

Study of arterial pattern of 200 renal pedicle through angiotomography

Estudo do padrão arterial de 200 pedículos renais por meio de angiotomografias

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A B S T R A C T

Objective: To investigate the prevalence and distribution of renal arteries and their branches in vivo, correlating the particularities found in them with sex and laterality. **Methods:** Two hundred renal pedicles were studied by CT angiography and its arteries analyzed according to number, position of origin, size, length and trajectory in relation to renal segments. Its frequency and laterality were surveyed regarding gender and age. **Results:** There were multiple arteries in 61.5% of the pedicles (56% in the right and 67% in the left), occurring in 65% of men and 58% of women. The aortic origin to the multiple arteries was more frequent on the right and, more often, the renal arteries originated between vertebrae L1 and L2 as pre-hilar division of the main artery. The average length of the main artery was higher in right kidneys with a single artery. There was no difference between the diameters of the main renal arteries. **Conclusion:** There is a higher prevalence of multiple renal arteries than the one described in the literature, with no difference for gender or laterality. The renal arteries originated more frequently between vertebrae L1 and L2, with divisions of the pre-hilar route and main artery to the hilum of the kidney. The average length of the main artery is greater on the right and in kidneys with single artery. There was no difference in diameter between the main renal artery between kidneys with single and multiple arteries.

Key words: Renal artery. Kidney / anatomy & histology.

INTRODUCTION

According to anatomical descriptions, each kidney is supplied by a single artery, named main renal artery, with position and path relatively constant up to the hilum. Its origin is the abdominal aorta, between the levels of L1 and L2¹⁻³. According to Testut and Latarjet⁴, the right renal artery in adults presents the path of about 5 cm, and the left approximately 7 cm. Both branch in two, three or four terminal branches in the vicinity of the hilum, most of them passing anteriorly to the renal pelvis. From each renal artery come one or more inferior suprarenal arteries, a branch to the ureter, plus several branches to the adjacent tissue and retroperitoneum.

Apparently, these arteries' anatomical variations do not interfere in renal function and should be differentiated from vascular malformations or anomalies that cause renal or systemic functional disorders. Changes in the origin of the renal arteries have been reported since Bartholin in the 17th century. However, the classical description of the renal vasculature, formed only by one

artery and one vein, occurs in less than 25% of cases^{5,6}. Thus, particularities in the kidney vascular pedicle cannot be considered exceptions. Conformations differ from the pattern in 33% of men and 20% of women. In relation to ethnicity, 37% of African Americans, 35% of Caucasians and 17% of Native Americans present with renal vascular particularities⁷.

Variations in renal arteries have been called ancillary, aberrant, dysfunctional, supernumerary, supplementary, among other terms. It is therefore necessary that the morphology and the nomenclature of these vessels are standardized. In addition, we must emphasize the importance of these arteries in renal irrigation and thus they cannot be deemed superfluous. According to Sampaio and Passos⁸, these arteries should be called multiple, since they are segmental vessels for the kidneys, without anastomoses between themselves.

Contrary to what has been described about the renal arteries, their number ranges from two to six and, according to the territory supplied, they are called hilar, superior polar and inferior polar. Usually, these vessels

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originate from the aorta or common iliac arteries between the levels of T11 and L4. Rarely, they may originate from the suprarenal artery, the celiac trunk, superior mesenteric, inferior mesenteric, median sacral and phrenic arteries⁹⁻¹¹. In General, the arteries which irrigate the renal poles are thinner than the hilar renal arteries from the main renal arteries^{12,13}.

The presence of multiple renal arteries, as well as the pattern of their pre-hilar divisions, should be assessed because of the importance in relation to renal blood supply and influence in the dissection and access plans to the renal hilum. In addition, one should investigate the coexistence of multiple renal arteries and other urovascular anatomical variations, such as the presence of an inferior polar artery originated in the aorta and retroreteral path in the etiology of hydronephrosis¹⁴.

