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# Evaluation of renal vascular variations with computed tomography

Azad Hekimoglu\* and Onur Ergun

## Abstract

**Background:** It is important to know the renal vascular variations before renal surgeries and invasive procedures. The aim of this study is to evaluate the prevalence and types of variation of renal arteries and veins.

**Methods:** The abdominal CT images of 460 patients, taken between 2019 and 2021, were retrospectively analyzed in axial and coronal planes. The presence and number of accessory renal arteries and early branching in the main renal artery were evaluated. Then, bilateral renal vein variations were investigated. Finally, the compression of the left renal vein by different anatomical structures was evaluated.

**Results:** Of the 450 patients included in the study, the mean age was 53 years. No variations were detected in 378 renal arteries on the right side (84%) and 392 renal arteries on the left side (87.1%). The most common variation in renal arteries was an accessory inferior hilar artery in 7.5% and 6% rates on the right and left, respectively. An accessory inferior renal polar artery was observed at an overall rate of 1.3%. An accessory superior renal hilar artery was found at 3.3% and 2% rates on the left and the right, respectively. An accessory superior renal polar artery was found at an overall rate of 3.5%. Multiple variations in the renal arteries were observed at a rate of 6.4%. Early branching was observed at a rate of 4.9% on the right and 2.2% on the left. The presence of two and three right renal veins was observed at rates of 13.1% and 0.6%, respectively. Retroaortic and circumaortic left renal veins were found at 3.5% and 4.4% rates, respectively. The compression on the anterior and posterior left renal veins was observed at 4.6% and 0.9% rates, respectively.

**Conclusion:** Considering that variations in renal arteries and veins are too many and of different types to underestimate, a CT examination for the renal vascular anatomy before and at the planning phase of renal surgery or interventional procedures will be of great benefit to avoid potential complications.

**Keywords:** Renal artery, Renal vein, Morphological findings, Variation

## 1 Background

The morphology and variations in the renal vascular structures should be known to perform any type of renal surgery, primarily before any renal transplantation surgery or before interventional radiologic procedures such as the treatment of renal artery stenosis and renal mass embolization. Also, it is important to know renal vascular variations before open or endovascular surgery

for the treatment of abdominal aortic aneurysms [1, 2]. Conventional angiography is the gold standard method to examine vascular structures; however, it is an invasive procedure and it is not adequate to determine renal vein variations in detail [3, 4]. Multidetector computed tomography (MDCT) is a highly sensitive method, allowing for the examination of the overall renal vascular anatomy along with arteries and veins together [2, 5].

The aim of this study was to investigate the prevalence and types of variations in renal arteries and veins in individuals, who had undergone abdominal MDCT for any reason. Furthermore, our study investigated the rate of

\*Correspondence: [azadhekimoglu@gmail.com](mailto:azadhekimoglu@gmail.com)

Department of Radiology, Diskapi Yildirim Beyazit Training and Research Hospital, Diskapi, 06110 Ankara, Turkey

compression of the left renal vein by other anatomical structures.

## 2 Methods

The CT images of 460 patients taken between January 2019 and January 2021, who had undergone an intravenously administered contrast-enhanced CT examination due to any reason in our hospital, were examined retrospectively. Patients with ectopic kidney, congenital kidney anomaly, or patients whose CT images were insufficient for vascular evaluation were excluded from the study.

