Rom J Morphol Embryol 2019, 60(3):1009–1014

RJME
Romanian Journal of Morphology & Embryology
http://www.rjme.ro/

CASE REPORT

Unilateral left four renal arteries: case report using MDCT angiography

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Abstract

We report a very rare case of a 57-year-old male who presented four left renal arteries (RAs) [one main RA and three additional renal arteries (AdRAs)] highlighted incidentally on multidetector computed tomography (MDCT) angiography, which was used to investigate the vascular system of the lower limbs. The distance between the extreme points of RAs origin (upper and lower points of origin) from abdominal aorta (AA) was in the left part of 9.83 cm. The distance between the extreme points of penetration (upper and lower points of penetration) into the left renal parenchyma was 5.23 cm. At the level of origin, the main left RA has an endoluminal diameter of 0.63 cm, much larger in comparison to the other additional left RAs (0.43 cm, 0.33 cm and 0.28 cm, respectively). The length of the main left RA was 2.16 cm, significantly shorter in comparison with the other additional left RAs (2.21 cm, 4.26 cm and 4.73 cm, respectively). The second left RA was the main RA; the first left RA was AdRA (polar superior RA); the third left RA was AdRA (hilar RA); the fourth RA was AdRA (polar inferior RA). Knowledge of this anatomical variation should be considered in planning and performing renal vessel surgery, and kidney transplantation.

***Keywords*:** renal arteries, kidney, anatomic variants, morphological considerations, clinical and surgical implications.

Introduction

The classically anatomical descriptions presented each kidney being vascularized by a single renal artery (RA), arising from the lateral edge of the abdominal aorta (AA) [1, 2]. According with Bayazit *et al.* [3], the variations of the renal vasculature is presented with an incidence of 20–75%. Variation in the number of RAs (the multiple RAs) constitutes the most frequent group of renal variations. Depending of the origin level, the multiple RAs are divided into (*i*) additional RAs (AdRAs), which have their origin in the AA, and (*ii*) accessory RAs (AcRAs), which have their origin from branches of the AA [4]. In a series of 440 kidneys, Satyapal *et al.* [5] detected 27.7% AdRAs (first AdRA in 23.2% of kidneys and the second AdRA in 4.5% of kidneys). In this series of cases, a first AdRA was found bilaterally in 10.2% of cases. On a continuous series of 1000 angiographies, Matusz *et al.* [6] achieve a total prevalence of 18.2% of cases with AdRAs, with the presence from one to six AdRAs. One AdRA was highlighted in 9% of cases; two AdRAs were highlighted in 7% of cases; three AdRAs were highlighted in 1.6% of cases; four AdRAs were highlighted in 0.3% of cases; five AdRAs were highlighted in 0.2% of cases; six AdRAs were highlighted in 0.1% of cases. The bilateral symmetry of RAs was highlighted in 88.4% of cases. Of these, only 6.3% of cases were bilateral double, 0.2% of cases bilateral triple, and 0.1% of cases bilateral quadruple. The right/left difference in the number of AdRAs is one [7–9] or two [10, 11]. The presence of a difference of three RAs between the right and left kidneys is exceptional; Matusz *et al.* [12] describe a single congenital right kidney with three RAs (one main RA and two AdRAs) and Türkvatan *et al.* [13] present one multidetector computed tomography (MDCT) angiography of a case with four right RAs (one main RA, two AdRAs and one AcRA). Wróbel *et al.* [14] describe a dissection case with four left RAs (one main RA and three AdRAs).

We report an extremely rare case with four left RAs (one main RA and three AdRAs). The examination was performed by MDCT angiography. Cases like these highlight the importance of having knowledge about relevant anatomy, embryology, and the clinical significance of the arterial variations of the kidneys for better training of physicians for planning and perform surgical procedures.

Case presentation

The authors report the case of a 57-year-old male examined at the Neuromed Diagnostic Imaging Center (Timişoara, Romania).

