Journal of Morphological Sciences
J Morphol Sci
Brazilian Society of Anatomy

Original Article
J Morphol Sci 2023;40:516-522

Comparative Analysis of Variants of the Structure of Extra-Organ Renal Arteries According to Multispiral Computed Tomography

Z.U. Lechiev[1], E.S. Kafarov[1], Kh.M. Bataev[1]

[1]Medical Institute, Chechen State University named after A.A. Kadyrov, Grozny, Russia

Disclose and conflicts of interest: none to be declared by all authors

ABSTRACT
Introduction: this study aimed to conduct a 3D analysis of the extra-organ part of the renal arteries in men and women.
Methods: the analysis of 162 multispiral computed tomograms of men and women was carried out. Spatial orientation, course, topography, and their number were determined in a 3D projection.
Results: tThe authors observed that the sources of blood supply to the kidneys, their topography, and the number of renal arteries, had some differences. It was found that regardless of gender and side of the body, the main renal artery divided medially from the plane tangent to the medial edge of the kidney, i.e., extrarenally. The variants of intra- and extrarenal division of the main renal artery influence the length of the branches. The topographic and anatomical features of the location of tubular structures in the renal hilum depend on the variants of their division, which do not always fit into the framework of the classical vein-artery-ureter scheme. The authors found that, on average, regardless of gender characteristics, in 80.5% of cases, the blood supply to the kidney was carried out by one renal artery, and in 19.5%, there were variants of accessory, perforating, and multiple renal arteries. Moreover, accessory arteries were found in 11.3% of cases, perforating arteries in 5.1%, and multiple renal arteries in 3.1%, at p≤0.05.
Conclusion: they had certain topographic and anatomical features of the structure regarding the veins of the kidney and the ureters, especially in the development of vascular-ureteral conflicts, which is a very important factor to consider in urological practice.
Keywords: kidney; Artery; 3D analysis.

Introduction

There is no consensus in the published literature regarding the renal arteries (RAs) and in particular their extra-organ section[1-3]. The RAs can be single or the kidney can have additional blood supply in the form of accessory arteries or multiple arteries, which is of both fundamental and clinical importance[4]. However, not only the number of RAs has theoretical and practical significance. The source of the arteries is also important since the abdominal aorta is the main source of kidney blood supply[5-8].

Therefore, as mentioned above, the RAs, which are the visceral branches of the abdominal aorta, are the main source of blood supply to the kidney itself[9,10]. Subsequently, they break up into branches with various forms of branching, heading to the corresponding departments of the kidney parenchyma.

The founders of the doctrine of the forms of branching of the intra-organ arteries of the kidneys were P.L. Kupriyanov and S.A. Reinberg[11].

According to Reinberg (1923) (quoted by V.A. Rozhko)[12,13], the most common variant is the division of the renal arterial trunk into anterior and posterior branches, covering the pelvis on both sides. The same opinion is held by Ya.M. Smirnov[14], who distinguished two types of division of the RA (juxtarenal and juxtaaortic). Smirnov discovered that the RA split into branches juxtarenally in 2/3 of all cases, and in the remaining 1/3 of cases, branching occurred next to the abdominal aorta, that is, juxtaaortically[9,15]. These researchers claim that most often the main RA splits into two, less often into three branches.

L.J. Testut[16] observed the division of the RA in the renal hilum not into two, but into four branches: two ventral ones, one superior polar, and one dorsal branch. Various variants of the division of the RA are highlighted in the works of many authors[1,2,9,10,17,18]. Generalization of existing data and development of new approaches to the analysis of extra-organ arterial vessels of the kidneys is of paramount importance for creating a personalized approach in clinical practice[3,18,19]. Thus, a review of the literature makes it clear to us that in the vast majority of cases we will observe the bifurcation of the main trunk of the RA, and in addition, each of the vessels will have a different type of branching: either the magistral or the dispersed one. Undoubtedly, there are other variants when the RAs are divided into more branches,

DOI: 10.51929/jms.40.516.2023
ISSN 2177-0298

but they are much less common and have not been studied in detail.

The study aimed to conduct a 3D anatomical analysis of the extra-organ part of the RAs in men and women.

