



3D Analysis of Topographic and Anatomical Features of the Arterial and Venous Vessel Structure in Kidney

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ABSTRACT

The study aimed to review the topographic and anatomical features of the intra-organ structure of the arterial and venous bed of the human kidney. The study was carried out on 124 polychrome corrosive preparations of the arterial and venous systems of the human kidney. For digitization, the preparations were subjected to 3D scanning. In a computer program, in a 3D projection, the zones of local blood supply to the areas of the renal parenchyma and venous drainage were identified, depending on the variants of the division of the renal artery and the fusion of the renal vein. The analysis of polychrome corrosive preparations of arterial and venous vessels of the kidneys revealed 17 topographic and anatomical variants of the division of the arterial bed and formation of the venous bed of the kidney, where the main trunks in the renal hilum relative to the sagittal, frontal and horizontal planes occupied different positions. The 3D analysis of polychrome corrosive preparations of arterial and venous vessels of the kidneys showed that the great arterial vessels in 30.0% of cases repeated the course of the cognominal venous vessels, both concerning their location in the hilum of the kidney relative to the sagittal, frontal and horizontal planes, and their course, and topography in the parenchyma of the organ.

Keywords: Kidney, Renal veins, Renal artery, 3D modeling.

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INTRODUCTION

Recently, attempts have been made to clarify the anatomy and topography of the renal vessels using new means and methods [1-19].

Thus, some researchers confirm that the course of the intra-organ venous vessels of the kidneys largely coincides with the arterial ones. However, at the same time, the authors emphasize that there are more veins inside the kidney than arteries [6-19]. Many other authors argue that there are more arteries in the kidneys than there are veins. This feature is of great importance when performing any surgical interventions on the kidneys [8-16]. At the same time, anatomical studies of some authors indicate that one of the

topographic features of renal vessels, in particular their intra-organ section, is the discrepancy between the number and topography of renal arteries and veins [3, 7-12]. Thus, according to some authors, venous blood from the kidneys flows through the veins, the main trunks of which do not repeat the course of the arteries and have a sagittal distribution [12]. An analysis of the literature has shown that the issues concerning the topographic and anatomical features of the structure of the arterial vessels of the kidneys relative to the veins, both in the hilum of the kidney and inside the organ, have not yet been fully clarified. The available literature contains scanty and sometimes contradictory data on the venous

outflow zones from the kidney. Information about those zones would play a huge role in neoplastic lesions of the kidneys, for example, to identify the pathways of regional metastasis [15-17].

Scope of the study

To study the topographic and anatomical features of the intra-organ structure of the arterial and venous bed of the human kidney.

MATERIALS AND METHODS

This study was carried out on 124 polychrome corrosive preparations of the arterial and venous system of the human kidney, made from the kidneys of corpses of people of both genders, in the age range from 22 to 75 years, who had died from diseases not related to the pathology of the urinary system, acquired as part of a grant from the Russian Foundation for Basic Research (RFBR) No. 20-315-90008 of 2020. Since the study involved the topographic and anatomical features of the structure of the arterial and venous bed of the human kidney, variants of intra-organ branching of the arterial vessels of the kidney in the parenchyma of the organ and the types of fusion of venous vessels that do not change at the stages of ontogenesis and are genetically determined, we did not study those vessels in the age aspect, which is consistent with the data of F.R. Asfandiyarova (2011) [1].

Algorithm of the study

1. Polychrome corrosive preparations of the arterial and venous system of the human kidney for digitization were subjected to 3D scanning using a 3D microcomputer tomographic digital system *RayScan 130* (Germany), at a current strength of 132 mAs, voltage 140 kV, with a helix pitch of 1.0 mm, and subsequent 3D modeling (Agreement No. 5 dated July 18, 2020).
2. On polychrome corrosion preparations of arterial and venous vessels of the kidney, we studied the following about the intra-organ branches of the renal artery and vein: a) the number of intra-organ arteries and veins of the kidney; b) the topography of the renal arteries and veins inside the kidney.
3. In a computer program in a 3D projection, the zones of local blood supply to the areas of the renal parenchyma and venous drainage were identified depending on the variants of the division of the renal artery and the fusion of the renal vein, as well as on

the types of intra-organ branching of the branches of the renal artery and the fusion of the tributaries of the renal vein in 3D projection with di- and trichotomy variants of arterial division, and fusion of venous sub-branches.