Angiotomography (Angio-CT) has a near 100% sensitivity in detection of number and length of renal arteries. Thus, multi-slice Angio-CT has replaced the conventional arteriography in the evaluation and study of vascular anatomy and diagnosis of vascular diseases of the kidney. Smith *et al.*¹⁵ showed that Angio-CT correctly identified renal arterial anatomy in 41 out of 42 patients undergoing preoperative evaluation for nephrectomies. According to Rubin *et al.*¹⁶, this method has 100% sensitivity in the identification of renal arteries. Platt *et al.*¹⁷ found that the three-dimensional Angio-CT does not differ from conventional angiography in renal vascular study. These findings were evidenced in 2007 by El Fettouh *et al.*¹⁸, who concluded that the three-dimensional Angio-CT correctly identified the number and caliber of renal arteries.

The three-dimensional Angio-CT is useful in the investigation and diagnosis of renovascular hypertension (accuracy of 90%)¹², arterial stenosis (sensitivity and specificity of 92% and 83%, respectively)¹⁹, arterial aneurysms, renal artery embolization, vascular reconstructions, in various operations on the kidney and in the pre and postoperative evaluation of kidney transplants^{20,21}. The existence of multiple renal arteries must be taken into consideration during the imaging assessment of the kidney.

METHODS

The study was developed after approval by the Committee of ethics in research at the Federal University of Minas Gerais, being registered under the No. ETIC 187/08.

We retrospectively studied 100 Angio-CT scans of the kidneys, performed as part of the investigation of abdominal disorders. The examinations were from the ECO-AR Diagnostic Medicine Clinic ECHO – in Belo Horizonte/MG, Brazil. Patients were distributed into two groups: 50 females and 50 males, with mean age 53.3 ± 17.5 years,

ranging between 18 and 75 years, without difference between genders ($p = 0.67$).

The examinations were randomly included in this work. Were excluded patients who had a number of kidneys different from two or disturbances which could interfere in the evaluation of renal vessels.

The same protocol was used for all 100 Angio-CTs, which were held in a 16-channel machine (Brilliance; Philips Medical Systems, Best, Netherlands). Before the exams, patients responded to a questionnaire in which they reported the indication of the examination, presence of symptoms during the preliminary examination, abdominal operations, presence of comorbidities, chronic use of medication and allergic past. Detailed information about the entire procedure and its potential complications were communicated to the patient.

We studied the arterial phase of Angio-CTs and the field extended from the diaphragm to the pubic symphysis. The length of vessels was measured by the maximum intensity projection technique (MIP) and the diameter measured in multiplanar images (MPR). All exams were analyzed by two radiologists, who had consistent views with regard to the number of arteries and their morphological characteristics.

We studied the arteries arising from the abdominal aorta and pre-hilar branches of the main artery, directed to the kidneys. The aortic branch of larger caliber was called renal artery and its pre-hilar branches were those arising at the hilum. The hilum limits were set by a line drawn between the two most medial points in the frontal plane of each kidney.

The renal arteries were surveyed according to their number (sum of renal arteries originating from the aorta and pre-hilar branches of the main renal artery on each kidney), origin position in relation to the vertebrae (vertebral body or intervertebral space), caliber (diameter in mm), length in centimeters of primary renal artery in aorta from the aortic origin till its branching, as well as the path of each artery in relation to the renal segments.

We used the nomenclature adapted by Sampaio and Passos⁹ in 1992: hilar artery – branch of the aorta that penetrates the kidney in hilum; extra-hilar artery – branch of the renal artery that presents an extra-hilar penetration (in superior or inferior poles); superior polar artery – branch of the aorta that penetrates the kidney at the superior pole; inferior polar artery – branch of the aorta that penetrates the kidney at the inferior pole.

All arteries and their branches were studied as for frequency and laterality, taking into account gender and age of the patients. The differences were established using Student's t test after proof of a normal distribution by the Kolmogorov-Smirnov test. The frequency of the origins of these vessels, as well as their different paths, was compared for the kidneys, genders and age groups, via the Chi-square test. We used a level of 5% for the definition of

statistical significance. The statistical calculations were performed with the aid of the software SPSS 16.0.