Materials and Methods

Multispiral computed tomograms (MSCTs) taken from 162 men and women of mature, old, and elderly ages who had no diseases of the urinary system organs were used to study the variant anatomy of the extra-organ (accessory, perforating, and multiple arteries) section of the RAs. A Ultra Speed JE spiral computed tomograph (Republican Clinical Hospital named after Sh.Sh. Ependiev, Grozny, Russia) was used to scan the patients. In MSCTs of kidney arterial vessels, after 3D modeling, the spatial orientation, course, topography, and their number in a 3D projection were determined.

In the calculations, we used the Excel application from the Microsoft Office 2007 application package.

The accuracy of the study was determined by the probability of an error-free forecast less than or equal to 0.95%, with the level of statistical significance p≤0.05.

Results and Discussion

Among men, the main right RA in 27.06% of cases and the main left RA in 32.47% were divided at the renal hilum (intrarenal variant); and in 72.94 and 67.53%, respectively, it is divided at a distance from the renal hilum (extrarenal variant). In women, the division of the right and left main RAs in 37.65 and 35.29%, respectively, occurred at the renal hilum, i.e. intrarenally, and in 62.35 and 64.71%, respectively, it occurs extrarenally.

MSCTs of 77 men and 85 women were used to study the variant anatomy of the extra-organ part (accessory, perforating, and multiple arteries) of the kidneys.

A comparative characteristic of the extra-organ arrangement of the RAs in the study cohort according to MSCT data (n=162) is shown in Figure 1.

The comparative characteristics of the extra-organ arrangement of the RAs in men and women of different age groups according to MSCT data are given in Tables 1 and 2 and in Figures 2 and 3.

In 80.52% (p <0.05), the kidney was supplied with blood by a single RA, and in the remaining 18.98% also accessory, perforating, and multiple arteries were observed.

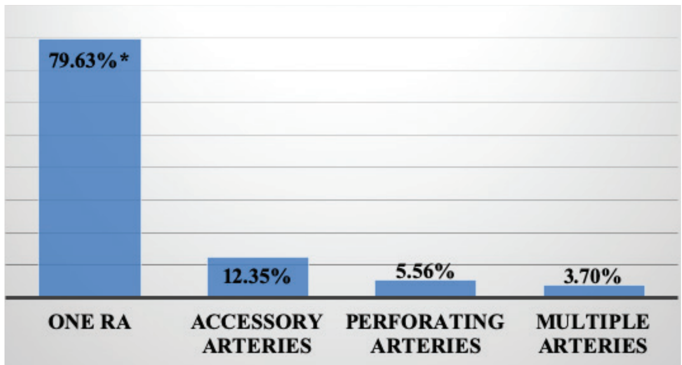

Figure 1. Comparative characteristics of the extra-organ arrangement of the RAs in the study cohort according to MSCT data (percentage ratio). Note: *p<0.05: the reliability of the difference of the trait between the groups.

Table 1. Comparative characteristics of extra-organ arrangement of RAs in men of different age groups according to MSCT data (n=77).

	Mature Age 1		Mature Age 2		Old Age		Elderly	
	Relative	% From the Group	Relative	% From the Group	Relative	% From the Group	Relative	% From the Ggroup
One RA	15	19.48	40	51.95	5	6.49	2	2.60
Accessory Arteries	2	2.60	4	5.19	2	2.60	0	0
Perforating Arteries	0	0	3	3.90	1	2.60	0	0
Multiple RAs	0	0	2	2.60	1	1.30	0	0

Table 2. Comparative characteristics of extra-organ arrangement of RAs in women of different age groups according to MSCT data (n=85).

	Mature Age 1		Mature Age 2		Old Age		Elderly	
	Relative	% From the Group	Relative	% From the Group	Relative	% From the Group	Relative	% From the Group
One RA	17	20	41	48.24	6	7.06	3	3.53
Accessory Arteries	3	4.71	5	7.06	3	4.71	1	1.18
Perforating Arteries	0	0	4	4.71	1	2.35	0	0
Multiple RAs	0	0	2	2.35	1	1.18	0	0

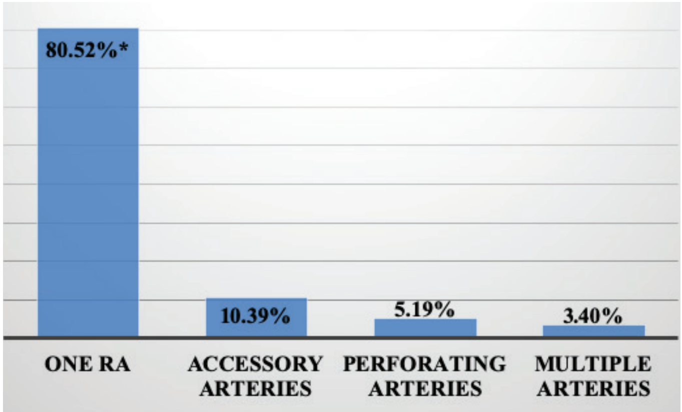

Figure 2. Comparative characteristics of the extra-organ location of the RAs in men of the study cohort according to MSCT data (percentage ratio). Note: *p<0.05: the reliability of the difference of the trait between the groups.

