and right renal stone disease ($p = 0.951$), a statistically significant correlation was found between left renal stone disease with RLRV and CLRV ($p < 0.001$, $p = 0.026$, respectively) (Figure 6a-d) (Table 3).

Table 2. Renal stone disease and renal tumors distribution of the gender

	Male	Female	Total	*p*
Renal Stone Disease	957 (18.4%)	566 (13.8%)	1523 (16.4%)	**<0.001**
Renal Tumors	51(1%)	55 (1.3%)	106 (1.1%)	0.101

*p < 0.05 were taken as statistically significant and significant p values have been highlighted in bold.

Table 3. Renal stone disease and renal tumors relationship with on same laterality as renal vein anomalies

	Renal Stone Disease	*p*	Renal Tumor	*p*
RVA	243 (17.5%)	.227	20 (1.4%)	0.255
RLRV	84 (23.3%)	**<.001**	3 (0.8%)	0.572
CLRV	18 (10.2%)	**.026**	2 (1.1%)	0.996
DRRV	146 (16.5%)	.951	15 (1.7%)	0.104

*p < 0.05 were taken as statistically significant and significant p values have been highlighted in bold.
RVA = renal vein anomaly, RLRV = retroaortic left renal vein, CLRV = circumaortic left renal vein, DRRV = double right renal vein

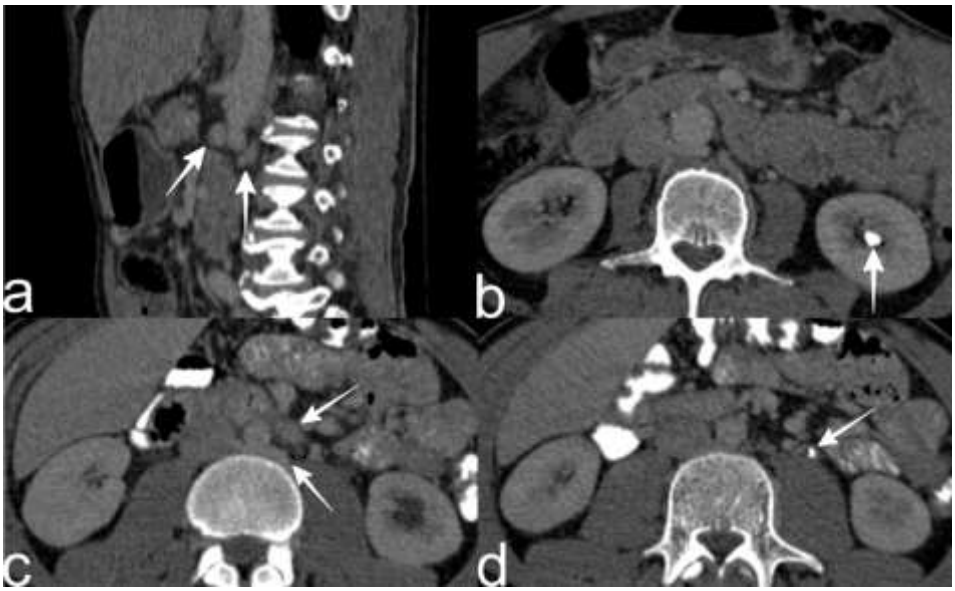

Figure 6. A 28-year-old male patient. a. Sagittal MPR images demonstrate RLRV (white arrows). b. Axial MDCT images of the same case show a stone in the right kidney (white arrow). A 33-year-old male patient. c. d. Axial MDCT images demonstrate CLRV (white arrows) and stone of the right ureter (white arrow).

Of the 9294 cases, 106 cases (1.1%) had renal tumors. Angiomyolipoma was seen in 49 patients (46.7%), clear type RCC in 32 patients (30.5%), chromofob type RCC and papillary type RCC in 7 patients (6.7%), cystic type RCC in 5 patients (4.8%), lymphoma and oncosytoma in 2 patients (1.9%) and TCC in 1 patient (1%). Renal tumors were more common in females than males, but the difference was not statistically significant (55 F vs. 51 M, respectively; $p = 0.101$). Renal tumors were detected in 20 out of the 1389 RVA cases, and there was not statistically significant correlation ($p = 0.255$). Among these 20 cases, RLRV was found in 3 cases (15%), CLRV in 2 cases (10%), and DRRV in 15 cases (80%). There was not statistically significant correlation between the RVA subgroups (RLRV, CLRV, and DRRV) and renal tumors ($p= 0.571$, $p = 0.996$, $p = 0.104$, respectively) (Table 2).

DISCUSSION

To date, our study has the largest case group in the literature investigating RVA, and the RVA rate was found to be 14.9% in the case group we reviewed. When we evaluated RVA subgroups separately, we found that DRRV occurred the most frequent DRRV (9.5%), followed by RLRV (3.9%), CLRV (1.9%) and both (RLRV + DRRV or CLRV + DRRV) (0.24%). When we evaluated the relationship between RVA and renal stone disease, we found no significant correlation. However, when investigating the relationship between the RVA subgroups and renal stone disease, there was a significant correlation between RLRV and CLRV and left renal stone disease. But, there was no significant correlation between DRRV and right renal stone disease. When we evaluated the relationship between RVA (including its subgroups) and renal tumors, there was no significant correlation.