Using MDCT angiography for vascular assessment of the lower limbs, in addition of peripheral arterial lesions of the lower limbs, a peculiar arterial renal network with five RAs was highlighted: one main RA for the right kidney and four RAs for the left kidney (one main RA and three AdRAs) (Figure 1). In the right side, there is only one RA, the main (hilar) RA (RRA1). In the left part, for ease of location, the RAs have been designated: LRA1 – the first left RA (the superior) was extra RA (polar superior RA); LRA2 – the second left RA (the middle-superior) was the main RA (hilar RA); LRA3 – the third left RA (the middle-inferior) was extra RA (hilar RA); LRA4 – the fourth left RA (the inferior) was extra RA (polar inferior RA). For the right RA were analyzed five morphological parameters, and for left RAs was studied a number of seven morphological parameters (Table 1).

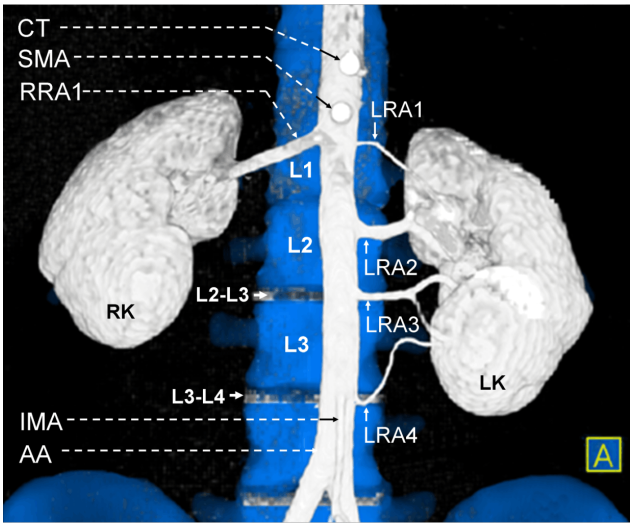

Figure 1 – *Coronal image with the highlight of the kidneys and AA on MDCT angiographies with 3D reconstruction. Coronal VRT image with the origins of the RAs from the AA, and their relationship to vertebral bodies. AA: Abdominal part of aorta; MDCT: Multidetector computed tomography; 3D: Three-dimensional; VRT: Volume rendering technique; RAs: Renal arteries; RK: Right kidney; LK: Left kidney; RRA1: First right renal artery (right main renal artery); LRA1: First left renal artery (polar superior renal artery – AdRA); LRA2: Second left renal artery (left main renal artery); LRA3: Third left renal artery (middle-inferior renal artery – AdRA); LRA4: Fourth left renal artery (polar inferior renal artery – AdRA); AdRA: Additional renal artery; CT: Celiac trunk; SMA: Superior mesenteric artery; IMA: Inferior mesenteric artery.*

Table 1 – *Morphological parameters of the renal arteries*

Morphological parameters measured [cm]	RRA1			
Right renal artery				
Vertebral level of renal arterial origin	Middle 1/3 of L1			
Intraluminal diameter at origin	0.63			
Arterial length	5.61			
Course (ascendant +; descendant –)	-1.76			
Parenchymal penetration	Hilar penetration			
Morphological parameters measured [cm]	**LRA1**	**LRA2**	**LRA3**	**LRA4**
Left renal arteries				
Vertebral level of renal arterial origin	Middle 1/3 of L1	Middle 1/3 of L2	Intervertebral disc L2–L3	Intervertebral disc L3–L4
Intraluminal diameter at origin	0.33	0.63	0.43	0.28
Arterial length	4.73	2.16	2.21	4.26
Course (ascendant +; descendant –)	-2.94	+0.3	Horizontally	+2.53
Parenchymal penetration	Hilar penetration	Hilar penetration	Hilar penetration	Inferior polar penetration
Distance between extreme points (upper and lower) of origin at aortic level				9.83
Distance between extreme points (upper and lower) of renal penetration				5.23

RRA1: First right renal artery; LRA1: First left renal artery; LRA2: Second left renal artery; LRA3: Third left renal artery; LRA4: Fourth left renal artery.

The right kidney has a length of 11.52 cm, a width of 5.73 cm, and a thickness of 5.52 cm. Upper pole is ascended to the level of the lower edge of T12 vertebral body; the distance between the upper pole and the middle-sagittal plane is 3.83 cm. The lower pole of the right kidney is located at the level of the middle third of the L3 vertebral body; the distance between the lower pole and the middle-sagittal plane is 7.54 cm. Upper pole is placed at 1.53 cm posterior to the coronal plane of the anterior aspect of the vertebral bodies and the inferior pole at the level of coronal plane passing from the anterior aspect of vertebral body. The right renal hilum is oriented antero-medially and inferiorly, realizing with the coronal plane an angle of 33°.

