Comparative Analysis of Human Kidney Venous Vessels at Various Method of Radiation Research

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Abstract

The aim of the study was to conduct a comparative assessment of the spatial characteristics of the kidney veins in a planar projection, in stereo projection, and according to the results of computed tomography after 3D modeling. To compare and identify the truth of the morphometric parameters of the renal veins, as well as the options for their formation during x-ray and computed tomography, 136 corrosive preparations of the kidney veins were made, which were taken as a control group. To identify the degree of similarity of the renal veins parameters on corrosion preparations, X-ray diffraction patterns (2D) and on computed tomograms (CT) with a helix pitch of 1.0 and 2.5 mm after 3D modeling, a comparative assessment of the obtained parameters was performed (degree of the angle similarity - simPhi; the degree of length similarity is simLen; and the general degree of similarity is sim). It was revealed that the greatest degree of parameters similarity was found between corrosive preparations and computed tomograms of kidney veins with a spiral pitch of 1.0 mm, which was 98.0%. Studies have shown that the informational content of x-ray examination of the kidneys' veins depends on the options for the formation and location of blood vessels in the gates of the kidney relative to the frontal, horizontal and sagittal planes. The informativeness of computed tomography studies does not depend on the options for the formation of renal veins, it determines the step of the spiral.

Keywords: *Kidney, renal veins, 3D - modeling.*

Introduction

Today in the literature there are single and conflicting data[2] on the morphometric indicators of human renal venous vessels[13]. The ambiguity of this information[9] depends on various methodological approaches used[6] in the study of these vessels[4]. Thus, morphometric indicators[3] obtained in the study of autopsy material do not always correspond to the data of radiation diagnostics[14]. There are frequent discrepancies in the data of X-ray diffraction patterns[5] with anatomical preparations[15]; in addition, there have been cases of the absence of certain sections of the intraorgan kidney veins[11] on the X-ray diffraction patterns[16].

Today, the clinic uses computed tomography[21] to study the vascular bed of the kidney[20]. However, this method does not always allow obtaining the exact parameters of blood vessels, since after 3D reconstruction[19] their true sizes may be lost[18], and sometimes some anatomical details important for diagnosis are missing or artificially formed structures[14] sometimes appear[17].

Materials and Method

We have made 136 corrosive preparations of the kidneys' venous channel of people in the age range from 22 to 90 years who died from diseases not related to kidney pathology. As the mass for pouring, Styracryl, Protacryl + Kraplak was used to simulate a radiopaque substance. To compare and identify the truth of the morphometric parameters of the renal veins, as well as the options for their formation during x-ray and computed tomography, the corrosion preparations of the kidney veins were taken as a control group[4].

Research Algorithm:

1. On corrosion preparations, 5 of the most common renal vein formation variants were identified.
2. Corrosive preparations of the kidneys veins were

subjected to digital radiography on an apparatus Clinodigit Compact X - FRAME, (Italy). The current strength was 200 mA, the voltage was 65 kV, the exposure was 300 seconds, and the focal length was 120 cm.

3. Corrosion preparations of the kidneys veins were subjected to computed tomography scanning using the Light Speed VCT apparatus (Germany). The current strength was 132 mAs, the voltage was 140 kV, the spiral pitch was 1.0 and 2.5 mm, followed by 3D modeling.

4. Corrosion preparations of the venous vessels of the kidneys, their lengths and diameters were measured on corrosion preparations of kidney veins, X-ray angiograms and computed tomograms.

5. To identify the degree of similarity of the renal veins parameters on corrosion preparations, X-ray angiograms (2D) and on computed tomograms (CT) with a helix pitch of 1.0 and 2.5 mm after 3D modeling, a comparative assessment of the obtained parameters was performed (degree of similarity of the angle - simPhi; degree of similarity of length - simLen; and general degree of similarity - sim).

The degree of similarity of corresponding vectors' pairs was revealed. Each category of the studied parameters was associated with a characteristic vector. We used the cosine measure of vectors proximity[1]. For this, they began to determine the function $simPhi(V_i, V_j)$ according to the formula 1.

$$simPhi(V_i, V_j) = \frac{\arccos(\cos\theta)}{\frac{\pi}{2}} * 100\% \quad (1)$$

Further, the function $simPhi(V_i, V_j)$ between corresponding vectors V_i и V_j uses the cosine of an angle.

The cosine of the angle, knowing the corresponding coordinates of the vectors, was revealed through the scalar product according to the formula 2.

$$\cos\theta = \frac{\vec{V_i} \cdot \vec{V_j}}{|\vec{V_i}| \cdot |\vec{V_j}|} \quad (2)$$

the scalar product was calculated by the formula 3:

$\vec{V_i} \cdot \vec{V_j} = \sum_{k=0}^{N} V_i^k * V_j^k$, где N – was the rank of the corresponding vector (3)

$|\vec{V_i}|$ и $|\vec{V_j}|$- the lengths of the corresponding vectors V_i и V_j.