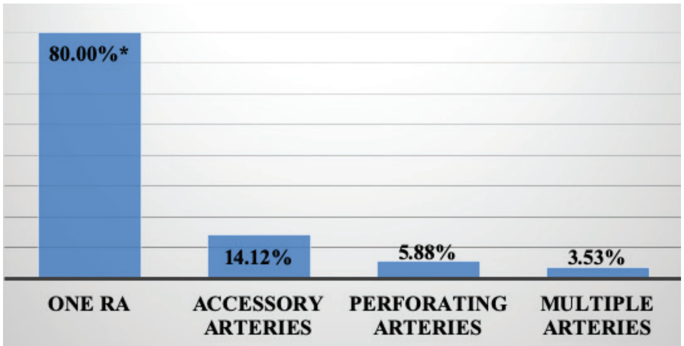

Figure 3. Comparative characteristics of the extra-organ location of the RAs in women of the study cohort according to MSCT data (percentage ratio). Note: *p<0.05: the reliability of the difference of the trait between the groups.

In men, in each of the age periods, there was a significant ($p < 0.05$) prevalence of people where the blood supply to the kidney was performed by one RA (in 19.48% of cases in mature age 1, in 51.95% in mature age 2; 6.49% in old age, and 2.60% in the elderly).

In 80.00% ($p < 0.05$) the kidney was supplied with blood by a single RA, and in the remaining 20.0% also accessory, perforating, and multiple arteries were observed.

In women, in each of the age periods, there was a significant ($p < 0.05$) prevalence of people where the blood supply to the kidney was performed by one RA (20.0% in mature age 1, 48.24% in mature age 2, 7.06% in old age, and 3.53% in the elderly).

With a detailed 3D anatomical analysis of the accessory renal vessels in MSCTs, we found that, regardless of the sources of their formation and topographical features, they were directed either to the renal hilum or to the poles. Based on the topographic and anatomical features seen on the MSCTs, we divided the accessory arteries into the following groups: 1) The first group included the kidneys (12 observations on the MSCTs) where the accessory RAs were directed to the superior pole of the kidney. In MSCT, these vessels departed from the abdominal aorta 20.5 mm above the main RA and followed at an acute angle of 84° to the superior pole of the kidney (Figure 4).

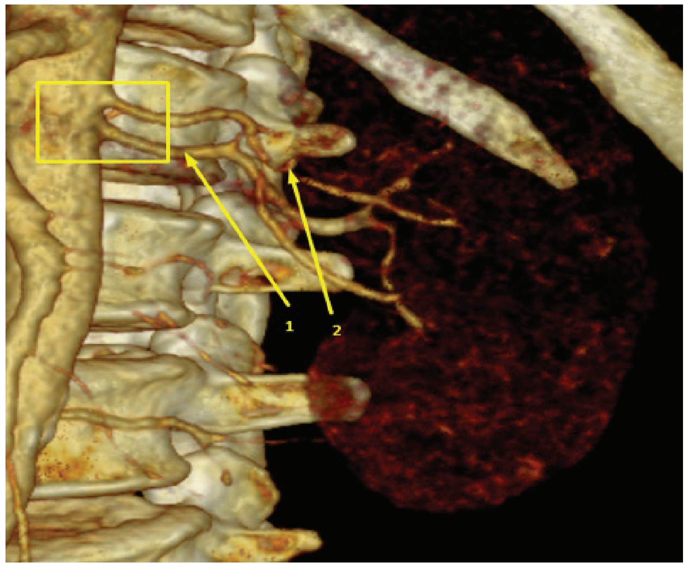

Figure 4. MSCT of kidney vessels (male, 54 years old). 1 – RA, 2 – accessory artery.

In the following observation, the accessory artery, being a branch of the abdominal aorta, departed 2.3 mm above the main RA and followed the parenchyma of the inferior pole of the kidney, and its length was 39 mm.