The left kidney has a length of 11.76 cm, a width of 4.98 cm, and a thickness of 4.65 cm. Upper pole is ascended to the level of upper edge of the L1 vertebral body; the distance between the upper pole and the middle-sagittal plane is 3.57 cm. The lower pole is located at the level of upper edge of the L4 vertebral body; the distance between the lower pole and the middle-sagittal plane is 5.85 cm. Upper pole is placed in the coronal plane passing from anterior aspect of the vertebral bodies; the inferior pole is placed as same level. The left renal hilum is oriented antero-medially, realizing with the coronal plane an angle of 46°.

The right kidney has a malrotation; the superior pole is oriented to posterior-superior and the inferior pole to antero-medial and inferiorly. The left kidney is normally positioned, but incompletely ascended.

Consent

Two written informed consents were obtained from the patient, the first for the MDCT angiographic examination and the second for the use of the data obtained for scientific purposes.

Discussions

Terminology and classification

The RAs, usually unique on each side, arise from the lateral aspect AA, most commonly in the interval between the upper edge of L1 and the lower edge of L2 vertebrae [15], slightly inferior the origin of the superior mesenteric artery (SMA) [13, 16]. The right RA aortic ostium is usually higher and antero-lateral than the left. The right RA is longer, and having a downward course, passes behind the inferior vena cava to deserve the right kidney that placed inferior to the left kidney level. The left RA is shorter and having a horizontal course, passes behind the left renal vein, the body of the pancreas and the splenic vein, to reach the left kidney [13, 16]. Close to the renal hilum, the RA divides in anterior and posterior branches. The anterior branch divides in four segmental arteries: (*i*) superior, (*ii*) anterior superior, (*iii*) anterior inferior, and (*iv*) inferior. The posterior branch continues only with the posterior segmental artery [17]. The five segmental arteries are end arteries.

According with Bayazit *et al.* [3] the variations of the RAs are shown in literature with a prevalence varying between 20% and 75% of cases. Of all types of anatomical variations of RAs, the variation in the number of the RAs is the most common. Analyzing anatomical literature regarding the name attributed to RAs (other than the "main" RA), Satyapal *et al.* [5] described it as: (*i*) "accessory", (*ii*) "aberrant", (*iii*) "anomalous", (*iv*) "supernumerary", (*v*) "supplementary", (*vi*) "multiple", (*vii*) "accessory aortic hilar", (*viii*) "aortic superior polar", (*ix*) "aortic inferior polar", (*x*) "upper polar artery", (*xi*) "lower polar artery". This analysis has been frequently reiterated in later published papers [2, 7, 18].

Özkan *et al.* [15] propose the classification of RAs in two groups, depending on the penetration level of the RAs in the renal parenchyma: (*i*) early division (ED) represents a proximal branching of the main RAs away from the renal hilus level; (*ii*) extra RAs divided in hilar (accessory) and polar (aberrant) RAs. Glodny *et al.* [4] correlate the origin of multiple RAs with proposed terminology and classifies multiple RAs in two categories: (*i*) AdRAs originating from the AA, and (*ii*) AcRAs originating from the AA branches.

For presenting our case, we used the terminology of Glodny *et al.* [4] for multiple RAs (other than the main RA). By taking in account that the three RAs associated with the main left RA originated in AA, they were considered as AdRAs.

Embryology

The urinary system develops from intermediate mesenchyme in three specific organs: (*i*) pronephros, (*ii*) mesonephros, and (*iii*) metanephros, succeeding each other in time and space [1, 16]. The pronephros appears during the 4th week of development (in stage 10 of embryos), in the cranial part of the nephrogenic cord and it atrophies in the 5th week of embryo-fetal life. Pronephros is usually nonfunctional and after the 5th week of embryo-fetal life, the pronephric ducts are taken over and used by the mesonephros.