RESULTS

Multiple arteries were observed in 61.5% of the 200 renal pedicles studied (56% of right kidney and 67% of left ones). There was no difference when the presence of multiple arteries was compared to laterality, $p = 0.11$ OR = 1.6 (0.86 – 2.95). The distribution of renal arteries by gender and laterality occurred as described in table 1.

We found multiple renal arteries in 65% of male patients and 58% in women. However, there was no difference between the presence of multiple arteries in relation to gender, $p = 0.31$ and AB = 1.34 (0.73 – 2.48). The relationship of the presence of multiple arteries between sex and laterality was also no different in right and left kidneys of males ($p = 0.29$) and between left and right kidneys in females ($p = 0.22$).

We identified bilateral multiple renal arteries in 41% of patients. Among the right kidneys with multiple arteries, 10.7% had a second renal artery with aortic origin, 75% had one or more arteries that had their origin as a division of a primary pre-hilar renal artery and 14.3% had one or more arteries from the aorta, in addition to pre-hilar branches from the main artery (Figure 1). In left pedicles with multiple renal arteries, these percentages were 23.9% for exclusive aortic origin, 62.7% for pre-hilar divisions and 13.4% for the combination of arteries from the aorta and pre-hilar divisions of the main artery. There was significant difference when comparing left to right aortic origins of renal arteries ($p = 0.05$), with the highest number on the left.

To the right, the average length of primary renal artery until its first branch was 3.96 ± 0.13 cm and on the left side it was 3.41 ± 0.11 cm ($p = 0.0023$). In right kidneys with a single artery, the average primary renal artery length found was 4.70 ± 1.19 cm and in those with multiple arteries it was 3.38 ± 1.10 cm ($p = 0.0001$). In left kidneys with a single artery the average length of the main artery was 3.68 ± 1.08 cm and in those with multiple arteries it was

3.28 ± 1.20 cm, with no difference between them ($p = 0.10$). We found just one case of early renal artery bifurcation, with division less than 1 cm from the aorta⁶.

As for the trajectory of vessels in the kidneys with multiple arteries, there was difference only when comparing the extra-hilar arteries reaching the superior pole between left and right kidneys ($p = 0.05$) (Table 2).

The renal arteries from the aorta originated with greater frequency in front of the L1-L2 intervertebral space, being on the right side 38.8% of the time and 35.7% of the time on the left side. There was no difference when comparing the origin between the vertebrae L2 and L3 in right and left, its prevalence being increased on the left ($p = 0.02$) (Table 3).

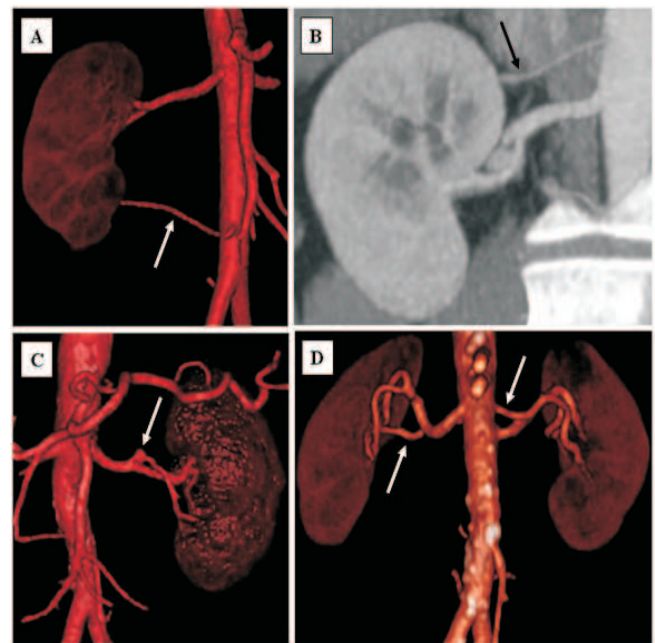


Figure 1 - Multiple renal arteries: A) inferior polar artery-(arrow) in the kidney right; B) superior polar artery (arrow) in the right kidney; C) pre-hilar division of the left renal artery, with small aneurysm (arrow) in the origin of the pre-hilar branch; D) pre-hilar division of the renal artery and second right aortic branch with trajectory to the hilum in the left (arrows).