DRRV is the most frequently reported RVA in the literature[9]. Similarly, in our study, the most common RVA was DRRV and its prevalence was 9.5%. Life-threatening complications of DRRV during surgery are less frequently reported; hence, DRRV has less clinical significance than RLRV and CLRV. One study reported that DRRV might be a contraindication for donor nephrectomy due to the higher risk of graft renal vein thrombosis[10].

RLRV is seen as a result of the persistence of the intersupracardinal and intersubcardinal anastomosis and regression of the ventral arch. Although two types are defined, the distinction between them is not important clinically. On the other hand, CLRV is considered a consequence of the persistence of the dorsal arch of the circumortic ring and the intersupracardinal anastomosis. There are variations in the prevalence of RLRV and CLRV reported in the literature. Of the studies with the largest number of cases, Hoeltl et al. found the prevalence of RLRV as 0.4% among 4520 cases, and Heidler et al. reported the prevalence of RLRV to be 0.77% among 7929 cases[11,12]. Satyapal et al. reported the occurence of CLRV as 0.3% among 1008 cases[13]. In their study involving 8517 cases, Ozgul et al. reported the prevalence of RLRV as 1.1% and CLRV as 0.3%[4]. In our study of 9294 cases, which is the largest number of cases in the literature, we found the prevalence of RLRV as 3.9% and CLRV as 1.9%. The incidence of RLRV was higher in our study than in other studies with large case groups -we attributed this to the high number of cases.

Many studies have examined the relationship between gender and RVA, but most of them have not found a significant difference[4,14]. Only one study, which was by Dilli et al., found RLRV to be significantly more common in females than males[3]. In our study, although the prevalance of CLRV and DRRV was more common in males than females, but the difference was not statistically significant. However, the prevalance of RLRV, similar to Dilli et al.'s study, it was higher in females than in males and there was a significant correlation.

RVAs are often asymptomatic and are detected incidentally. However, rare cases of RLRV associated with clinical symptoms have been reported in the literature. For example, Karaman et al. found that RLRV is associated with hematuria and nutcracker phenomenon; Macchi et al. associated it with renal ectopia; Arslan et al. reported that there is a correctable cause for varicocele. Furthermore, Heidler et al. stated that it may cause left flank pain[8,12,15,16]. Similar to the literature, in our study, there were no clinical symptoms that could be associated with RVA. Although RVAs are asymptomatic, it is vital to define RVA before retroperitoneal surgeries. Failure to identify these anomalies preoperatively may result in massive bleeding, nephrectomy, or even death[5]. In the literature, massive bleeding has been reported during RLRV - and CLRV-related surgery, and the risk of

vascular injury was reported to be close to 50% in patients with RVA[17]. Patients with CLRV have a higher risk of venous injury during surgery. In cases with CLRV, the thick anterior component of the circumaortic arch may cause the absence of RVA in the left renal vein during surgery. Again, in donor nephrectomies, the left kidney is often preferred due to the long course of the left renal vein. Knowing the presence of RVA in the left renal vein is very important for transplantation surgeons[3,5]. Similarly, it is essentia to be aware of the presence of RVA in surgeries requiring paraaortic lymphadenectomy[5].

Some studies in the literature have investigated the relationship between RVA and malignancy[2,18]. However, except for our study, there is no study exploring the relationship between RVA and renal tumors in the literature. In our study, we found the prevalence of renal tumors to be 0.14% in RVA cases, but was not statistically significant correlation between them. Similarly, was not statistically significant correlation between RVA subgroups and the presence of renal tumors. Based on our results, we think that there is no relationship between RVA and renal tumor development.

Our study is the first study in the literature to evaluate the relationship between RVA and renal stone disease. Renal stone disease was detected in 243 of the 1389 RVA cases, but was not statistically significant correlation. However, when the correlation between RVA subgroups and renal stone disease was investigated, the prevalence of left renal stone disease was high in RLRV and CLRV cases, and there was a significant correlation between them. Our results showed that RLRV and CLRV increase the development of left renal stone disease. We think that this situation may be due to the compression of the renal vein between the aorta and the vertebra in RLRV and CLRV cases. As a result of compression, the intrarenal venous impedance index may increase, leading to impaired venous drainage, renal congestion and consequently kidney stone disease. In their study in Boyacı et al., they put forward a similar theory[19]. However, multi-center and more studies are needed on this subject.

There were some limitations of our study. First, the study was designed retrospectively. Second, patients had not been subjected to a multivariant analysis according to age, gender and comorbid diseases. This may have affected the results. Third, since the past medical records of some patients cannot be reached, diet behaviors and previously had no knowledge whether there is a history of stone disease. Again, this may also have affected the results. Finally, imaging parameters (like contrast status) of MDCTs were not the same. This may have affected the visibility of small kidney stones.

In conclusion, contrary to popular belief, RVAs are not uncommon in the population. Being aware of these anomalies before retroperitoneal surgeries will greatly contribute to preventing intraoperative and postoperative morbidity and mortality. The presence of RVA can also be best described non-invasively by MDCT. In addition, according to the results of our study, RLRV and CLRV are predisposing factors for the development of left renal stone disease. Although our study has the largest case group on this subject, it is obvious that multi-center studies are required.

Yazar Katkıları: Çalışma konsepti/Tasarımı: SA, IMC; Veri toplama: SA, IMC; Veri analizi ve yorumlama: SA; Yazı taslağı: SA; İçeriğin eleştirel incelenmesi: SA; Son onay ve sorumluluk: SA, İMC; Teknik ve malzeme desteği: SA, IMC; Süpervizyon: SA; Fon sağlama (mevcut ise): yok.
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