The mesonephros develops between 5th and 16th week of embryo-fetal life (from stage 12 to 19 of embryos) [16] and contains functional primitive glomeruli [19]; is located between the 6th cervical and the 3rd lumbar vertebral body [20]. It is vascularized by a great number of temporary aortic branches (in maximum 30 mesonephric arteries) [1]. According with Arévalo Pérez *et al.* [21], the development of the mesonephric arteries is progressive cranio-caudal, following embryo-fetal evolution, and the degeneration of the mesonephros.

Initially, the mesonephric arteries are distributed only to the mesonephros; afterwards, supply the suprarenal bodies, the diaphragm, the reproductive glands, and the metanephros, at the end of the 8th week of embryo-fetal development. The extension of the mesonephric arteries territory prevents their complete degeneration [20]. According to Felix's studies, in case of an 18 mm embryo, to whom the mesonephros is completely degenerate, from the level of 10th thoracic to the level of 3rd lumbar vertebral body, persist nine mesonephric arteries [1, 21]. Located in the angle between the mesonephros and the metanephros, these nine pairs of mesonephric arteries, are placed in three groups: (*i*) cranial (1st and 2nd pair), (*ii*) middle (3rd to 5th pair), and (*iii*) caudal (6th to 9th pair) groups.

The metanephros develops during the 4th and 5th weeks of embryo-fetal life, in the sacral region, at the level of the S1 or S2 segment, inferior to the bifurcation of the aorta, in the inter-iliac angle, having the hila oriented anteriorly [22]. Between the 6th and 9th week, the metanephros develops in the retroperitoneal space, from the sacral to lumbar level. Metanephros ascent is completed at the time of contact with the suprarenal glands. During the metanephros ascent, renal hila rotate 90° towards the medial. During kidneys ascend, they receive their blood supply from the vascular structures close to them [9]: first from iliac arteries and their branches, and later from AA and abdominal aortic branches [19].

According with Graves [23], in the delimited space: (*i*) dorsally by the metanephros, (*ii*) ventrally by the reproductive gland, and (*iii*) laterally by the mesonephros, the remaining 5–9 mesonephric arteries form the rete *arteriosum urogenitale*. *Via* this arterial network, the mesonephros and metanephros arteries connect with the AA. The permanent main RAs develop at the level of L2 vertebral body, from a single pair of mesonephric arteries, from the middle group [24]. If in the transition phase between mesonephros and metanephros, more than one mesonephric artery persists, this leads to the appearance of several AdRAs. Considering this, the multiple RAs must be considered persistent mesonephric arteries [3].

In our case, a peculiar aspect appears, in which AdRAs are present only on the left side, and the difference between the number of RAs on the left and the right one is three. They all originate from the left aspect of AA. The left kidney is insufficiently ascended (the upper pole is located at the level of the upper edge of the first lumbar vertebral body). In case of incomplete elevation of the kidney, the mesonephric arteries persist and become persistent mesonephric arteries (Figure 2, A and B).

Prevalence of multiple RAs

According with Satyapal *et al.* [5], analyzing a number of 440 kidneys with a race distribution [in the context of the ethnic diversity of the South African population: (*i*) Africans – 167 kidneys; (*ii*) Indians – 178 kidneys; (*iii*) Whites – 68 kidneys, and (*iv*) "Colored" – 27 kidneys], the total prevalence of kidneys with multiple RAs was 27.7%, and the prevalence depending on the race distribution was: (*i*) African 37.1%; (*ii*) Indian 17.4%; (*iii*) White 35.3%, and (*iv*) "Colored" 18.5%.

According to Gulas *et al.* [25], range of the frequency of multiple RAs depending on ethnicity is between 4%

(Malaysians population – Hlaing *et al.* (2012) quoted by Gulas *et al.* [25] 61.5% (Brazilian population – Palmieri *et al.* (2011) quoted by Gulas *et al.* [25]).

Analyzing the casuistry of the 53 papers (17 573 cases) evaluated by Gulas *et al.* [25], we calculated a general prevalence of multiple RAs of 21.76%. On this case, we highlighted significant differences depending on geographical distribution: North Africa 14.4%, Asia 19.77%, Europe 21.95%, North America 23.55%, New Zealand 26%, South America, and Caribbean 32.33%.

