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Anatomical differences in the right and left renal arterial patterns

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The aim of this study was to determine the pattern and character of the renal arteries in patients referred for preoperative or diagnostic evaluation of the renal or abdominal arteries by multi-detector computed tomography and, by comparing the arterial anatomy of the right and left kidneys, to evaluate the effect of differences in their anatomical position on the characteristics of the arteries.

During a cross-sectional study from August 2005 to October 2007, 117 patients underwent contrast-enhanced 64-slice multi-detector computed tomography renal angiography in Tabriz Imam Khomeini Hospital (Parsian Centre). The number of arteries, the number of branches and the presence of accessory arteries and early branching were assessed in the renal arteries on both sides.

In all, the data for 117 patients data were analysed, 76 (65%) of whom were male and 41 (35%) female. The mean of age of the patients was 39.26 ± ± 17.03 years. The mean diameters of the aorta and renal artery were 2.62 ± ± 1.55 mm and 0.62 ± 0.11 mm respectively and the distance to branching was 3.39 ± 1.59 mm. There was no significant difference in diameter between the left and right renal arteries or in the distance to branching (0.62 ± 0.11 vs. *0.61 ± 0.12 mm; p = 0.35; 3.24 ± 1.2* vs. *3.56 ± 1.77 mm; p = 0.11). An accessory artery was presented in 58 kidneys and this significantly more often occurred on the right side than on the left side: 38 of 117 (32.47%) right kidneys* vs. *20 of 117 (17.09%) left kidneys (p = 0.01). There was early branching in 42 subjects (35.89%). In a comparison of early branching of the arteries of the right and left kidneys, no significant difference was found, despite the higher incidence of branching on the right side.*

The diameters of the right and left renal arteries and the distances to branching did not differ. Apart from width, there was no difference in kidney size. An accessory artery occurred more frequently in the right renal artery than in the left. (Folia Morphol 2008; 67: 104–110)

Key words: computed tomography angiography, renal artery pattern, accessory artery, early branching

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INTRODUCTION

Accurate radiological assessment of the renal vascular anatomy of a kidney donor is of paramount importance in preoperative planning, allowing the surgeon to plan which kidney to remove [3, 18–20]. As we know, the right and left kidneys have different anatomical positions with differing proximity to other organs and the aorta, which may affect their vascular anatomy [12]. Recent advances in computed tomography (CT) technology now provide better vascular assessment.

In this study we report on the anatomy of the renal arteries and the characteristics of the kidneys of patients referred to the CT angiography unit for renal or abdominal artery evaluation, and the right and left renal arteries are compared anatomically.

MATERIAL AND METHODS

During cross-sectional renal angiography performed between August 2005 and October 2007 117 patients were evaluated who had been referred for pretransplantation or abdominal artery study. The CT angiographic examination was performed by multi-detector CT (Somatom Sensation 64, Siemens, Germany) in the Imam Khomeini Hospital, Tabriz.

After fasting for at least three hours, each donor ingested 700–800 mL of water over 30 min before the scan in an attempt to improve hydration. First the topogram of the abdomen was scanned and then the selected region of interest from the upper margin of the Th12 vertebra to the lower margin of the L5 vertebra. The bolus tracking method was used for timing. This was carried out by injecting 80 mL iopromide 300 mgI/ /mL (Ultravist 300, Schering, Germany) followed by 40 mL normal saline bolus chase with the use of a dual-head pressure injector (Medrad, USA). Slices of 0.6 mm were acquired in a single breath hold using 0.6 mm collimation, 120 KV, 110 mAs, with a beam pitch of 1.2 and a rotation speed of 0.5 s. After CT angiography images were processed by using various techniques, including multiplanar reconstructions (MPR), maximum intensity projection (MIP) and volume rendering techniques (VRT) on the Advantage Windows 3D workstation. For arterial phase reconstruction the images were reconstructed at 1 mm slice thickness and 50% overlap.

The following parameters were evaluated:
- the length of the main renal artery (from the ostium to branching);
- the diameter of the main renal artery at emergence from the aorta;
- the number of accessory arteries, if any;
- the presence of early branching;
- kidney length, width and anterioposterior diameter (APD).

Each observation and measurement was performed in MPR, MIP, and VRT mode to compare the findings.

