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Level Organization of the Venous Bed of the Human Kidney Depending on the Options and Types of Intraorgan Veins Fusion

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***Abstract* – The article aims to conduct a 3D analysis of links and levels of the intraorgan venous system of the human kidney and build a model of its levels and spatial hierarchy. 46 corrosive preparations of the renal venous system were produced. The preparations were subjected to 3D scanning. Using Mimics-8.1, options and types of fusion of intraorgan venous vessels of the kidneys were studied. The 3D stereo-anatomical analysis of the intraorgan venous system of the kidneys showed that there are upper polar, lower polar, central, ventral and dorsal veins, depending on the options of fusion of the renal veins. 25.4% of the second order vessels are ventral and dorsal. The intraorgan venous bed of the kidney is not represented by the pole veins. 32.4% of the second order vessels are upper pole and lower pole veins. The 3D analysis of the intraorgan venous system of the human kidney revealed new links in the hierarchy of the structure of the venous system of the kidney which differs from the scheme presented by A. Kugelgen (1928) where there were four orders. The new hierarchy differs from the scheme presented in the International Anatomical Nomenclature (2003). The authors presented a new concept of spatial and level organization of the venous bed of the human kidney. The range of individual variability of the angioarchitecture of the venous system of the human kidney, namely the presence of venous vessel links and levels, depends on the options of formation of the renal vein in the kidney gate, and types of fusion of the intraorgan venous system of the kidney.**

Keywords: kidney, veins, architectonics.

I. INTRODUCTION

In the 1930s, A. Kukelgeyn (1928) developed a clear scheme reflecting the system of links and levels of organization of the intraorgan venous bed of the human kidney. These links and levels of the venous system of the kidney are distributed from the periphery of the organ to the renal vein: vv. Stellatae -, vv. Interlobares, – vv. Arcuatae, – vv. Interlobares II, – Interlobares I, – vv. Renales III, – vv. renales II, – vv. Renales I, – seu v. Renalis [14]. However, many researchers did not agree with this scheme. The International Anatomical Nomenclature 2003 contains a new scheme of the venous hierarchy of the human kidney. The venous system of the kidney system was distributed as follows: 1. Star veins (V) – 2. Interlobular veins (IV) – 3. Arc veins (III) – 4. Interlobar veins (II) – 5. Renal vein (I).

Azmi Mahmoud Ali Hussein studied the venous system of 20 human kidneys using the injection-corrosion method [1]. The author conducted a selective decomposition analysis of corrosive preparations of the venous system of the human kidney and identified: 1) the common renal venous vessel; 2). the anterior and posterior renal venous vessels; 3) the upper and lower polar venous vessels (tributaries of the anterior renal vein); 4) interlobar (segmental) veins (tributaries of the upper pole and lower pole vessels), the posterior renal vein, and 5) the parapyramidal veins (inflows of the interlobar veins). The author gave the names of the levels and links of the venous system of the human kidney.

Yu.P. Kostilenko who examined the arterial and venous system of the kidneys found that venous blood from the brain substance of the kidney enters the direct veins and flows into the arc venous vessels located in the cortical-medullary zone [10]. In the cortical substance of the kidney, interlobular venous vessels are located parallel to the location of the

interlobular arteries. According to the authors, the interlobular venous vessels located in the cortical substance of the kidney are formed from the small venous vessels of the subcapsular zone of the cortical substance of the kidney – that is, from the stellate veins. The stellate veins are located perpendicular to the interlobular ones. These venous vessels receive veins from the secondary venous capillary network which braid the renal tubules. The interlobular venous vessels flow into the arcuate veins located in the cortico-medullary zone. The venous vessels of two adjacent lobes of the kidneys formed the interlobar venous vessels which were directed through the renal pillars in parallel with the interlobar arteries. The interlobar veins in the apex of the pyramids, namely in the renal papilla, left the renal parenchyma for the sinus papilla, where they formed the main trunk of the renal vein.

D.W. Giel found that the venous outflow from the renal parenchyma occurs through the venous vessels whose main vessels do not repeat the course of the same-named arterial vessels [13]. Many authors pay attention to the venous vessels of the renal sinus, where there is a large number of anastomoses and venous plexuses [3, 8, 12, 15–16].

Thus, an analysis showed that the venous system of the kidney is quite variable. The authors state that in comparison with the arterial system of the kidney, the venous system has many options for distribution of vessels in the parenchyma of the organ and various types of vessel fusion [1, 2, 5–11].

The researchers do not agree on the structure and morphology of the venous bed of the kidney, intraorgan distribution and hierarchy of its venous links.

II. Methods and materials

The research object is the venous bed of the human kidney. 46 corrosive preparations of the human kidney venous system were produced. The preparations were subjected to 3D scanning. Using Mimics-8.1, options and types of fusion of intraorganic venous vessels of the kidneys were studied [4]. The 3D and stereoanatomical analysis of various parts of the venous bed was carried out depending on the options and types of fusion of its intraorgan venous vessels. All the digital data were processed using an Intel Core2Duo T5250 1.5 GHz processor, a RAM on the Windows 7 platform. The Excel application package was used.

III. Results

The studies showed that 57.8 % of renal veins are formed from two venous vessels. Moreover, 25.4 % of renal veins are formed from the ventral and dorsal venous vessels. 32.4 % of renal veins are formed from the upper pole and lower pole venous vessels. For stereometric analysis of the intraorganic venous bed of the kidney, we chose the variant of formation of the main renal vein from the upper pole and lower pole venous vessels (32.4 % of cases).

The 3D stereometric analysis of the venous system of the human kidney using the corrosive preparations showed that 1) stellate veins (VI) are followed by 2) interlobular veins (V), 3) arc veins (IV), 4) interlobar veins (III), forming 5) the superior pole vein (II) which forms 6) the renal vein (I).