The abdominal CT examination was performed with a 128-slice multi-detector CT scanner (GE, Optima CT 660). Thin-sliced source images obtained in the axial plan were recalled from PACS and examined retrospectively. Multiplanar reformatted images and maximum intensity projection images were obtained for all patients. All CT images were evaluated by two experienced radiologists, and the reports were prepared in consensus between them. The examinations were performed in the axial and coronal planes. Firstly, renal artery variations were examined. The presence and counts of accessory renal arteries in both kidneys in the axial and coronal planes, their origins in respect to the native renal artery, and their place of entry into the kidney [either from the hilus (hilar) or the cortex (polar)] were determined. Also, the presence of early branching was investigated in renal arteries. Then, the variations in renal veins were investigated in the axial and coronal planes. The right renal vein count

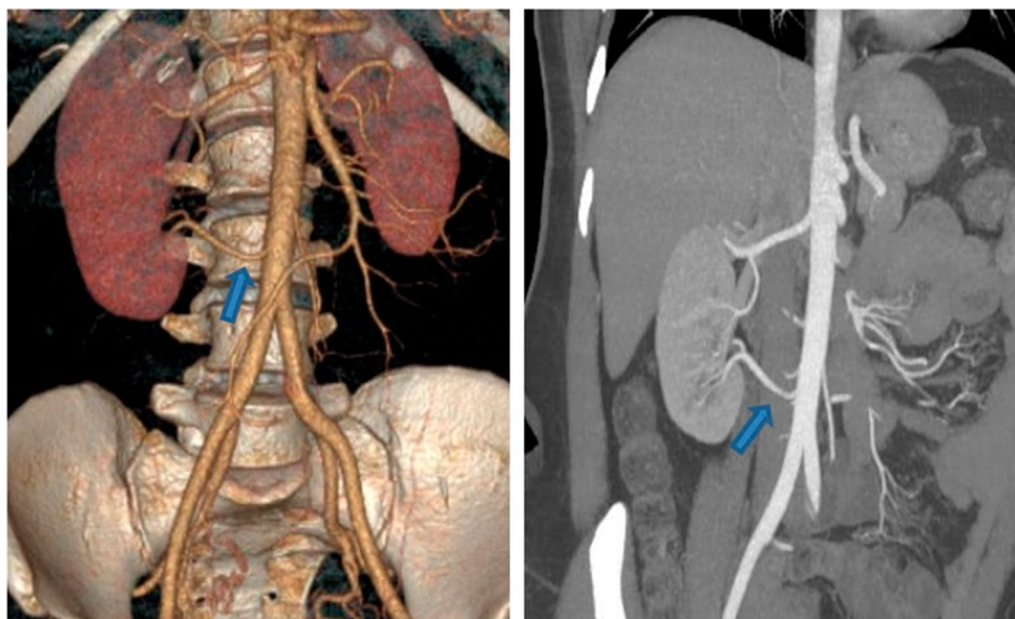
and the course of the left renal vein with respect to the abdominal aorta were noted. Finally, the compression of left renal vein by different anatomical structures was evaluated.

## 3 Results

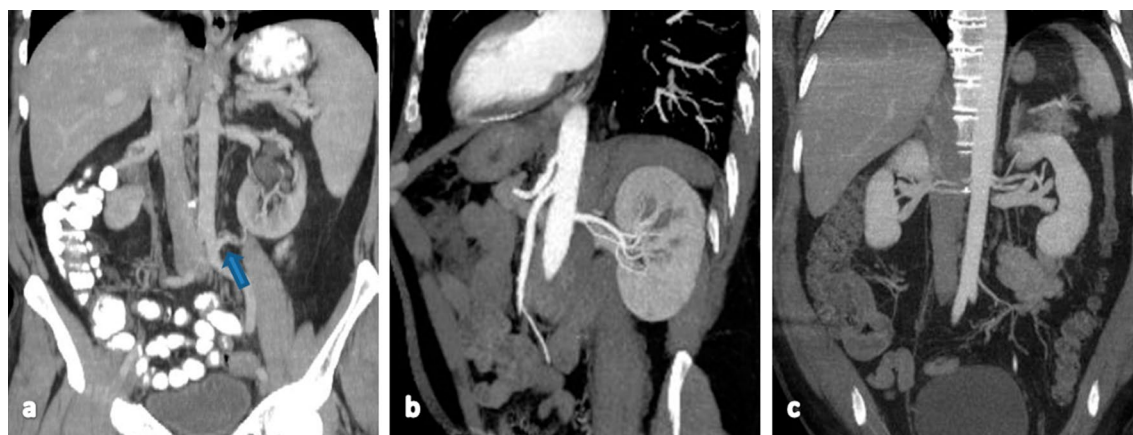
Of the 460 patients who were examined, 5 patients were excluded because 3 had ectopic kidney and 2 had horse-shoe kidney anomaly. In addition, 5 patients were not included in the study due to insufficient CT images for vascular evaluation. Of the 450 patients (900 kidneys; 249 men and 201 women) included in the study, the mean age was 53 years (age range: 18–83 years).