Statistical analyses were performed by the SPSS version 13.0 for Windows software package (SPSS, Chicago, USA). Results are presented as mean ± standard deviation. Statistical significance between the groups compared was estimated using an independent sample *t*-test, Fisher's exact test, and Pearson's correlation. The results were considered significant when the p value was < 0.05.

RESULTS

In all, the data for 117 patients data were analysed, 76 (65%) of whom were male and 41 (35%) female. The mean of age of the patients was 39.26 ± ± 17.03 years. The mean diameters of the aorta and renal artery were 2.62 ± 1.55 mm and 0.62 ± 0.11 mm respectively and the distance to branching was 3.39 ± 1.59 mm.

The mean values for main renal artery diameter, distance to branching, length, width, and APD of the kidneys according to side are shown in Table 1. There was no significant difference between the diameters of the right and left kidney arteries or in the distance to branching ($p = 0.35$ and $p = 0.11$, respectively) (Table 1). A comparison of left and right kidney length and APD showed that the length and APD of the left kidney were greater than of the right, but these differences were not significant ($p = 0.48$ and $p = 0.1$, respectively). However, the width of the right kidney was significantly greater than that of the left ($p = 0.005$).

A comparison between males and females of aortic APD showed the diameters of the left and right renal arteries in males to be significantly higher than those in females (Table 2). Furthermore, a comparison of kidney size between males and females revealed that, although the length and APD of both left and right kidneys in males were higher than in females, there was no statistically significant difference between males and females in the widths of the left and right kidneys (Table 2).

A single artery was presented in 174 kidneys, two arteries (one main and one accessory artery) in 53, and three arteries (one main and two accessory) in 5 kidneys (Fig. 1). The main renal artery was

Table 1. Comparison of right side and left side kidney and artery characteristics

	Left side	Right side	Difference	p
Renal artery diameter	0.62 ± 0.11	0.61 ± 0.12	0.014	0.35
Renal artery distance	3.24 ± 1.2	3.56 ± 1.77	0.31	0.11
Kidney length	10.41 ± 1.16	10.31 ± 1.07	0.1	0.48
Kidney width	5.44 ± 0.85	5.71 ± 0.73	0.27	0.01
Kidney anterioposterior	4.97 ± 0.7	4.82 ± 0.69	0.15	0.1

Table 2. Comparison of characteristics of arteries and kidneys in males and females

	Male	Female	p
Aorta diameter	1.61 ± 2.26	1.43 ± 0.18	< 0.001
Left renal artery diameter	0.65 ± 0.10	0.57 ± 0.10	< 0.001
Right renal artery diameter	0.64 ± 0.10	0.56 ± 0.13	0.001
Left kidney length	10.67 ± 1.03	9.95 ± 1.24	0.001
Right kidney length	10.51 ± 0.90	9.92 ± 1.26	0.005
Left kidney width	5.52 ± 0.84	5.29 ± 0.85	NS
Right kidney width	5.79 ± 0.69	5.56 ± 0.79	NS
Left kidney anterior posterior diameter	5.10 ± 0.74	4.74 ± 0.57	0.004
Right kidney anterior posterior diameter	4.92 ± 0.67	4.63 ± 0.70	0.032

