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Renal artery origins and variations: angiographic evaluation of 855 consecutive patients

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PURPOSE
To determine angiographically the origins and variations of renal arteries.

MATERIALS AND METHODS
The study included 855 consecutive patients (163 females, 692 males; mean age, 61 years) living in the Çukurova region of Turkey, who underwent either aortofemoropopliteal (AFP) angiography for the investigation of peripheral arterial disease, or renal angiography for renovascular hypertension, and were prospectively evaluated. Renal arteries were visualized by non-selective catheterization during AFP angiography and by selective or non-selective catheterization during renal angiography. Locations of renal artery origins and renal artery variations, including the presence of extra renal arteries and division patterns were analyzed on angiograms.

RESULTS
The origin of main renal arteries off the aorta was between the upper margin of L1 and lower margin of L2 vertebra in 98% of the patients, and in 74%, this was the origin of extra renal arteries. The most common location for renal artery origin was the L1-L2 intervertebral disc level. A single renal artery was present in both kidneys in 76% of patients. Renal artery variations included multiple arteries in 24%, bilateral multiple arteries in 5%, and early division in 8% of the cases. Additional renal arteries on the right side were found in 16% and on the left side in 13% of cases. Of all the extra renal arteries, the percentage of accessory and aberrant renal arteries were 49% and 51%, respectively.

CONCLUSION
Renal arteries originated between the first and the second lumbar vertebral levels in most patients. Extra renal arteries were quite frequent. These results should be kept in mind when a non-invasive diagnostic search is performed for renal artery stenosis, or when renal surgery related to renal arteries is performed.

Key words: • renal artery • angiography

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Renal artery variations are common in the general population and the frequency of variations shows social, ethnic, and racial differences (1,2). It is more common in Africans (37%) and Caucasians (35%), and is less common in Hindus (17%) and the populations except Caucasians (18%). The frequency of extra renal arteries (ERA) shows variability from 9% to 76% and is generally between 28%–30% in anatomic and cadaver studies (1, 3, 4). Renal artery variations are becoming more important due to the gradual increase in interventional radiological procedures, urological and vascular operations, and renal transplantation (3–6).

Renal artery variations are divided into 2 groups: early division and ERA. Branching of the main renal arteries into segmental branches more proximally than the renal hilus level, is called early division. ERA are divided into 2 groups: hilar (accessory) and polar (aberrant) arteries. Hilar arteries enter kidneys from the hilus with the main renal artery, whereas polar arteries enter kidneys directly from the capsule outside the hilus.

The aim of this study was to determine the location of origins of renal arteries and the variation rates of renal arteries in patients living in the Çukurova region of Turkey who underwent angiography for the investigation of peripheral arterial disease or renovascular hypertension.

Materials and methods

The study included 855 patients who underwent aortofemoropopliteal (AFP) or renal angiography between December 2003 and June 2005. Of those, 18 patients whose aortographies were not suitable for evaluation and in whom selective renal angiography could not be performed were excluded from study. Detailed information about the angiographic procedure and probable complications were given to all patients and informed consent was received from all of them. During this study no additional interventions were performed on the patients.

Patients underwent angiography for the following reasons: claudicatio (n = 615, 72%), critical foot ischemia (n = 91, 11%), suspicion of renovascular hypertension (n = 70, 8%), abdominal aorta aneurysm (n = 13, 1%), and other reasons (n = 66, 8%). The age range of the participants was 14–85 years (mean age: 61 ± 12.28 years). The study group included 692 (81%) males and 163 (19%) females.

Digital subtraction angiography (DSA) was performed in a unitary device (Multistar, Siemens, Erlangen, Germany). Arterial punctures were made primarily from the right main femoral artery, and when this was not possible, puncture was made from the left femoral or left brachial arteries. Either a 5 or 6 F vascular sheath (Cordis, Johnson & Johnson, Miami, FL, USA) was placed in all arteries with single wall needle. After putting a 5 F multi-holed pigtail catheter (Cordis, Johnson & Johnson, Miami, FL, USA) at the level of the proximal abdominal aorta, originating