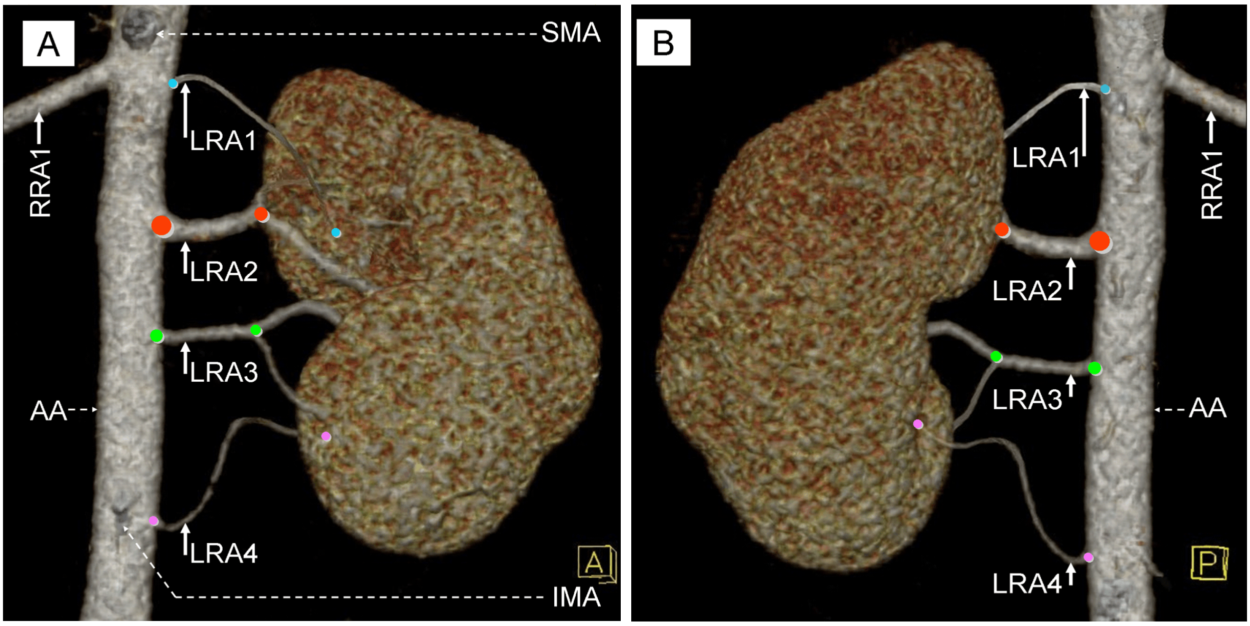

Figure 2 – ***MDCT angiography of the left kidney. VRT images of the abdominal part of aorta shows the presence of four left RAs: (A) Anterior 3D VRT image shows the origin and the points of renal penetration of the left RAs, after subtraction of the skeletal structures; (B) Posterior 3D VRT image after subtraction of the skeletal structures. MDCT: Multidetector computed tomography; VRT: Volume rendering technique; RAs: Renal arteries; 3D: Three-dimensional; AA: Abdominal part of aorta; SMA: Superior mesenteric artery; IMA: Inferior mesenteric artery; RRA1: First right renal artery (right main renal artery); LRA1: First left renal artery (polar superior renal artery – AdRA); LRA2: Second left renal artery (left main renal artery); LRA3: Third left renal artery (middle-inferior renal artery – AdRA); LRA4: Fourth left renal artery (polar inferior renal artery – AdRA); AdRA: Additional renal artery. With colored dots: Points of left RAs origin at aortic level; Points of left RAs penetration (or bifurcation).***

The analysis of the gender prevalence of cases with the presence of multiple RAs should take in account the way the study group is achieved and the purpose for which the renal assessment was performed. Use of cases with peripheral arterial disease of the lower limbs (with predominance of male sex) can lead to false positives in favor of male gender. Thus, in the study of Özkan *et al.* [15], to which they have been achieved angiography for claudicatio (72%), critical foot ischemia (11%), suspicion of renovascular hypertension (8%), AA aneurysm (1%), and other reasons (8%), 81% were males and 19% females. On study groups explicitly made for the morphological analysis of the kidneys and its vasculo-ductal elements, there is a slight predominance of the male gender of cases with multiple RAs. Therefore, Khamanarong *et al.* [26] highlights on 534 kidneys, a percentage of 60.3% cases of males. Glodny *et al.* [27], on 1071 patients examined through MDCT angiography, highlights a percentage of 55.9% was males' cases.