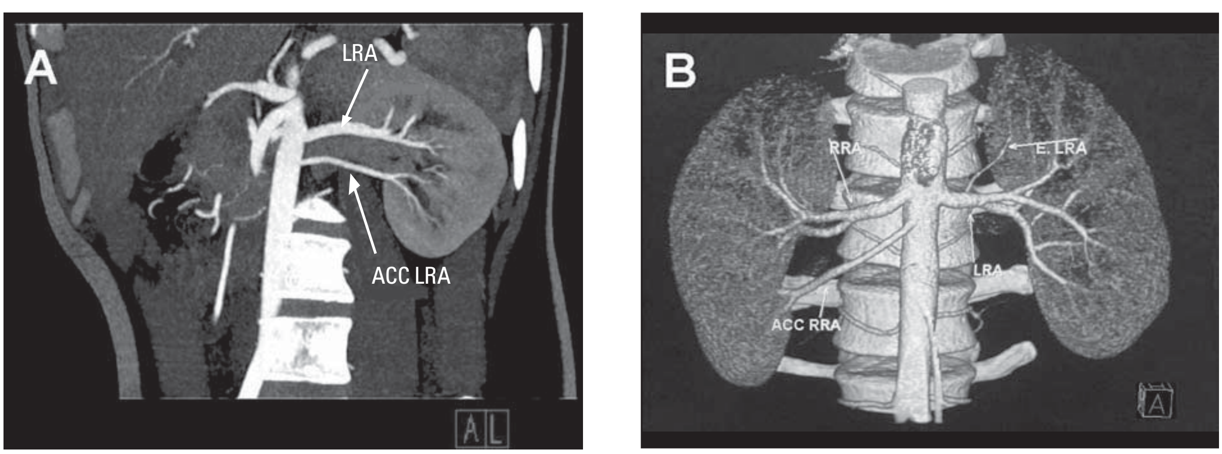

Figure 1. A, B. Multi-slice spiral computerised angiography showing single accessory renal artery on left (MIP) and right (VRT) kidney; LRA — left renal artery, ACC LRA — accessory artery of left renal artery, RRA — right renal artery, ACC RRA — accessory artery of right renal artery, E.LRA — early branching of left renal artery, AL view — anterior left view; AHR view — anterior head right view.

associated with an accessory artery in 47 subjects: in 11 patients on both sides, in 27 cases only on the right side, while in 9 cases only the left side was involved (Fig. 2). A comparison of kidney side and accessory artery development revealed that an accessory artery occurred significantly more often on the right than on the left side; 38 of 117 (32.47%) and 20 of 117 (17.09%), respectively ($p = 0.01$).

Early branching of the main renal artery was shown in 42 (35.89%) subjects (Fig. 3), 50 of 234

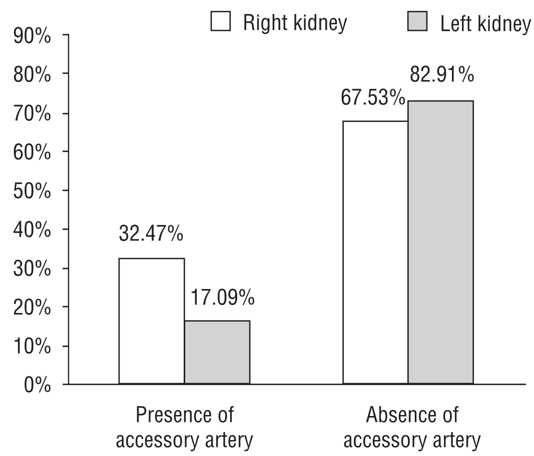

Figure 2. Comparison of accessory artery development rate between the right and left kidneys.

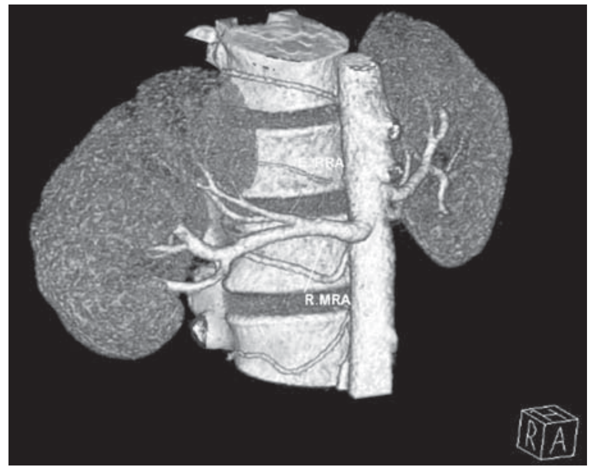

Figure 3. Axial volume-rendered image demonstrating early branching in the right renal artery; E.RRA — early branching of right renal artery, R.MRA — right main renal artery, AHR view — anterior head right view.

Table 3. Frequency of segmental arteries

Segmental arteries number	Left side		Right side		Total	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
2	55	47%	51	51%	106	45.3%
3	47	40.2%	48	41%	95	40.6%
4	11	9.4%	17	14.5%	28	12%
5	4	3.4%	1	0.9%	5	2.1%

kidneys (21.36%). It occurred bilaterally in 8 cases, in the right kidney in 21 cases and in the left kidney in 13 cases. A comparison of early branching development in left and right renal arteries showed no significant difference: 21 of 117 (17.94%) *vs*. 29 of 117 (24.78%), respectively ($p = 0.264$).

The mean number of segmental arteries on the right and left sides was 2.69 ± 0.782 and $2.73 \pm \pm 0.738$ respectively and there was no difference between right and left sides ($p = 0.73$). Table 3 shows the in number of segmental arteries according to the side of renal artery and total.