These vessels bypassed the renal hilum, heading to the parenchyma, where they perforated from its poles, in connection with which they received the name of the perforating arteries.

The second group of accessory RAs (nine observations in MSCTs) included the kidneys that departed from the abdominal part of the aorta above the level of the main RA and headed to the renal hilum. Thus, in one of the observations in MSCT, the accessory artery followed the renal hilum, to its lower corner, and then went medially upwards, crossing the RA. The diameter of the accessory artery was 2.3 mm, and the length was 70 mm (Figure 5).

The third group included the kidneys where accessory arteries branched off from the aorta below

Figure 5. MSCT of kidney vessels (female, 34 years old). 1 – RA, 2 – accessory artery.

the main RA and headed to the inferior poles (Figures 6-8).

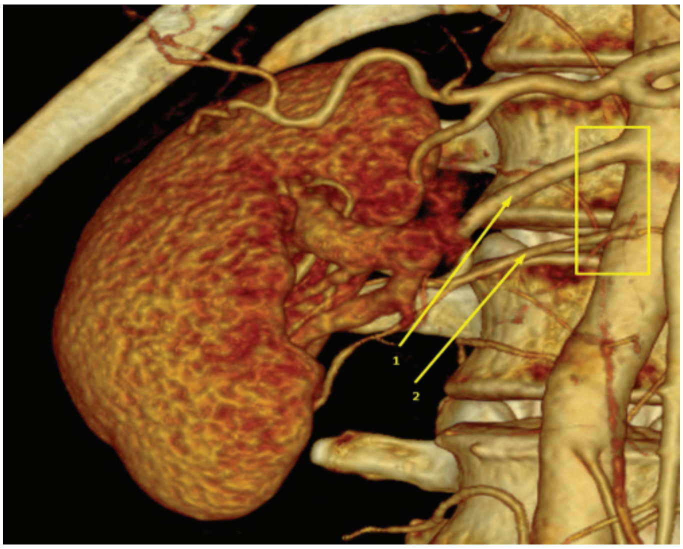

Figure 6. MSCT of kidney vessels (female, 42 years old). 1 – RA, 2 – accessory artery.

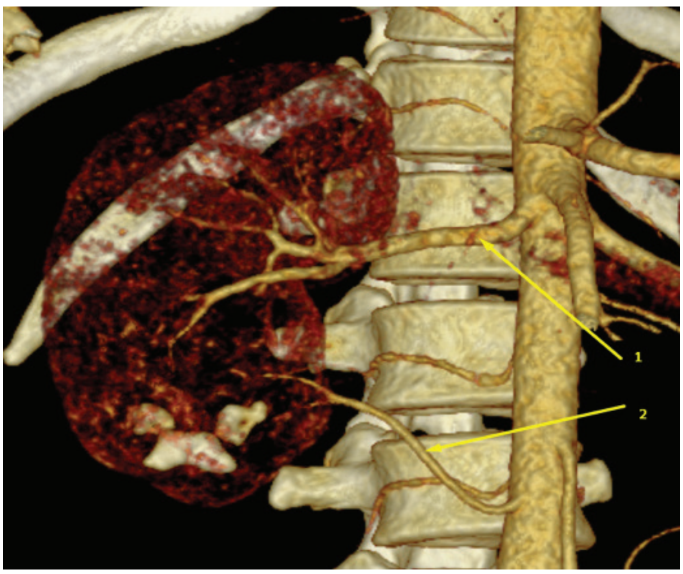

Figure 7. MSCT of kidney vessels (male, 53 years old). 1 – RA, 2 – accessory artery.

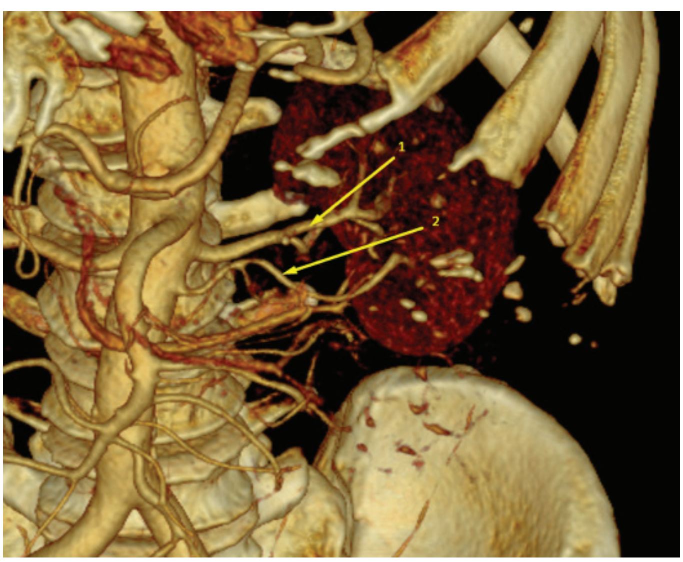

Figure 8. MSCT of kidney vessels (male, 56 years old). 1 – RA, 2 – accessory artery.