Studies of Satyapal *et al.* [5], Sośnik & Sośnik [28], Glodny *et al.* [27], and Saldarriaga *et al.* [29] clearly highlight the predominance of the left side for the origin of multiple RAs: 32%, 31.3%, 28.36%, and 27.3% of cases, respectively, compared to 23.3%, 24.4%, 27.7% and 22.2% of cases for the right part, respectively. Analyzing a number of five case reports with right/left differences of the RAs was highlighted that: of the three cases with difference of one RA the right and the left part, in two cases [1, 7] there is a left predominance, and from the two cases with the difference of two RAs between right and left, in one case there is a right predominance [10], and in other left predominance [11]. Of these, three cases were males [2, 10, 11] and two cases were females [7, 9].

We analyzed distinctly and comparatively the two cases with the right/left difference of three RAs presented in the literature and compared them to our own case.

Türkvatan *et al.* [13] present one MDCT angiography of a case with four right RAs and one RA (main) in the left (unspecified gender). On the right, the first RA is the main RA. The following two RAs are AdRAs originating from the lateral aspect of AA and hilar penetration; the fourth right RA is AcRA originated on the right aspect of the common iliac artery and penetration of the right kidney at the lower renal pole. Main left RA arises from the lateral left aspect of AA, above the origin level of main right RA.

Wróbel *et al.* [14] present a dissection case with four left RAs and one main RA in the right (female cadaver). On the left side, the first RA is AdRA with the origin on the left aspect of AA (at the same level as the right main RA) and hilar renal penetration. The second left RA is the left main RA with aortic origin and hilar renal penetration. The third RA is AdRA aortic origin and hilar renal penetration. The fourth left AR is AdRA; it originates on the left aspect of the AA at approximately 2 cm above the aortic bifurcation and lower polar parenchymal penetration.

Our case (Figure 3), as is the case of Wróbel *et al.* [14], present AdRAs on the left side. The first left AdRA originates from AA at the same level as the right main RA, as in the case of Wróbel *et al.* [14]. If the first three RAs (main and first two AdRAs), in the case of Wróbel *et al.* [14] have origin grouped in the vicinity of SMA origin, and the last AdRA in the vicinity of inferior mesenteric artery origin (IMA), in our case the four left RAs (main and the third AdRAs) are metamorphically spread between the origin level of SMA and IMA. The left inferior RAs, in the case of Wróbel *et al.* [14] and in our case, have origin in the left aspect of AA, so they must be considered as AdRAs. In the case of Türkvatan *et al.* [13], the last RA originating from the right aspect of the common iliac artery must be considered AcRA.