No variations were detected in 378 renal arteries on the right side (84%) and 392 renal arteries on the left side (87.1%). The most common variation in renal arteries was an accessory inferior hilar artery in 34 (7.5%) patients on the right and 27 (6%) patients on the left (Fig. 1). An accessory inferior renal polar artery was observed in 3 (0.6%) patients on each side, making a total of 6 (1.3%) patients (Fig. 2a). An accessory superior renal hilar artery was observed in 15 (3.3%) patients on the left and 9 (2%) patients on the right, while an accessory superior renal polar artery was observed in 8 (1.8%) patients on each side, making a total of 16 (3.5%) patients. The number of patients, having both superior and inferior accessory arteries was 5 (1.1%).

The number of patients with renal artery variations on both sides was 27 (6%) (Fig. 2c). The number of patients with more than one renal artery variation was 29 (6.4%).



**Fig. 1** Right inferior accessory hilar renal artery



**Fig. 2** **a** Left inferior accessory polar renal artery, originated from left main iliac artery. **b** Early branching of the left renal artery. **c** Bilateral accessory hilar renal artery

Of these patients, the number of patients with two variations was 20 (4.4%), the number of patients with three variations was 6 (1.3%), the number of patients with four variations was 2 (0.4%), and the number of patients with five variations was only 1 (0.2%).

Early branching was observed in a total of 32 (7.1%) patients, 22 (4.9%) on the right and 10 (2.2%) on the left (Fig. 2b). Of the patients with early branching of the renal arteries, early branching artery entered the kidney from the cortex like the renal polar artery in 7 (21.9%) patients.

The most common renal vein variation was having two renal veins, which was observed in 59 (13.1%) patients (Fig. 3a). The number of patients with three right renal veins was 3 (0.6%) (Fig. 3b).

While the number of patients having left renal vein in front of the abdominal aorta and then coursing normally was 414 (92%), the number of patients with the left renal vein coursing behind the abdominal aorta was 16 (3.5%). The number of patients, having circumaortic left renal veins coursing posteriorly and anteriorly to the abdominal aorta was 20 (4.4%) (Fig. 3c). Left renal vein, coursing anteriorly to the abdominal aorta, was compressed between abdominal aorta and superior mesenteric artery in 21 patients (4.6%); while in 4 patients (0.9%), left renal vein coursed posteriorly to the abdominal aorta and was compressed between abdominal aorta and lumbar vertebrae (the Nutcracker phenomenon) (Fig. 3d, e).

All renal vascular variations detected in our study are presented in Table 1.

#### 4 Discussion

CT is an excellent imaging method to evaluate the normal anatomy of renal vascular structures, as well as its variations. The number and course of the renal artery and