The upper pole vein is formed as follows 1) stellate veins (VI) are follows by 2) interlobular veins (V), 3) arc veins (IV), 4) interlobar veins (III), 5) the inferior pole vein (II) which forms the 6) renal vein (I).

In 25.4 % of cases, the renal vein is formed from ventral and dorsal venous vessels. The following hierarchy of the structure of various parts of the venous bed of the kidney was revealed: 1) stellate veins (VI), 2) interlobular veins (V), 3) arc veins (IV), 4) interlobar veins (III) 5) the ventral vein (II), forming 6) the renal vein (I).

The dorsal vein is formed as follows: 1) stellate veins (VI), 2) interlobular veins (V), 3) arc veins (IV), 4) interlobar veins (III), 5) the dorsal vein (II), 6) the renal vein (I).

When studying the venous system of the kidney of other options of formation of the main renal vein, similar principles of the structure and hierarchy of its links were identified. The main feature was the types of fusion of the vessels of the intraorgan venous bed of the kidney.

The 3D stereoanatomical analysis of corrosion preparations of the intraorgan venous bed of the kidney revealed two main types of venous vessel fusion: main and scattered ones. Thus, for the first type, the hierarchy of the venous system of the kidney is as follows: the kidney cortex – 1) stellate veins (VI) 2) interlobular veins (V) 3) arc veins (IV), 4) interlobar veins (IV) III), 5) the upper pole vein (II), 6) main renal vein (I).

For the scattered type, the hierarchy of the venous system is as follows: the kidney cortex – 1) stellate veins (VI), 2) interlobular veins (V), 3) arc veins (IV), 4) second order interlobar veins (III), 5) first order interlobar veins (III), 6) upper pole vein (II), 7) main renal vein (I).

We conducted a stereometric analysis of various types of fusion of the intraorgan venous bed of the human kidney, depending on the main renal vein formation options. The studies showed that in men both vessels had the scattered type of fusion of intraorgan venous branches (6.3 %). This type was observed in 7 % of cases for the left renal vein.

In women for the same renal vein formation option, both vessels had a scattered type of fusion of the intraorgan venous branches (7.0 %). This type was observed in 8,4% of cases for the left renal vein.

In men, the pool of the upper pole vein had the main type of fusion of intraorgan vessels, and the pool of the lower pole – the scattered type of fusion of intraorgan vessels (0.7 %). In the left kidney, this type of fusion was not observed. In women, on the contrary, it was typical only of the left kidney (0.7 %).

In men, formation of the right renal vein from the ventral and dorsal venous vessels was scattered (6.3 %). Formation of the left renal vein from the ventral and dorsal venous vessels was scattered in 9.1 % of cases. In both kidneys of the same formation option, both of these vessels had a scattered type of intraorgan branch fusion which was found in 4.9 % of women. In men, with this variant of formation of the renal veins, the ventral venous vessel had a scattered type of fusion of the intraorgan venous branches, and the dorsal vessel was the

main one, which was found in 0.7 % of men. In women, this variant of fusion of intraorgan venous vessels of the kidney was observed only on the right – in 1.4 % of cases.

When the main renal vein was formed from the superior pole vessel, the central and lower polar venous vessels, all intraorgan venous vessels had a scattered type of fusion regardless of the side of the body which was found in 4.2 % of men. Intraorgan venous vessels had a scattered type of fusion, regardless of the side of the body which was found in 4.2 % of women.

When the main renal vein was formed from the superior pole vein, the lower pole and dorsal central vein, all intraorgan venous vessels had a scattered type of fusion which was found in 2.8 % of men regardless. Intraorgan venous vessels of both kidneys had a scattered type of fusion which was found in 2.1 % of women. In another variant of formation of the main renal vein from the same vessels, the upper pole and lower pole veins had a scattered type of intraorgan vessels fusion, while the dorsal central one was formed by the main type of fusion which was found in 1.4 % of cases. In the left kidney, this variant was not observed. This type was observed in both kidneys of 0.7 % of women.

In men, during the formation of the right renal vein from the ventral, dorsal and inferior pole venous vessels, all intraorgan veins had a scattered type of branch fusion (2.8 %), and during the formation of the left renal vein, this type was observed in 2.1% of men. This variant was observed in 1.4 % of women.

In men, during the formation of the right renal vein from the ventral, dorsal, and superior pole venous vessels, all intraorgan veins had a scattered type of fusion (0.7 % regardless of the side of the body). In women, this variant was not observed. Formation of the main renal vein from the ventral superior pole vein, central vein, inferior pole vein, and dorsal central vein, where all vessels had a scattered type of fusion was observed in 0.7 % of women regardless of the side of the body.

IV. Conclusion

3D-stereoanatomical analysis of the intraorgan venous system of the human kidney revealed new links in the hierarchy of the structure of the angioarchitecture of the venous channel of the kidney which is different from the scheme by A. Kugelgen (1928) where there are veins of four orders and from the scheme presented in the International Anatomical Nomenclature (2003).

Based on the research results, we created a new concept of the level and spatial organization of the venous bed of the human kidney. The range of individual variability of the angioarchitecture of the venous system of the human kidney, namely the presence of venous vessel links and levels, depends on the variants of formation of the renal vein in the kidney gate, and types of fusion of the intraorgan venous system of the kidney.

It was identified that 1) stellate veins, 2) interlobular veins, 3) arc veins, 4) interlobar veins and 5) pole veins forming the trunk 6) renal veins participate in the main type of fusion. For the scattered type of fusion, the venous channel of the kidney has a more complex structure including interlobar veins of the first, second and sometimes third orders.

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