Tabela 1 - Percentage distribution of the renal arteries as for gender and laterality.

	Right Kidney		Left Kidney	
Masculino	1 artery	(40%)	1 artery	(30%)
	2 arteries	(34%)	2 arteries	(46%)
	3 arteries	(22%)	3 arteries	(20%)
	4 arteries	(4%)	4 arteries	(4%)
Feminino	1 artery	(48%)	1 artery	(36%)
	2 arteries	(32%)	2 arteries	(42%)
	3 arteries	(18%)	3 arteries	(16%)
	4 arteries	(2%)	4 arteries	(4%)
			6 arteries	(2%)

The average diameter of the primary renal artery on the right side was 6.8 ± 0.16 mm in kidneys with a single artery and 6.5 ± 0.17 mm in those with multiple arteries ($p = 0.114$). On the left side, the value was 6.9 ± 0.2 mm in single-artery kidneys and 6.8 ± 0.2 mm in the case of kidneys with more than one artery ($p = 0.423$). Also, there was no difference in the comparison between left and right kidneys ($p = 0.592$ for kidneys with a single artery, and $p = 0.156$ for kidneys with multiple arteries).

In men, the average diameter of the main artery was 7.11 ± 0.16 mm to the right and 7.17 ± 0.17 mm ($p = 0.78$) in the left. In women, on their turn, we found values of 6.14 ± 0.14 mm to the right and 6.53 ± 0.15 mm on the left ($p = 0.0671$). There was significant difference when comparing diameters, both right and left, between men and women ($p < 0.0001$ and $p = 0.0066$, respectively).

Tabela 2 - Percentage distribution of the trajectory of vessels as for laterality in renal pedicles with more than one artery.

Arterial Feature	Right Kidney	Left Kidney
Two Hilar Arteries	37.50%	53.6%
Three Hilar Arteries	23.2%	14.5%
Four Hilar Arteries	1.79%	4.4%
One Superior Polar	7.14%	11.6%
One Inferior Polar	3.57%	2.9%
Extra- Hilar Superior Polar	28.6%	11.6%
Extra- Hilar Inferior Polar	0%	1.4%

Hilar Artery – branch of the aorta that penetrates the kidney in the hilum; *extra-hilar artery* – branch of the renal artery, which presents a extra-hilar penetration (superior or inferior); *superior polar artery* – branch of the aorta that penetrates the kidney at the superior pole; *inferior polar artery* – branch of the aorta that penetrates the kidney at the inferior pole (adapted from Sampaio and Passos)⁸.

Tabela 3 - Distribution of renal arteries originating from aorta as for laterality and origin position in relation to vertebrae.

Vertebra	Right Kidney	Left Kidney
T11	0%	0%
T11-12	0.9%	0.8%
T12	0%	0%
T12-L1	2.6%	0.8%
L1	35.3%	29.4%
L1-2	38.8%	35.7%
L2	20.7%	26.3%
L2-3	0%	4.7%
L3	1.7%	0%
L3-4	0%	2.3%
L4	0%	0%

DISCUSSION

Multiple renal arteries occur in 20% to 50% of the population, its variation being more common than for other organs^{6,8,22}. These vessels are branches of a single segmental renal artery or independent vessels emerged directly from the aorta²².

The multiple renal arteries relate to the persistence of mesonephric arteries, which embryonically form a vascular network that nourishes the kidneys, the suprarenal glands and the gonads on both sides of the aorta, between the sixth cervical and the third lumbar vertebrae, a region called urogenital arterial network. With the progression of development, this network becomes just one mesonephric artery, which assumes the renal circulation²³. Disability in the development of the mesonephric arteries results in more of a renal artery and each tends to be a terminal vessel, responsible for irrigation of the renal segment(s) to which it directs. Therefore, the interruption of blood flow by injury or ligation of an artery causes ischemia and necrosis of parenchyma, leading to the exclusion of the corresponding renal segment^{5,8}. Moreover, the persistence of embryonic irrigation pattern may be associated to anomalous renal development and ectopic kidneys⁸.