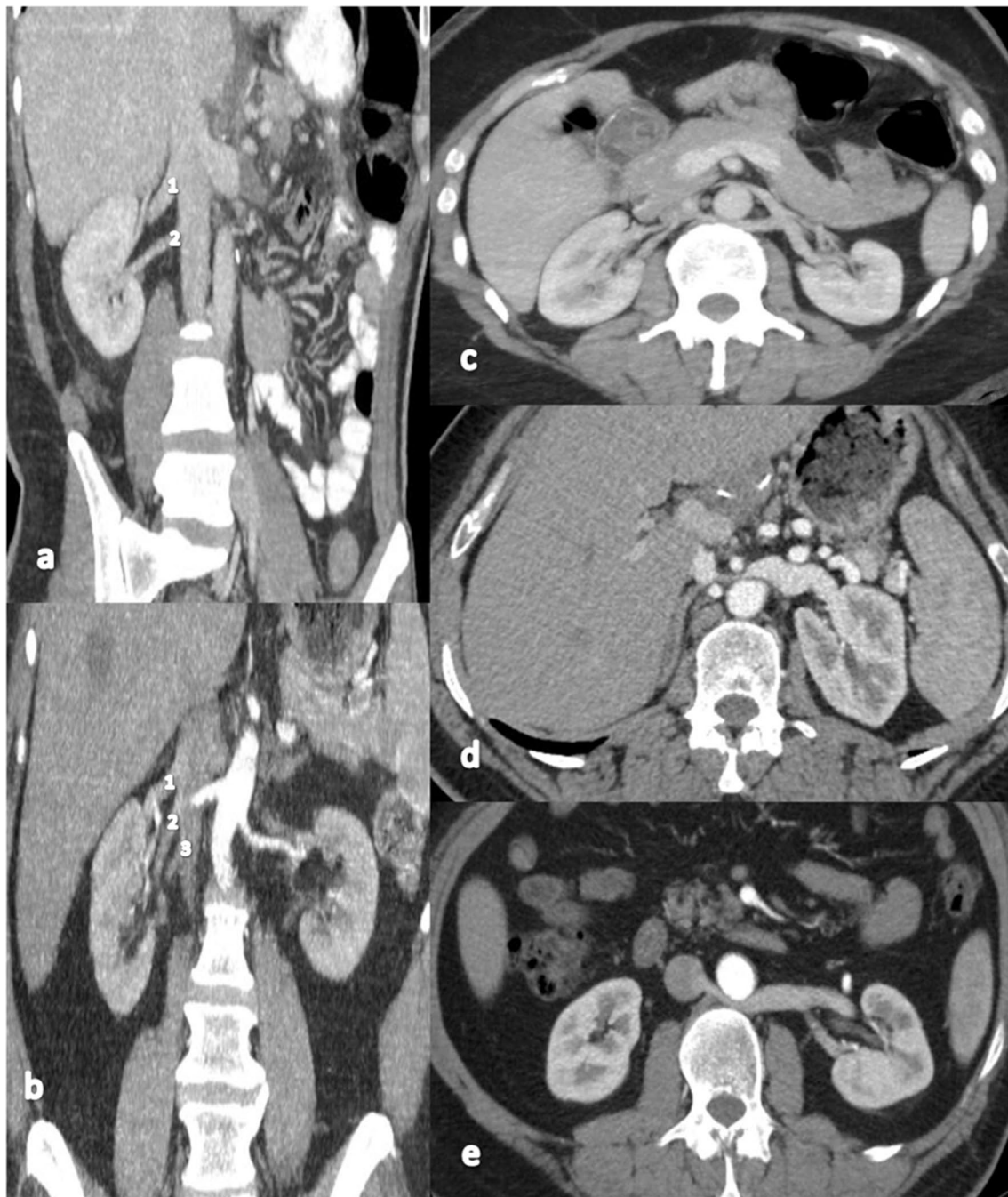
renal veins could easily and precisely defined by performing a CT angiography [5]. The main renal arteries usually originate from abdominal aorta, at the level of the L1–L2 vertebrae, just below the superior mesenteric artery. The right main renal artery generally originates more superiorly compared to the left renal artery [6].

Variations in renal vessels may occur due to the atypical position of the kidneys during cephalic migration of the kidneys in embryogenesis. In addition, the number of mesonephric arteries feeding the kidney decreases to one during embryonic development, and abnormalities in this process may cause an increase in the number of ectopic arteries [6, 7].