DISCUSSION

Multi-detector CT angiography provides quick, accurate determination of the anatomical location and course of the renal vessels [6, 10, 11, 13–17]. Angioscopic and MIP views supply additional information about the renal arteries and veins and complement conventional volume-rendered images (Fig. 4A–D).

Typically, arterial branches of the renal artery can be identified up to the segmental level, but detection of vessels smaller than 2 mm is limited [13]. The sensitivity of volume-rendered CT angiography for the demonstration and location of the main renal arteries, however, approaches 100% [13, 14, 16]. Surgical and CT findings correlate in over 95% of patients [13] and as CT angiography technology has progressed, its accuracy has improved. Some researchers have shown that use of 3D volume-rendered CT angiography enables correct identification of renal artery anatomy even up to 100% sensitivity [13, 14, 17].

The ovoid kidneys lie, as is well known, retroperitoneally on the posterior abdominal wall, one on each side of the vertebral column at the level of the Th12 to that of the L3 vertebrae. The right kidney usually lies slightly inferior to the left kidney because of the

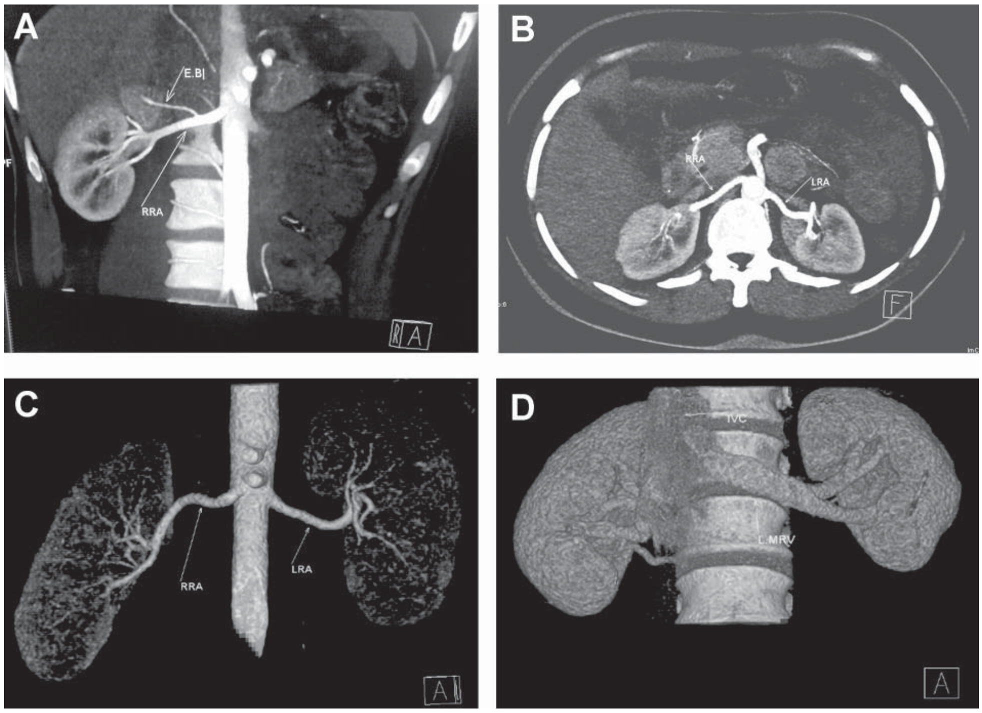

Figure 4. A, B. Multi-slice spiral computerised angiography MIP showing renal arteries in coronal and transverse cuts, respectively; **C.** Multi-slice spiral computerised angiogram of main renal vessels in VRT display; **D.** Multi-slice spiral computerised angiography VRT showing renal veins on right and left kidney; EB — early branching of right renal arter; LRA — left renal artery; RRA — right renal artery; IVC — inferior vena cava; LMRV — left main renal vein; RA view — anterior right view; F view — foot view; AL view — anterior left view; A — anterior view.

large size of the right lobe of the liver. Superiorly, the kidneys are associated with the diaphragm and, more inferiorly, the posterior surfaces of the kidney are related to the quadratus lumborum muscle. The liver, duodenum, and ascending colon are anterior to the right kidney and it is separated from the liver by the hepatorenal recess. The left kidney is related to the stomach, spleen, pancreas, jejunum, and descending colon. In view of the differing anatomical positions and varying proximities to other organs of the right and left kidneys, we designed the present study to compare the size and vascular anatomy of the right kidney with that of the left and to evaluate the effect of the differences in anatomical position [12].