All the obtained digital material and the data of instrumental research methods were processed by the methods of variation statistics using a workstation with an *Intel Core2Duo T5250 1.5 GHz processor, RAM up to 2 GB on the Windows 7 platform*. In the course of the work, we used the *Excel* application package from *Microsoft Office 2007*.

RESULTS AND DISCUSSION

As a result of the studies carried out on polychrome corrosion preparations of renal vessels, we found that in most cases (16.4%, at $p \leq 0.05$) with a dichotomous division of the main renal artery, A. renalis (I), relative to the frontal plane at the hilum of the kidney to the ventral, A. ventralis (zonal) (II) and dorsal branches, A. dorsalis (zonal) (II), the main renal vein, V. renalis (I), is formed relative to the horizontal plane from the superior polar vein, V. superius polus (zonal) (II) and inferior polar veins, V. inferior polus (zonal) (II), coming out of the superior and inferior corners of the renal sinus. The ventral and dorsal branches of the main renal artery cover the renal pelvis from its ventral and dorsal surfaces, supplying blood to the corresponding parts of the anterior and posterior half of the kidney. In this variant, the polar veins, draining the parenchyma of the superior and inferior renal poles, go from the superior and inferior corners of the renal sinus and exit the renal hilum, located above and below the pelvis, gradually merging and forming the main trunk of the renal vein.

In the next group of preparations, identified in 12.4% of cases, with a dichotomous division of the main renal artery, A. renalis (I), relative to the horizontal plane into the superior polar artery, A. superius polus (zonal) (II) and the inferior polar artery, A. inferior polus (zonal) (II), the polar veins of the main renal venous trunk follow the same course as the main arteries, merging relative to the horizontal plane from the superior polar vein, V. superius polus (zonal) (II) and inferior polar vein, V. inferior polus (zonal) (II), at $p \leq 0.05$. The polar main arteries supplying the

parenchyma of the superior and inferior poles of the kidney and the main veins that repeat the course of the arteries, draining the parenchyma of the renal poles, exit in the area of the renal hilum from the superior and inferior corners of the renal sinus. At the same time, the superior and inferior polar arteries and veins were topographically located above and below the renal pelvis, merging to form the main trunk of the main vein, *V. renalis* (I), as well as being the site of the division of the renal artery, *A. renalis* (I).

Further, it was found that during the dichotomous division of the main renal artery, *A. renalis* (I) in the hilum of the kidney relative to the horizontal plane to the superior polar artery, *A. superius polus* (zonal) (II), and the inferior polar artery, *A. inferior polus* (zonal) (II), the main renal vein, *V. renalis* is formed from merging relative to the frontal plane of the ventral vein, *V. ventralis* (zonal) (II) and the dorsal vein, *V. dorsalis* (zonal) (II), which was observed in 11.1% of cases, with $p \leq 0.05$. Further, it was found that during the dichotomous division of the main renal artery, *A. renalis* (I), in the hilum of the kidney relative to the horizontal plane to the superior polar artery, *A. superius polus* (zonal) (II) and the inferior polar artery, *A. inferior polus* (zonal) (II), the main renal vein, *V. renalis*, is formed from merging of the ventral vein, *V. ventralis* (zonal) (II), and the dorsal vein, *V. dorsalis* (zonal) (II), relative to the frontal plane, which was observed in 11.1% of cases, with $p \leq 0.05$. The polar arteries, in this case, are directed to the superior and inferior corner of the renal sinus at the hilum of the kidney, located above and below the renal pelvis.