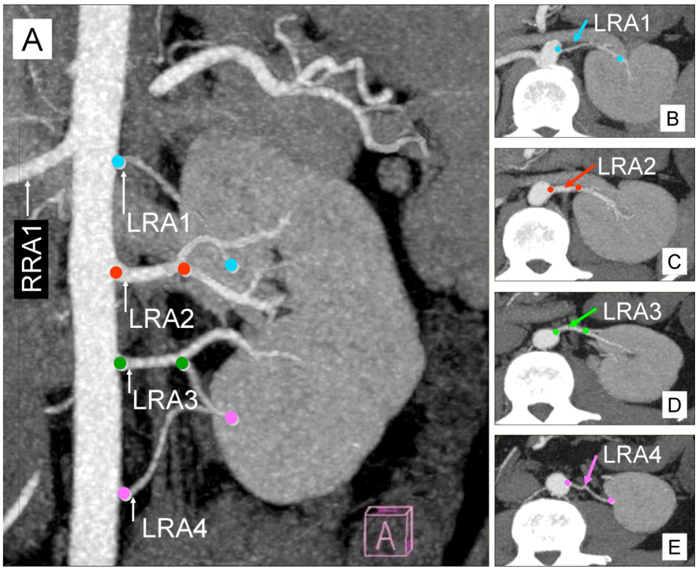

Figure 3 – ***Coronal (A) and transversal views (B–E) of the left kidney, left RAs and AA on MIP. RAs: Renal arteries; AA: Abdominal part of aorta; MIP: Maximum intensity projection; RRA1: First right renal artery (right main renal artery); LRA1: First left renal artery (polar superior renal artery – AdRA); LRA2: Second left renal artery (left main renal artery); LRA3: Third left renal artery (middle-inferior renal artery – AdRA); LRA4: Fourth left renal artery (polar inferior renal artery – AdRA); AdRA: Additional renal artery. With colored dots: Points of left RAs origin at aortic level; Points of left RAs penetration (or bifurcation).***

Morphological considerations with clinical and surgical implications

The prolonged development of surgical techniques and postoperative immunosuppression has determined that in recent decades, kidney transplantation is the best definitive treatment option for advanced stages of chronic renal failure [30, 31]. According with Usta *et al.* [30], the kidney transplantation with multiple RAs is much more difficult because of: (*i*) extension of warm ischemia time; (*ii*) increased the incidence of acute tubular necrosis; (*iii*) growth the incidence of rejection episodes, (*iv*) high graft function failure, and (*v*) prolonged time of hospitalization. Also, in case of transplanting a kidney with multiple RAs was highlighted a higher rate of vascular complications (RAs stenosis and thrombosis) and urological complications (ureteral necrosis or calyceal cutaneous fistulas, delayed graft function) [30, 32].

Zorgdrager *et al.* [31] perform a meta-analysis of the current literature (a total of 23 articles – 18 289 patients) on the outcomes of kidney transplantations from any type of donor with multiple RAs grafts, compared to single RA grafts in terms of: (*i*) delayed graft function, (*ii*) graft survival, (*iii*) patient survival, and (*iv*) complication rates. The results highlight that:

▪ delayed graft function highlights a significant difference in favor of the single RA group, 10.3% compared to 8.2% for multiple RAs;

▪ graft survival at one year was 93.2% in the multiple RAs group, and 94.5% in the single RA group; and graft survival at 5-year was 81.4% in the multiple RAs group, and 81.6% in the single RA group;

▪ the patient survival rates at one year was 95.4% in the multiple RAs group and 95.4% in the single RA group; and the patient survival rates at 5-year was 95.4% in the multiple RAs group and 87% in the single RA group;

▪ recipients of a multiple RAs graft have a significantly higher level of vascular complications compared to those who received a single RA graft, 10.8% *versus* 8.1%, respectively.

By the mechanism of rennin–angiotensin system activation, major RA stenosis (usually due to atherosclerosis) is considered one of the vascular causes of arterial hypertension [33]. A statistical correlation was also highlighted between with stenosed AdRAs and arterial hypertension [34]. An association between AdRAs and hypertension has been suspected over a long time [35]. AdRAs tend to be longer and narrower than the main RAs. These morphological features lead to higher resistance across arteries and lower perfusion pressure [33]. Studies of Chan & Tan [36] highlighted a correlation between the presence of the AdRAs and the hypertension with secondary hyperaldosteronism.

In our case, the right kidney has a malrotation, and the left kidney is normally positioned, but incompletely ascended. This incomplete ascension is associated with the presence of AdRAs. Also, in the cases presented by Türkvatan *et al.* [12] and Wróbel *et al.* [14], the kidney with AdRAs is insufficiently ascended. AdRAs have a diameter significantly lower than that of the main RA; also, the length of AdRA's is significantly greater than the main RA length; these features are favored factors in the occurrence and development of renal arterial hypertension.

Conclusions

We have presented in this paper a very rare case in which the left kidney is served by four RAs (one main RA and three AdRAs), all with the origin of the AA. AdRAs must be considered persistent mesonephric arteries. Description and knowledge of such anatomical variations is very important both for anatomists and clinicians. The presence and multiple variations of AdRAs should be considered in planning and performing renal vessel surgery, and kidney transplantation.

Conflict of interests

The authors declare that they have no conflict of interests.

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Received: June 17, 2019 *Accepted: December 10, 2019*