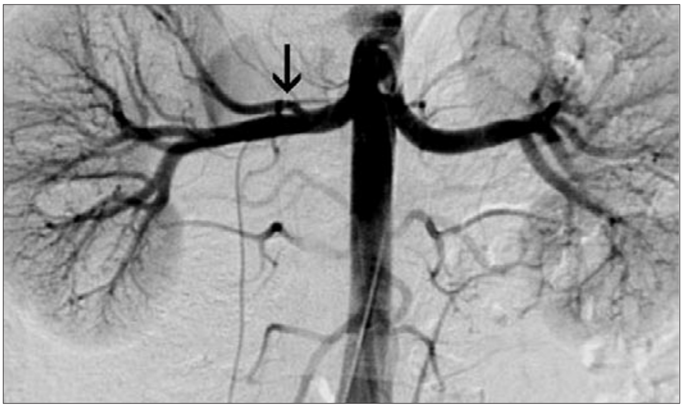

Figure 1. In nonselective renal angiogram, early division *(black arrow)* is observed in the main renal artery on the right.

Figure 2. In nonselective renal angiogram, an aberrant renal artery *(black arrow)* is observed below the main renal artery on the right.

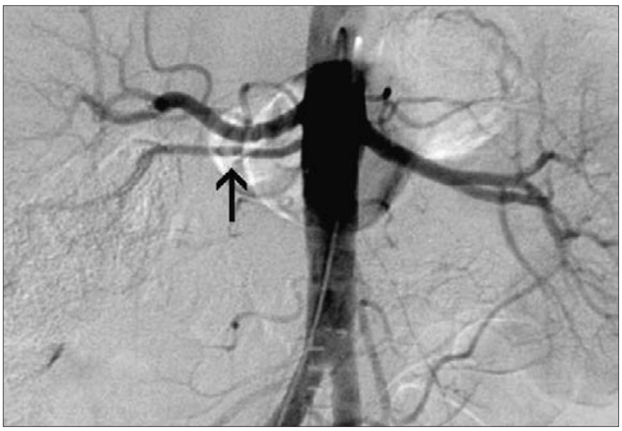

Figure 3. In nonselective renal angiogram, an accessory renal artery *(black arrow)* is observed below the main renal artery on the right.

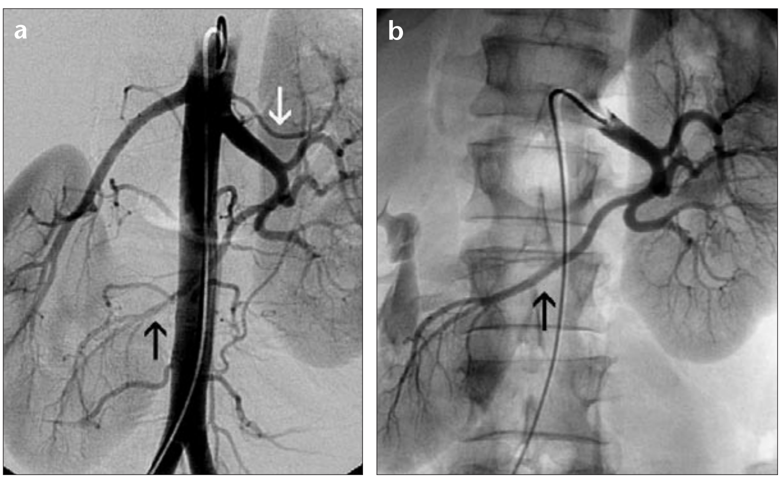

Figure 4. a, b. In nonselective renal **(a)** and left selective renal angiograms **(b),** an accessory renal artery *(white arrow)* is observed over the main renal artery on the left and an aberrant renal artery *(black arrow)* originating from the left segmental artery is observed on the right.

level of the renal arteries was identified by administering 7–8 ml contrast agent [iohexol (Omnipaque 300, Amersham, Carrigtohill, Ireland) and iopromid (Ultravist 300, Schering, Germany)] with fluoroscopy-guided manual injection. Catheter holes were placed at the level of renal orifices. When the catheter was in the originating level of renal arteries, the abdominal aorta and renal arteries were imaged in single plane by injecting 30 ml contrast agent with an automatic injector at a speed of 15 or 20 ml/s. When renal arteries could not be adequately evaluated, oblique plane images or additional images by selectively entering the artery with the catheter were taken. Renal arteries and branches were imaged at the arterial phase at a speed of 3 images per sec, and kidneys were imaged at the nephrogram phase at a speed of 1 image per seconds. If renal arteries could be evaluated by aortography in patients who underwent angiography for the investigation of renovascular hypertension, selective catheterization was not performed. In patients who underwent peripheral angiography, the catheter was pulled to the iliac artery bifurcation and peripheral arteries continued to be visualized.