Accessory renal arteries are clinically the most important variations in renal vascular anatomy, occurring in one-third of patients. Multiple renal arteries are either unilateral or bilateral, accounting for approximately 30% and 10% of the patient population, respectively [3, 4]. In our study, the inferior and superior, and hilar and polar accessory renal artery variations were detected in a total of 107 (23.8%) patients. This finding is similar to the 24% accessory renal artery prevalence found in the study conducted by Ozkan et al. [6]. Studies have reported that accessory renal arteries are seen more frequently on the right side than on the left, although the difference is not statistically significant [6, 8]. In our study, inferior variations and early branching (8.2%, 4.9%, respectively) were more common on the right compared to the left side (6.6% and 2.2%, respectively), while superior variations were more common on the left (5.1%) compared to the right side (3.8%). Overall, the variations were more common on the right (16.8%) compared to the left side (14%).

Accessory arteries can originate from the aorta or iliac arteries anywhere from the level of the T11 vertebra to





**Fig. 3** **a** Two right renal veins. **b** Three right renal veins. **c** Circumaortic left renal vein. **d** Anterior left renal vein and anterior nutcracker phenomenon. **e** Retroaortic left renal vein and posterior nutcracker phenomenon

the level of the L4 vertebra. Rarely, an accessory artery can originate from the lower thoracic aorta or lumbar or mesenteric arteries [3]. In our study, the origins of the accessory arteries were from left main iliac artery in two patients (Fig. 2b). Therefore, radiographic images of patients should visualise the main iliac artery to detect

renal vascular variations [9]. Accessory arteries usually course towards the renal hilum to perfuse the upper or lower poles of kidneys. Accessory arteries supplying the poles of the kidneys are usually narrower than accessory renal hilar arteries with calibers similar to those of native renal arteries [3].

**Table 1** Renal vascular variations

	Right	Left	All
Inferior HAA	34 (7.5%)	27 (6%)	61 (13.5%)
Inferior PAA	3 (0.66%)	3 (0.66%)	6 (1.33%)
Superior HAA	9 (2%)	15 (3.3%)	24 (5.3%)
Superior PAA	8 (1.77%)	8 (1.77%)	16 (3.55%)
Early branching	22 (4.9%)	10 (2.2%)	32 (7.1%)
Two RRV	59 (13.1%)		
Three RRV	3 (0.6%)		
Retroaortic LRV		16 (3.5%)	
Circumaortic LRV		20 (4.4%)	
Anterior nutcracker phenomenon		21 (4.6%)	
Posterior nutcracker phenomenon		4 (0.9%)	

\*HAA hilar accessory artery, PAA polar accessory artery, RRV right renal vein, LRV left renal vein

Early (prehilar) arterial branching is another common variant that should be checked in patients, who are evaluated for donor nephrectomy [10]. To obtain a favorable anastomosis during kidney transplantation, it is very important to determine the presence of early branching in the main renal artery, as the renal artery incision is made 1.5–2 cm distal to the origin from the aorta [5]. Several studies in the literature report the rates of early branching from the main renal artery in the range from 6.5 to 12% [5, 6, 8]. In our study, early branching originated from the right and left renal arteries at rates of 4.9% and 2.2%, respectively. In total, early branching was observed in 7.1% of the patients in our study. These rates are compatible with those reported in the literature.

The rate of two or more renal artery variations existing concurrently in a patient was found out to be 6.4% in our study. This rate is lower compared to the rate reported by Çinar et al. [5]. In the study of Çinar et al. [5], the presence of two concurrent variations in a patient was reported as 22.2%, while the concurrent presence of three, four, and five variations in a patient were reported at rates of 7.5%, 1.4%, and 0.2%, respectively. In our study, those rates were 4.4%, 1.3%, 0.4%, and 0.2%, respectively. A maximum of five concurrent variations was observed in one patient in our study. In this patient having five variations, one accessory inferior renal hilar artery and one accessory inferior renal polar artery were observed on the right, while two accessory inferior renal hilar arteries and one accessory inferior renal polar artery were found on the left. The accessory inferior renal polar artery on the left originated from the left main iliac artery in this patient.