In the next group of preparations, found in 10.2% of cases with a dichotomous division of the main renal artery, *A. renalis* (I), in the hilum of the kidney relative to the frontal plane to the ventral branch, *A. ventralis* (zonal) (II) and the dorsal branch, *A. dorsalis* (zonal) (II), renal venous vessels repeat the course of the main arteries, merging from the ventral vein, *V. ventralis* (zonal) (II), and the dorsal vein, *V. dorsalis* (zonal) (II) in the main trunk of the renal vein, *V. renalis* (I), at $p \leq 0.05$. In this variant, the main arteries and veins, duplicating each other, supply and drain the parenchyma of the corresponding parts of the ventral and dorsal half of the kidneys. In 8.2% of cases, at $p \leq 0.05$, in the next group of preparations, a dichotomous division of the main

renal artery, *A. renalis* (I), was observed in the hilum of the kidney relative to the frontal plane to the ventral artery, *A. ventralis* (zonal) (II) and the dorsal artery, *A. dorsalis* (zonal) (II). In this case, the formation of the main renal vein, *V. renalis* (I) came from the superior polar, central, and inferior polar veins, located in the same frontal plane. In this variant, the main arteries, being distributed in the ventral and dorsal half of the kidney, supply blood to the parenchyma of its corresponding parts, and the veins drain the parenchyma of the ventral and dorsal half of the kidneys in the region of its poles and the central part.

Further, when analyzing corrosive preparations, we found a variant of a dichotomous division of the main renal artery, *A. renalis* (I) in the hilum of the kidney relative to the frontal plane to the ventral artery, *A. ventralis* (zonal) (II) and the dorsal artery, *A. dorsalis* (zonal) (II), while the renal vein, *V. renalis* (I) was formed from the superior polar vein, *V. superius polus* (zonal) (II), the inferior polar vein, *V. inferior polus* (zonal) (II) and the dorsal central vein, *V. dorsalis, centralis* (zonal) (II), which was observed in 7.3% of cases, with $p \leq 0.05$. The main arteries in this variant are involved in the blood supply to the ventral and dorsal half of the kidney, while the main veins drain the parenchyma of the poles of the kidney and its dorsal central part.

In the next group of corrosive preparations of renal vessels, we found a variant of a trichotomous division of the main renal artery, *A. renalis* (I) in the hilum of the kidney relative to the frontal and horizontal planes to the ventral artery, *A. ventralis* (zonal) (II), the dorsal artery, *A. dorsalis* (zonal) (II) and the inferior polar artery, *A. inferior polus* (zonal) (II). In this case, the renal veins, *V. renalis* (I), repeat the course of the main arteries, merging at the hilum of the kidney relative to the frontal and horizontal plane from the ventral vein, *V. ventralis* (zonal) (II), the dorsal vein, *V. dorsalis* (zonal) (II) and the inferior polar vein, *V. inferior polus* (zonal) (II) into the main trunk of the renal vein, *V. renalis* (I), which was observed in 6.1% of cases, at $p \leq 0.05$. The ventral artery supplies with blood the parenchyma of the anterior half of the superior pole of the kidney, and the dorsal artery supplies the posterior half. In this case, the inferior polar artery is located in the parenchyma of the inferior pole of the

kidney from the ventral and dorsal surfaces. The main veins, duplicating the course of the arteries, drain the corresponding zones of the renal parenchyma.

In 4.5% of cases, at $p \leq 0.05$, we observed the following group of corrosive preparations with a variant of a trichotomous division of the main renal artery, A. renalis (I) in the hilum of the kidney relative to the frontal and horizontal planes to the ventral artery, A. ventralis (zonal) (II), the dorsal artery, A. dorsalis (zonal) (II) and the inferior polar artery, A. inferior polus (zonal) (II). It should be noted that the formation of the renal vein, V. renalis (I) in this case starts from the superior polar vein, V. superius polus (zonal) (II), the central vein, V. centralis (zonal) (II), and the inferior polar vein, V. inferior polus (zonal) (II). The branches of the ventral artery are located in the parenchyma of the anterior half of the superior pole of the kidney, and the dorsal one in the posterior half. In this case, the inferior polar artery is involved in the blood supply to the parenchyma of the inferior pole of the kidney from the ventral and dorsal sides.