All angiographies were evaluated by 2 radiologists on angiography screens as serial images before being printed to film. All evaluations by the 2 radiologists were made by consensus. In angiography images, the number of renal arteries on both sides, the presence of aberrant or accessory renal arteries, and originating level of main renal artery, and others if present, were evaluated prospectively.

Segmental divisions, being more proximal than hilus level, were considered early divisions (Fig. 1). ERA were divided into 2 groups: hilar (accessory) and polar (aberrant) arteries. The ERA, which entered kidneys from the hilus with the main renal artery were called accessory, the ones that entered directly from the capsule outside the hilus were called aberrant renal arteries (Fig. 2–4). Renal arteries were divided into 9 groups according to their originating levels from T12-L1 level to L5 level and originating except from these locations (Table 1). The origin levels of renal arteries were more common in the levels of L1 and L2 vertebrae than any other localizations; therefore, the level of L1 and L2 vertebrae were divided into 3 subunits.

Chi-square test was used to compare the frequency of ERA on both sides, accessory/aberrant artery frequency rates, and renal artery variation rates between genders.

Results

Right renal artery origins

In 98% of the patients, main renal artery originated between the upper margin of L1 and the lower margin of L2 vertebrae. Right main renal artery originated from the lower margin of the L1 vertebra in 25%, from the level of the L1-L2 intervertebral disc in 23%, and from the upper margin of the L2 vertebra in 20% of the patients. On the right side, 77% of ERA originated between the upper margin of L1 and the lower margin of L2 vertebrae, and 20% originated from the level of the L1-L2 intervertebral disc.

Left renal artery origins

In 97% of the patients, main renal artery originated between the upper margin of L1 and the lower margin of L2 vertebrae. Main renal artery originated from the upper margin of the L2 vertebra in 24% of the patients, from the lower margin of the L1 vertebra in 23% of the patients, and from the level of the L1-L2 intervertebral disc in 22% of the patients. On the left side, 72% of ERA originated between the upper margin of L1 and the lower margin of L2 vertebrae and 20% originated from the level of the L1-L2 intervertebral disc, just like on the right side. The origin location frequency rates of the MRAs, according to vertebral column, are given in Table 1.

Renal artery variations

There was only one renal artery feeding both of the kidneys in 76% of the patients. More than one renal artery was found in 202 (24%) patients. More than one renal artery was observed on the right side in 135 (16%) patients and on the left side in 113 (13%) patients. In 46 (5%) patients, there was more than one renal artery on both sides. Of all the observed ERA, 16% were on the right and 13% were on the left; however, a statistically significant difference between these rates was not determined (Chi-square test, $P = 0.131$).

In 7 (0.8%) patients, renal arteries could not be observed on the right side due to nephrectomy. There was only one right renal artery in 713 (83%) patients, 2 in 126 (15%) patients, and 3 renal arteries in 9 (1%) patients. On the right side, 71 aberrant and 69 accessory renal arteries were observed.

On the left side in 6 (0.7%) patients, renal arteries could not be observed due to nephrectomy. In 736 (86%) patients, only one left renal artery was observed, 2 were observed in 105 (12%) patients, in 6 (0.7%) patients, 3 were seen, and in 2 (0.2%) patients, 4 left renal arteries were observed. On the left side, there were 58 aberrant and 58 accessory renal arteries. On both sides, a statistically significant difference between accessory and aberrant renal artery frequencies was not determined (Chi-square test, $P = 0.892$). The quantity variations of renal arteries on the right and left sides are shown in Table 2.

There were early divisions in 67 (8%) patients, 32% of which occurred on the right side, 25% on the left, and 22% on the both sides. A statistically significant difference in early division and ERA between the genders was not found on either side (Chi-square test, $P > 0.05$).