In MSCT, the accessory vessels branched off at an obtuse angle (from 93 to 115°). In one of the MSCT observations, both the accessory and main RAs followed anteriorly from the inferior vena cava. In the interval from the edge of the aorta to the renal hilum, both arteries were located superior and ventrally from the renal vein. In this variant, the RA branched into anterior and posterior branches 6.0 mm to the plane tangent to the medial edge of the kidneys, and the accessory vessel entered the renal sinus of the kidney in front of the pelvis.

The analysis shows that in all observations, the presence of an accessory artery to the inferior polar segment of the kidney was combined with various features of the topography of the kidney and renal vessels.

With further 3D analysis of MSCTs, we identified the following group (10 observations in MSCTs), which was called perforating arteries. According to the research data, variants of blood supply to the kidneys by perforating arteries were found in 4.2%, at $p < 0.05$. It was believed that the perforating arteries were those that departed either from the main RA or from branches of the 2[nd] order, penetrating the parenchyma into one of the poles of the kidney, past the RAs (Figures 9-11). These arteries were found in men in six right and four left kidneys and in women in six right and two left kidneys. The MSCT analysis showed that in the four variants studied, the perforating artery branched off either from the ventral or from the dorsal branch of the RA. We would like to note that the peculiarity of these variants of perforating artery branching was their proximity to the place of the division of the main trunk of the RA into branches of the 2[nd] order.

In our observations, the perforating arteries with an average diameter (X ± m) of 2.2 ± 0.1 mm branched off from the anterior branch of the main trunk of the RA, and followed into the parenchyma of the medial

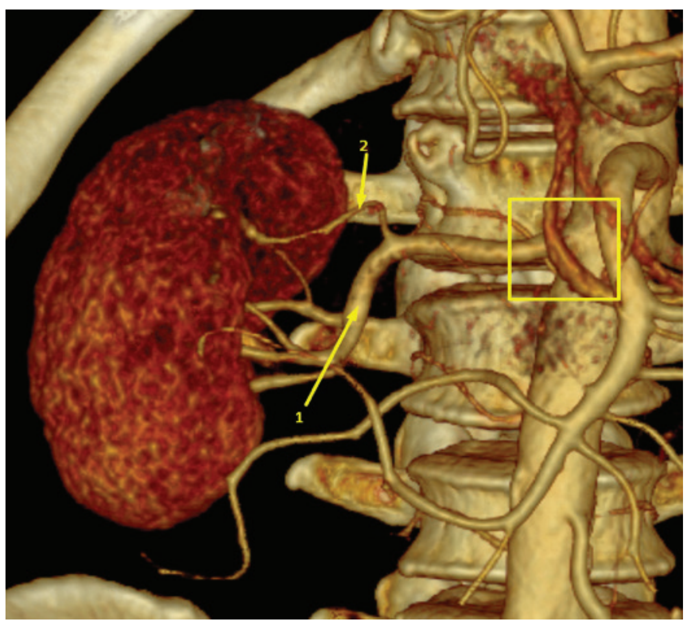

Figure 9. MSCT of kidney vessels (male, 54 years old). 1 – RA, 2 – perforating artery.