Although in our study left kidney length and APD were higher than those of the right kidney, these differences were not significant. However, it is interesting that the width of the right kidney is significantly greater than that of the left. This may be due to anatomical position and relative proximities. As noted in anatomical references, the right kidney is pushed down and located lower than the left kidney because of the pressure of the right lobe of the liver. This pressure on the upper right kidney may result in compression of the kidney in one dimension, its length, so that this would be less than for the left one. This decrease in length would then be compensated for by an increase in width, so that the right kidney, despite its smaller length, had a greater width.

In most individuals each kidney is supplied by a single renal artery that originates from the abdominal aorta [1, 2, 8, 9]. The renal arteries typically arise from the aorta at the level of L2, below the origin of the superior mesenteric artery, with the renal vein being anterior to the renal artery. The renal arteries course anterior to the renal pelvis before they enter the medial aspect of the renal hilum. The right renal artery typically demonstrates a long downward course to the relatively inferior right kidney, traversing behind the inferior vena cava. Conversely, the left renal artery, which arises below the right renal artery and has a more horizontal orientation, has a fairly direct upward course to the superiorly positioned left kidney. Both renal arteries usually course in a slightly posterior direction because of the position of the kidneys [8, 9].

In our study distance to branching, evaluated for each kidney, was not significantly different between the two sides, despite the fact that anatomically the right renal artery traverses a greater distance to reach the kidney hilum than the left. Of course, distance to branching is more important than distance to kidney with regard to donation, as the donor renal artery on the side selected is severed before bifurcation. We found no difference between the two sides in this respect.

The main renal artery divides into segmental arteries near the renal hilum [1, 2, 8, 9]. The first division is typically the posterior branch, followed by division into four anterior branches as the superior (apical), anterosuperior, anteroinferior, and inferior segmental arteries. Our findings showed there was no difference between right and left sides in the number of segmental arteries. Accessory renal arteries constitute the most common, clinically important renal vascular variant and are seen in up to one third of patients. Multiple renal arteries are unilateral in approximately 30% of patients and bilateral in approximately 10% [8, 18]. Accessory arteries usually arise from the aorta or iliac arteries anywhere from the level of Th11 to the level of L4. In rare cases, they can arise from the lower thoracic aorta or from the lumbar or mesenteric arteries [8]. The accessory artery usually courses into the renal hilum to perfuse the upper or lower renal poles. Accessory vessels to the polar regions are usually smaller than accessory hilar renal arteries, which are typically equal in size to a single renal artery [8].

The prevalence of bilateral and unilateral accessory arteries in our study was approximately the same as in previous studies at 9.4% (11 subjects) and 30.76% (36 subjects) respectively. In all cases the accessory arteries arose from the aorta and not from iliac or lower thoracic, lumbar or mesenteric arteries. We also showed that accessory artery development on the right was twofold that on the left side. This may be due to the greater distance traversed by the right renal artery to reach the kidney from the aorta located to the left of vertebral column [12]. On the basis of Poiseuille's Law, an increase in distance associated with an increase in resistance results in a decrease in flow rate and would result in kidney ischaemia, albeit at a low level [4]. During foetal development, therefore, the kidney probably produces local angiogenetic mediators and assay to abate this condition by means of an accessory artery, which is associated with supplementary flow.

Early branching, or prehilar arterial branching, is another common variant that must be checked for in patients being evaluated for donor nephrectomy. Volume-rendered images, MIP images, shaded surface display images, and multiplanar reformatted images have all demonstrated a high sensitivity (approaching 100%) in the detection of early branching [6, 7, 13, 14, 17]. Images must be obtained during the arterial phase of vascular enhancement to obtain such good results [5].

The results of our study demonstrated that although early branching occurred in the right renal artery more than in the left, the difference was not significant and early branching may develop on either side.

Anatomically the arterial patterns of the left and right kidneys do not differ, except in the accessory pattern, which is of importance for donation. In addition the diameter of the aorta, left and right renal arterial diameters and the length and anterioposterior diameters of the left and right kidneys were higher in males than in females.

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