Table 1. Distribution of renal arteries according to the level of origin

	T12-L1 (%)	L1 (%)	L1-L2 (%)	L2 (%)	L2-L3 (%)	L3 (%)	L3-L4 (%)	L4 (%)	Other (%)
Right MRA	0.4	43	23	32	0.6	0.1	0.0	0.2	0.8
Left MRA	0.2	37	22	38	1	0.5	0.2	0.0	0.7
Right ERA	0.0	31	20	30	2	8	4	5	0.7
Left ERA	0.0	25	22	34	5	8	1	5	2

MRA: main renal artery, ERA: extra renal artery

Table 2. Distribution of renal arteries on the right and left sides according to quantity

	None (%)	One (%)	Two (%)	Three (%)	Four (%)
Right RA number	7 (0.8%)	713 (83%)	126 (15%)	9 (1%)	0 (0%)
Left RA number	6 (0.7%)	736 (86%)	105 (12%)	6 (0.7%)	2 (0.2%)

RA: renal artery

Discussion

Different origins of renal arteries and frequent variations are explained by the development of mesonephric arteries. These arteries form a vascular net feeding the kidneys, suprarenal glands, and gonads on both sides of the aorta between cervical 6 and lumbar 3 vertebrae, a region known as rete arteriosum urogenitale. Over time, these arteries degenerate, leaving only one mesonephric artery, which undertakes arterial circulation of the kidneys. Deficiency in the development of mesonephric arteries results in more than one renal artery (7, 8).

Main renal artery generally originate from the abdominal aorta, just below the superior mesenteric artery in the level of L1 and L2 vertebrae. With respect to the vertebral column, right main renal artery originate above the left renal artery. The location of both renal arteries in older patients is below the location of younger ones (9, 10). There is no detailed angiographic study showing the origins of renal arteries off the aorta. Kadir declared that in 75% of the general population, main renal artery originate from the level of the L1-L2 intervertebral disc and the other 25% originate somewhere between the lower end-plates of T12 and L2 (1). In our study, 23% and 22% of renal arteries originated between the L1-L2 intervertebral disc on the right and left sides, respectively, which is quite different than the 75% reported by Kadir. However, Kadir's reported percentage of the renal arteries originating between the lower end-plates of the T12-L2 vertebrae is compatible with our study results. Main renal artery commonly originated from the lower margin of the L1 vertebra (25%) on the right side and from the upper margin of the L2 vertebra (24%) on the left side in our study.

ERAs show dissimilarity according to society, ethnicity, and race. Satyapal et al. stated that the frequency of ERA is between 9% and 76% (average 28%) (3, 4). It is reported that ERA are detected less in angiography than anatomic dissection studies. In several angiographic studies, ERA frequency rate was between 20% and 27% (7, 11–14). This rate was 24% in our study and is compatible with other results. The reason why ERA are detected with less frequency in angiographic series is that thin arteries originating directly from the aorta cannot be observed in angiography, and/or arteries that enter parenchyma directly without passing the renal hilus are frequently confused with adrenal or capsular arteries.

In several anatomic and angiographic studies, the rate of bilateral ERA is stated to be 10%–15% (1, 15, 16). Kadir stated that the rate of early division in the general population is 15%, that aberrant renal arteries are observed twice as often as accessory renal arteries, the frequency rate of ERA is the same on the right and left sides, and that in 12% of the general population ERA are bilateral (1). In our patients, the frequency rate of early division and bilateral ERA was 8% and 5%, respectively, which is low when compared to other major series.

In our patients, no statistically significant differences were detected between the frequency rates of ERA on the right and left sides, and this finding was compatible with other studies. In our study, the frequency of accessory/aberrant arteries was the same on the right and left sides and this result is different from Kadir's report (1).

Color Doppler ultrasonography, computed tomography, and magnetic resonance angiography are frequently used in the investigation of renal artery stenosis. In agreement with other major series, our study showed that ERA are also common among people from Turkey. Because of this, these frequency rates must be considered while using non-invasive renal artery imaging methods. The results of our study are also important for renal transplantation surgery. Transplantation of kidneys that have one renal artery is technically easier than when there is more than one renal artery. Moreover, in transplantation of kidneys with one renal artery, post-surgical rates of complication and kidney loss are lower compared to transplantation of kidneys with more than one renal artery (17, 18). Although ERA are common (24%) in Turkish population, the probability of ERA being bilateral, in other words, the probability of having more than one renal artery in both kidneys of a kidney donor is low (5%).

In our study group, renal arteries generally originated between the margins of L1 and L2 vertebrae. ERA frequency did not show a significant difference with respect to other populations. It is important to consider these results while using non-angiographic, non-invasive methods for investigating renal artery stenosis, as well as during surgeries related to renal arteries.

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