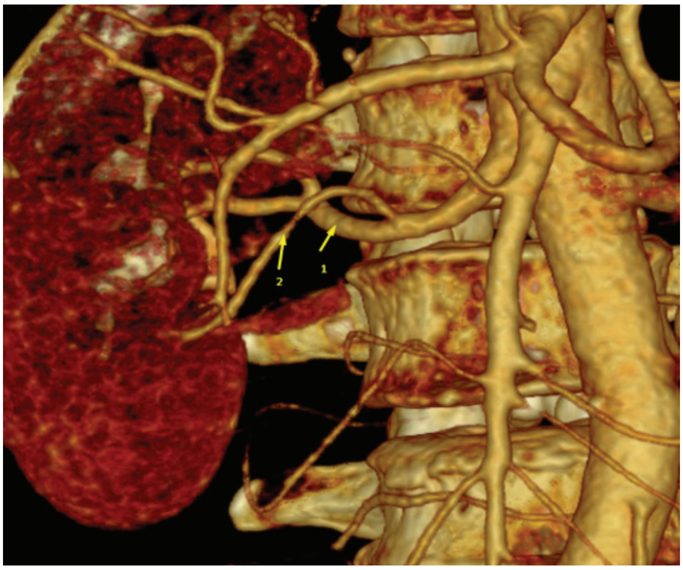

Figure 10. MSCT of kidney vessels (female, 34 years old). 1 – RA, 2 – perforating artery.

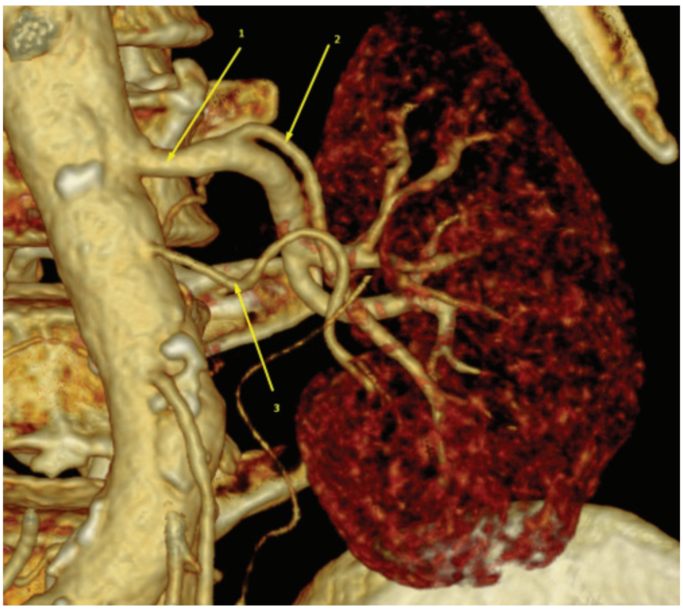

Figure 11. MSCT of kidney vessels (male, 66 years old). 1 – RA, 2 – perforating artery.

edge of the superior polar segment. In two MSCTs, the perforating artery departed from the dorsal branch and was directed to the parenchyma of the medial edge of the superior polar segment of the kidney with a diameter of 2.2 mm. It was demonstrated that in four MSCT observations, the perforating artery departed from the distal third of the main RA.

A relative decrease in the length of the RAs was found on both sides because it was divided at the level of the plane tangent to the medial edge of the kidney.

Upon further investigation, we identified variants of the presence of more than one accessory artery in the kidneys, and they were already considered multiple arteries. When analyzing MSCTs, we found that multiple RAs accounted for 2% of all MSCTs examined by us. This group of MSCT analyses included eight observations (in five right and three left kidneys), including five observations in women and three in men (Figures 12-14).

Figure 12. MSCT of kidney vessels (female, 47 years old, multiple kidney arteries). 1 – RA, 2 and 3 – accessory arteries.

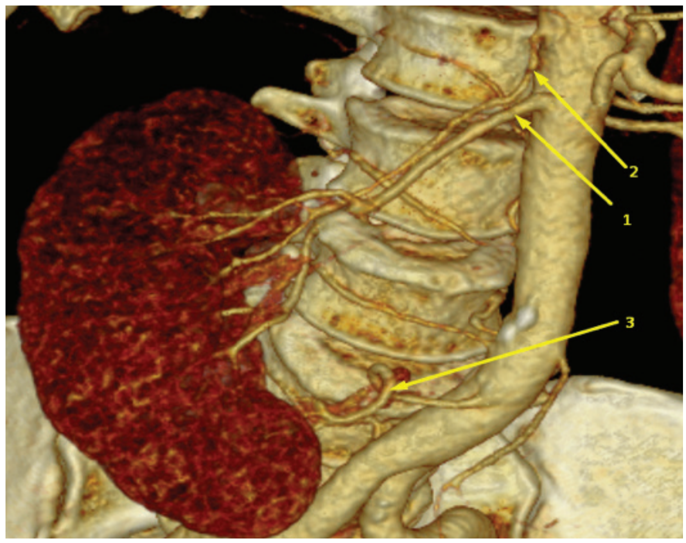

Figure 13. MSCT of kidney vessels (male, 74 years old, multiple kidney arteries). 1 – RA, 2 and 3 – accessory arteries.