Further, in 4.4% of cases, at $p \leq 0.05$, we observed a group of corrosive preparations where the main renal artery, A. renalis (I) was divided in the hilum of the kidney relative to the frontal plane into the ventral artery, A. ventralis (zonal) (II) and the dorsal artery, A. dorsalis (zonal) (II). In this case, the renal vein, V. renalis (I) is formed from the ventral (superior polar, central, inferior polar) veins V. ventralis, superius polus (zonal) (II), V. centralis (zonal) (II), V. inferior polus (zonal) (II) and the dorsal central vein, V. dorsalis, centralis (zonal) (II). The ventral and dorsal arteries supply blood to the parenchyma of the corresponding parts of the anterior and posterior half of the kidney, and the main veins drain the parenchyma of the poles and its central part.

In the next group of corrosive preparations, we found a variant of a dichotomous division of the main renal artery, A. renalis (I), relative to the horizontal plane into the superior polar artery, A. superius polus (zonal) (II), and the inferior polar artery, A. inferior polus (zonal) (II), while the formation of the renal vein, V. renalis (I) in the hilum of the kidney started from the superior polar vein, V. superius polus (zonal) (II), the central vein, V. centralis (zonal) (II) and the inferior polar vein, V. inferior polus (zonal) (II)

located in the same frontal plane, which was observed in 4.1% of cases, at $p \leq 0.05$. With this variant, the main arteries are located with their branches in the parenchyma of the superior and inferior poles of the kidney. The veins, at the same time, are involved in the drainage of the poles of the kidney and its central part.

Further investigation of corrosive preparations revealed a group with a variant of a dichotomous division of the main renal artery, A. renalis (I) to the ventral, A. ventralis (zonal) (II), and dorsal, A. dorsalis (zonal) (II) branches. In this case, the formation of renal veins, V. renalis (I) relative to the frontal and horizontal plane starts from the ventral, V. ventralis (zonal) (II), dorsal, V. dorsalis (zonal) (II), and superior polar veins, V. superius polus (zonal) (II), which was found in 3.3% of cases, with $p \leq 0.05$. In this variant, the corresponding arteries branch out in the ventral and dorsal halves of the kidney, and the venous vessels take part in the drainage of the parenchyma of the ventral and dorsal halves of the inferior and superior poles of the kidney.

In the next group of corrosive preparations, found in 2.5% of cases, at $p \leq 0.05$, the renal artery, A. renalis (I) is divided into ventral, A. ventralis (zonal) (II), dorsal, A. dorsalis (zonal) (II) and inferior polar, V. inferior polus (zonal) (II) branches relative to the frontal and horizontal planes. Renal veins, V. renalis (I) in this case are formed in the hilum of the kidneys relative to the frontal plane from the ventral, V. ventralis (zonal) (II) and dorsal, V. dorsalis (zonal) (II) veins. The ventral and dorsal arteries branch out in the parenchyma of the anterior and posterior half of the superior pole of the kidney, and the main veins take part in the drainage of the parenchyma of the ventral and dorsal halves of the kidney.

In 2.4% of cases, at $p \leq 0.05$, we observed the following group of corrosive preparations with a variant of a trichotomous division of the main renal artery, A. renalis (I), relative to the frontal and horizontal planes into the ventral, A. ventralis (zonal) (II), dorsal, A. dorsalis (zonal) (II) and superior polar, A. superius polus (zonal) (II) branches, while the renal vein, V. renalis (I) was formed in the hilum of the kidneys relative to the horizontal plane from the superior polar, V. superius polus (zonal) (II) and the inferior polar, V. inferior polus (zonal) (II) veins. The ventral and dorsal arteries supply blood to the parenchyma of the anterior and posterior halves

of the inferior pole of the kidney, and the superior polar artery supplies blood to the corresponding ventral and dorsal parts of the superior pole of the kidney, while the venous vessels drain the parenchyma of the ventral and dorsal halves of the poles of the kidney.

Further, we observed the following group of corrosive preparations with a variant of a dichotomous division of the main renal artery, A. renalis (I), relative to the horizontal plane into the superior polar artery, A. superius polus (zonal) (II), and the inferior polar artery, A. inferior polus (zonal) (II), while the renal vein, V. renalis (I), is formed from the ventral (superior polar, central, inferior polar) veins, V. ventralis, superius polus (zonal) (II), V. centralis (zonal) (II), V. inferior polus (zonal) (II) and dorsal central veins, V. dorsalis, centralis (zonal) (II), which was observed in 2.3% of cases, at $p \leq 0.05$. In these preparations, the superior and inferior polar arteries supply blood to the corresponding parts of the ventral and dorsal half of the kidney poles, while the corresponding main venous vessels drain the parenchyma of the poles and the central part of the kidneys.