The presence of multiple arteries increases the complexity of kidney operations, its knowledge being vital for the operative planning²⁴⁻²⁶. In renal transplants with presence of multiple arteries, the rate of late arterial stenosis is higher ($p = 0.0196$)²⁷.

Most published anatomical studies regarding renal arteries are based on autopsies or anatomical parts. In this case, multiple renal arteries occurred in a greater numbers than that reported in the review of Satyapal *et al.*⁷ (28.2%). Sampaio and Passos⁸ found a single renal artery in 55.3% of pedicles studied and multiple arteries in only 30.4%. The presence of bilateral, multiple renal arteries was also higher (41% of the studied pedicles *versus* 10.2% described by Satyapal *et al.*⁷). There was no difference as for gender and laterality.

Most often, the multiple renal arteries originated as main artery branches on both sides and the average length of the main renal artery until branching was 3.96 cm at the right and 3.41 cm at the left, given the position of the aorta to the left of the median plane and the lengthier path of the renal arteries on the right side.

The comparison of the length of the main artery between kidneys with multiple and single arteries was significantly different only at the right, as there were arteries originating from the aorta more frequently at the left. Most of these vessels headed to the hilum on both sides.

According to the classic anatomic descriptions, as well as in a research on the origin of the renal arteries in human fetuses by Çiçekcibaşı *et al.*⁵ and the study on the origin of the renal arteries by angiography by Özkan *et al.*¹, renal arteries originating between the vertebrae L1 and L2

were more frequently found, both in the right and left sides. However, they observed a higher frequency of renal arteries originating from inferior positions of the aorta on the left, mainly in the intervertebral space of L3 and L4. Together, these data must be taken into consideration during kidney operations, as they enable to predict most of the patterns of multiple renal arteries.

Although each renal artery independently irrigates a specific renal segment, there was no difference in the diameter measured at the origin of the main artery between kidneys with single and multiple arteries. However, this data must be assessed with caution, since most of the renal arteries originated as pre-hilar divisions of the main artery and not as independent branches of the aorta in both kidneys.

The preoperative arterial anatomy study of the kidneys allows predicting most of the distribution patterns of the renal arteries. Knowledge of anatomy before deciding which operative tactic to employ can prevent operational accidents or inadequate treatments.

There is a higher prevalence of multiple renal arteries than that described in the literature, no difference between genders or laterality. The renal arteries originated more frequently between the vertebrae L1 and L2, as pre-hilar divisions of the main artery and with path to the renal hilum. The average length of the main artery on the right is larger and in kidneys with a single artery. There was no difference in the diameter of the primary renal artery between kidneys with single and multiple arteries.

R E S U M O

Objetivo: Verificar a prevalência e a distribuição das artérias renais e de seus ramos in vivo, relacionando as particularidades encontradas nas artérias renais com o sexo e sua lateralidade. **Método:** Duzentos pedículos renais foram estudados por meio de angiotomografias e suas artérias analisadas de acordo com número, posição de origem, calibre, comprimento e trajeto em relação aos segmentos renais. Sua frequência e lateralidade foram pesquisadas quanto ao sexo e idade. **Resultados:** Foram observadas múltiplas artérias em 61,5% dos pedículos (56% à direita e 67% à esquerda), ocorrendo em 65% dos homens e 58% das mulheres. A origem aórtica para as múltiplas artérias foi mais frequente à direita e, com maior frequência, as artérias renais se originaram entre as vértebras L1 e L2 como divisões pré-hilares da artéria principal. O comprimento médio da artéria principal foi maior em rins direitos com artéria única. Não houve diferença entre o diâmetro da artéria renal principal. **Conclusão:** Existe maior prevalência das múltiplas artérias renais do que aquela descrita na literatura, sem diferença entre os sexos ou lateralidade. As artérias renais originaram-se com maior frequência entre as vértebras L1 e L2, como divisões pré-hilares da artéria principal e com trajeto ao hilo do rim. O comprimento médio da artéria principal é maior à direita e nos rins com artéria única. Não houve diferença no diâmetro da artéria renal principal entre rins com artérias únicas e múltiplas.

Descritores: Artéria renal. Rim. Rim/anatomia & histologia.

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