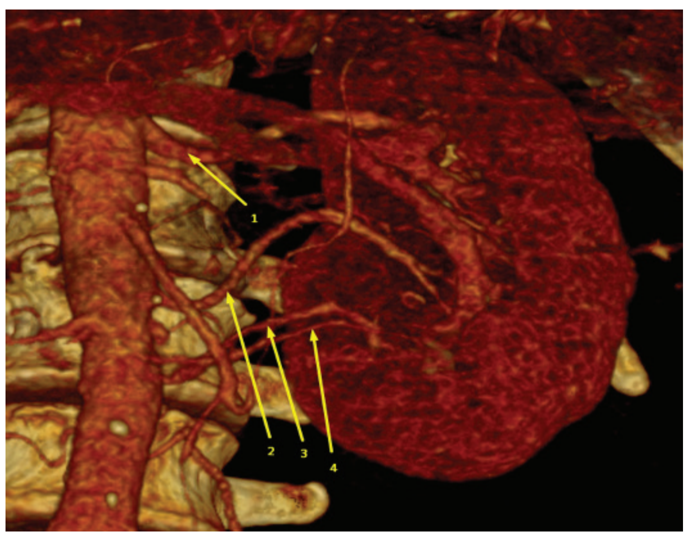

Figure 14. MSCT of kidney vessels (male, 74 years old, multiple kidney arteries). 1 – RA, 2, 3, and 4 – accessory arteries.

In five of the identified variants in MSCT of multiple arteries, two accessory arteries going to the kidneys were found. In three cases, we identified three accessory arteries, with different topography of these vessels.

Thus, in one of the variants, MSCT showed the departure of the first accessory artery from the abdominal aorta 11.3 mm above the main trunk of the RA. Its diameter was 2.3 mm, and its length was 34 mm. The place of origin of the second accessory artery was 7 mm higher than the previous one and was directed to the parenchyma of the superior pole segment. The diameter of this artery was 2.3 mm and its length was 43 mm (Figure 12).

In the following MSCT observations, it was found that both accessory arteries departed from the abdominal aorta below the level of the main RA by 23 mm and 35 mm. These vessels had a relatively rectilinear course and departed from the abdominal aorta, flowing into the parenchyma of the medial surface of the inferior polar segment of the kidney.

The analysis of the remaining MSCTs (three observations) showed three accessory RAs. The first accessory artery departed from the abdominal aorta 32.0 mm below the main RA. It had a diameter of 3.2 mm and a length of 54.0 mm. It was directed from the abdominal aorta in the lateral direction with the formation of an arch facing upwards, penetrating through the renal hilum (Figure 14).

The second artery departed from the aorta 32.0 mm below the superior accessory artery, following in the lateral direction, and penetrated the kidney in the area of the lower corner of its hilum. The third accessory vessel departed from the abdominal aorta 9.0 mm below the second accessory artery, forming a slight arc, with a bulge facing upwards, and was directed to the lower corner of the renal hilum (Figure 14).

We were interested in the variants of the division of the RA in the renal hilum, which, as it was found, did not change during ontogenesis and were genetically determined, which is consistent with the data of E.S. Kafarov and F.R. Asfandiyarov[9,10], who studied the arterial system of the kidney. Further, it was found that most often, regardless of gender and side of the body, the main RA was divided medially from the plane tangent to the medial edge of the kidney, i.e., extrarenally. The variants of intra- and extrarenal division of the main RA influence the length of the branches, and besides that, the topographic and anatomical features of the location of tubular structures in the renal hilum depend on the variants of their division, which do not always fit into the framework of the classical vein-artery-ureter scheme[9,10].

Conclusion

Thus, the 3D analysis showed that the sources of blood supply to the kidneys, their topography, and the number of RAs had some differences. We found that, on average, regardless of gender characteristics, in 80.5% of cases, the blood supply to the kidney was carried out by one RA, and in 19.5%, there were variants of accessory, perforating, and multiple RAs. Moreover, accessory arteries were found in 11.3%, perforating arteries in 5.1%, and multiple RAs in 3.1%, at $p \leq 0.05$.