In the next group of preparations, found in 2.1% of cases, at $p \leq 0.05$, the renal artery, A. renalis (I), in the hilum of the kidney was divided into the superior polar, A. superius polus (zonal) (II), central, A. centralis (zonal) (II) and the inferior polar arteries, A. inferior polus (zonal) (II), located in one frontal projection, while the renal vein, V. renalis (I), was formed relative to the horizontal plane from the superior polar, V. superius polus (zonal) (II), and inferior polar veins, V. inferior polus (zonal) (II). On these preparations, the main arteries are distributed in the ventral and dorsal halves of the poles of the kidney and its central part, while the superior and inferior polar veins drain the corresponding areas of the parenchyma of the ventral and dorsal halves of the kidney.

In the next group of corrosive preparations, which was encountered in 1.4% of cases, at $p \leq 0.05$, we observed a variant of a trichotomous division of the main renal artery, A. renalis in the hilum of the kidney relative to the horizontal and frontal plane into the ventral, A. ventralis (zonal) (II), dorsal, A. dorsalis (zonal) (II) and the inferior polar arteries, A. inferior polus (zonal) (II), while the renal vein, V. renalis (I), in the hilum of the kidney was formed relative to the horizontal

plane from the superior polar, V. superius polus (zonal) (II) and inferior polar veins, V. inferior polus (zonal) (II). In those preparations, the ventral and dorsal arteries supply blood to the parenchyma of the anterior and posterior halves of the superior pole of the kidney, and the inferior polar artery branches out with its branches in the parenchyma of its inferior pole, while the venous vessels drain the corresponding sections of the parenchyma of the superior and inferior poles of the kidney.

Finally, we observed the last group of corrosive preparations, where the renal artery, A. renalis, and renal vein, V. renalis (I) had the shape of a single trunk, with perforated veins and arteries, which was found in 1.3% of cases, at $p \leq 0.05$.

Our experimental morphological study is based on a 3D analysis of variants of the intra-organ division of the main branches of the renal arteries and the fusion of the main renal venous vessels. We have carried out studies to study the topographic and anatomical features of the structure of the arterial vessels of the kidneys relative to the venous vessels, since, according to some researchers, the renal veins repeat the course of the cognominal arteries [6-19], with which we cannot agree. The results of our studies revealed 17 topographic and anatomical variants of the location of the arteries relative to the venous vessels. Studies have shown that, relative to the division options, the arterial vessels of the kidneys repeat the course of the venous vessels on average ($X \pm m$) in 31.7% of cases, and regarding the types of branching (magistral or loose) the veins duplicate the course of the arteries on average ($X \pm m$) in 30.0 % of cases, at $p \leq 0.05$. In most cases, already in the hilum of the kidneys, one can see the inconsistency of the course of the main arterial and venous vessels, which corresponds to the data of many authors who examined the kidneys of human corpses by the corrosive and radiographic method and established different topography of the intra-organ arterial and venous vessels of the kidney [3, 7, 8] indicating that that one of the topographic features of the renal vessels, in particular their intra-organ part, is the discrepancy between the number and topography of the arteries and veins of the kidneys.

CONCLUSION

The analysis of polychrome corrosion preparations of arterial and venous vessels of the kidneys has revealed 17 topographic and anatomical variants of the division of the arterial bed and the formation of the venous bed of the kidney, where the main trunks in the renal hilum occupy different positions relative to the sagittal, frontal and horizontal planes.

The 3D analysis of polychrome corrosive preparations of arterial and venous vessels of the kidneys showed that the great arterial vessels in 30.0% of cases repeated the course of the cognominal venous vessels, both concerning their location in the hilum of the kidney relative to the sagittal, frontal and horizontal planes, and their course, and topography in the parenchyma of the organ.

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