In the study performed by Çinar et al. [5], the rates of patients with two, three, and four right renal veins were reported to be 19.2%, 2.2%, and 0.2%, respectively.

In our study, the rates of the concurrent presence of more than one renal vein in a patient were found out to be lower than those reported by Çinar et al. [5]. In our study, the rate of patients with two right renal veins was 13.1% and the rate of patients with three right renal veins was 0.6%. No patients were found to have four renal veins in our study. Çinar et al. [5] reported the presence of left retroaortic renal veins and circumaortic left renal veins at rates of 4.2% and 5.2%, respectively. Those rates are partially compatible with these found in our study, as left retroaortic veins and circumaortic left renal veins were detected at rates of 3.5% and 4.4%, respectively.

Due to the long course of the left renal vein, the left kidney is preferred in donor nephrectomy. Therefore, it is vital to know the course of the left renal vein before the surgery [11, 12]. Left renal vein variations rarely manifest with clinical symptoms. Most of them are revealed by imaging methods [13]. Rare clinical symptoms of anatomical variations of the left renal vein include proteinuria, hematuria, varicocele in men, and the pelvic varicocele in the left ovary in women [14–16].

Nutcracker syndrome (NCS) describes the compression on the left renal vein trapped between SMA and abdominal aorta (meso-aortic trap). While NCS is a clinical diagnosis, the Nutcracker phenomenon only refers to the radiological compression of left renal vein between the SMA and aorta [17]. The symptoms of NCS are variable depending on the capacity of developing collateral vasculature via compensatory mechanisms. Individuals with NCS can be asymptomatic, too. NCS can be clinically diagnosed when left-sided pain, varicocele, proteinuria, and anemia occur [18, 19]. The posterior nutcracker phenomenon is a variant characterized by compression of left renal vein between aorta and vertebral column [20]. In the study by Poyraz et al. [21], the prevalences of anterior and posterior left renal vein compression were 4.1% and 6.5%, respectively. In another study, posterior left renal vein compression was found at a rate of 2.06% [22]. In our study, the rate of anterior left renal vein compression was 4.6% and this rate was compatible with that reported in the previous study. However, the frequency of posterior left renal vein compression was 0.9% in our study and was lower compared to the rate reported in the previous study. However, when only the patients with retroaortic left renal veins were examined in our study, the nutcracker phenomenon was detected in 4 out of 16 patients (25%) with retroaortic left renal veins in which the incidence is quite high.

One of the limitations of our study is that some patients were excluded because the enhancement in renal venous structures was sometimes not at the desired level and did not allow optimal evaluation.

## 5 Conclusion

In our study, we concluded that variations in renal arteries and veins were very high. Considering that variations are too many and of different types to underestimate, a CT examination of the renal vascular anatomy before and at the planning phase of renal surgery or interventional procedures will be of great benefit to avoid potential complications.

### Abbreviations

CT: Computerized tomography; NCS: Nutcracker syndrome.

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### Author contributions

This study was directed and coordinated by AH, design of the study was by OE, literature search was suggested and executed by AH, The manuscript was written by AH and OE and commented on by all authors. Both authors read and approved the final manuscript.

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### Availability of data and materials

Not applicable.

### Declarations

#### Ethics approval and consent to participate

This study has been approved by the Ethics Committee of the Diskapi Yildirim Beyazit Training and Research Hospital (Protocol number: 79/07-2020). All methods were performed in accordance with the relevant guidelines and regulations. Consent for participation from all the patients has been taken.

#### Consent for publication

Not applicable.

#### Competing interests

The authors declare that they have no competing interests.

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