They had certain topographic and anatomical features of the structure regarding the veins of the kidney and the ureters, especially in the development of vascular-ureteral conflicts, which is a very important factor to consider in urological practice.

References

1. Zenin OK, Gusak VK, Kiryakulov GS, Vakulenko IP, Elsky VN, Klysa MN. Arterialnaya Sistema Cheloveka v Tsifrakh i Formulakh [Human Arterial System in Numbers and Formulas]. Donetsk: Aleks; 2002:196 p.
2. Zenin OK, Beshulya OA. Morfometricheskii analiz dikhotomii vnutriorgannogo arterialnogo rusla pochki [Morphometric analysis of dichotomies of the intraorgan arterial bed of the kidney]. Izvestiya vysshikh uchebnykh zavedenii. Povolzhskii region. Meditsinskie nauki 2013;4:26-34.
3. Kolsanov AV, Nazaryan AK, Ivanova VD, *et al*. Metody virtualnogo modelirovaniya pri izuchenii anatomii krovenosnykh sosudov [Methods of virtual modeling in the study of the anatomy of blood vessels]. Zhurnal anatomii i gistopatologii 2014;3(2):24-7.
4. Bordei PSt, Antohe D. Etude anatomique des arteres renales. Paper presented at: Al VI-lea Congres Naţional cu Participare Inter-Naţională al Societăţii Anatomiştilor din România, Iaşi, România; 2002:20.
5. Bordei P, Iliescu D, Bulbuc I, Ionescu C. Morfologia vaselor renale la un rinichi în potcoavă. Paper presented at: Al VI-lea Congres Naţional cu Participare Inter-Naţională al Societăţii Anatomiştilor din România, Iaşi, România; 2002:145-6.
6. Şapte E, Bordei P, Maxim R, Ionescu C. Peculiarities of the aortic origin of the renal arteries. Paper presented at: Congress of European Association of Clinical Anatomy the 4th National Congress of the Romanian Society of Anatomists, Constanţa, Romania; 1999:181-2.
7. Precup D, Grigorescu-Sido Fr. Variante anatomice si angiografice ale arterelor renale. Acta Anatom Roman 1996;26:38-9.
8. Şapte E, Bordei P, Ionescu C. Aspects morphologiques des arteres renales – étude comparative sur les deux côtés des corps humain. Paper presented at: Congres de l´Association des Morphologistes, Constanţa, Roumanie; 1995.
9. Kafarov ES, Asfandiyarov FR. Kliniko-anatomicheskie aspekty topografii pochechnoi arterii, veny i lokhanki [Clinical and anatomical aspects of the topography of the renal artery, vein and pelvis]. Rossiiskie morfologicheskie vedomosti 2008;3:3-4.
10. Kafarov ES, Asfandiyarov FR, Trizno MN. Tipy vetvleniya arterialnykh i venoznykh sosudov pochki [Branching types of arterial and venous vessels of the kidney]. Morfologicheskie vedomosti 2008;3-4:41-2.
11. Kuprijanoff PA. Das intrarenale arterielle System gesunder und pathologischer. Deutsche Zeitschrift f. Chirurgie 1924;188:206-20.
12. Rozhko VA. Topografiya Vne- i Vnutripochechnykh Krovenosnykh Sosudov [Topography of Intra- and Extrarenal Blood Vessels] [Author's abstract of a Cand. Med. Sci. dissertation]. Leningrad: Leningrad Sanitary and Hygienic Medical Institute; 1952:10 p.

13. Kuan JK, Wright JL, Nathens AB, Rivara FP, Wessells H. American Association for the Surgery of Trauma Organ Injury Scale for kidney injuries predicts nephrectomy, dialysis, and death in patients with blunt injury and nephrectomy for penetrating injuries. J Trauma Inj Infect Critic Care 2006;60(2):351-6. doi:10.1097/01.ta.0000202509.32188.72

14. Smirnov YaM. O variantakh pochechnykh sosudov, imeyushchikh khirurgicheskoe znachenie [On renal vessel variants that have surgical significance]. In: Yubileinyi Sbornik v Chest 25-Letiya Vrachebno-Nauchnoi Deyatelnosti (1894–1919) Prof. I.I. Grekova [A Festschrift in Honor of the 25th Anniversary of Medical and Academic Career (1894–1919) of Prof. I.I. Grekov

Received: November 1, 2023
Accepted: November 18, 2023

Corresponding author
E.S. Kafarov
E-mail: ed.kafarov@gmail.com