We determined them according to the formula 4:

$$|\vec{V_i}| = \sqrt{\sum_{k=0}^{N} V_i^k * V_i^k} \quad (4)$$

As a result, simPhi was revealed - this is the degree of similarity of the angles of venous vessels. Identification of the correspondence and similarity degree of the venous vessels parameters by angle was insufficient. For this, an additional measure of correspondence and similarity of vectors along the length of venous vessels was introduced, i.e., a function $simLen(V_i, V_j)$ was revealed according to the formula 5:

$$simLen(V_i, V_j) = \frac{\min(|\vec{V_i}|, |\vec{V_j}|)}{\max(|\vec{V_i}|, |\vec{V_j}|)} * 100\% \quad (5)$$

Further, to reveal a comprehensive measure of correspondence and similarity of the two studied vectors, the formula 6 was used.

$$sim(V_i, V_j) = simPhi(V_i, V_j) * simLen(V_i, V_j) \quad (6)$$

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

Results

It was revealed that in 32.4% of cases, the renal vein is formed from the upper and lower pole veins. The average diameter of the renal vein was 26.2±1.3 mm. The fusion angle of the upper and lower pole veins was on average 21.2±1°. The length of the superior pole vein was on average 18.2±0.9 mm, and that of the inferior pole vein was 27.2±1.3 mm. According to the analysis of X-ray angiograms from the same corrosion preparations of the kidney veins, the average diameter of the renal vein did not differ from the parameters obtained on the corrosion preparations of the kidney and amounted to 26.4±1.3 mm. The average angle of confluence of the upper and lower pole veins was less than on corrosive preparations and amounted to 20.2±1°. The length of the superior pole vein averaged 17.2±0.8 mm, and the length of the inferior pole vein 26.4±1.3 mm. According to the analysis of computer tomograms (spiral pitch 1.0 mm with 3D modeling), the average diameter of the renal vein was 26.3±1.3 mm, not significantly different from the data on corrosion preparations. The average fusion angle of the upper and lower pole veins also did not differ from the data obtained by morphometry of corrosive preparations and amounted to 20.1±1°. The average length of the superior pole vein did not differ from the data on corrosive preparations and amounted to 18.3±0.9 mm. However, analysis of computed tomograms (2.5 mm pitch) showed significant differences in average values. So, the average diameter of the renal vein was significantly different and was 28.2±1.4 mm. The fusion angle of the upper and lower pole veins on average significantly differed from the parameters obtained on corrosion preparations and amounted to 16.7±1°. The average length of the superior pole vein was 16.4±0.8 mm, and that of the inferior pole vein was 24.3±1.2 mm, which was less than with corrosive preparations.

A comparative analysis of renal vein morphometry data on radiographs and computed tomograms with data on corrosion preparations showed that the similarity degree of the parameters was: simPhi - (3D, 2D) - 98,2%, simPhi - (3D, KT1) - 98,5%, simPhi - (3D, KT2,5) - 89,9%, simLen - (3D, 2D) - 97,8%, simLen - (3D, KT1) - 99,3%, simLen - (3D, KT2,5) - 96,5%, sim - (3D, 2D) - 96,0%, sim - (3D, KT1) - 97,8%, sim - (3D, KT2,5) - 86,8%.

In 25.4% of cases, renal veins are formed from the ventral and dorsal veins. It was revealed that the average diameter of the renal vein is 10.8±0.5 mm. The average fusion angle of the ventral and dorsal veins was 27.2±1.3°. The length of the ventral vein averaged 33.2±1.6 mm, and the dorsal vein 39.1±1.9 mm. Analysis of x-ray diffraction patterns showed that in 14% of cases, the shadow of the ventral vein in the frontal projection was visualized as an upper pole, and the dorsal as a lower pole (orthogonal principle of the depth of location). In 26% of cases, the shadows of both veins were projected onto each other, giving out the projection of a single trunk (orthogonal principle of competing lines). Morphometric analysis of computed tomograms (spiral pitch 1.0 mm) did not reveal significant differences from indicators obtained on corrosive preparations of kidney veins. However, computer tomograms (spiral pitch 2.5 mm) revealed that the average diameter of the renal vein did not differ significantly from the data of corrosive preparations and was 13.2±0.6 mm. The fusion angle of the ventral and dorsal veins differed and averaged 26.5±1.3°. The average length of the ventral vein was 26.2±1.3 mm, and that of the dorsal vein was 23.4±1.1 mm, which was significantly less than on corrosion preparations.

When comparing morphometry data, the degree of similarity was: simPhi - (3D, 2D) - 84.2%, simPhi - (3D, CT1) - 99.7%, simPhi - (3D, CT2.5) - 84.9%, simLen - (3D, 2D) - 84.0%, simLen - (3D, KT1) - 99.9%, simLen - (3D, KT2.5) - 79.7%, sim - (3D, 2D) - 70, 8%, sim - (3D, KT1.5) - 99.7%, sim - (3D, KT2.5) - 67.7%.

In 8.4% of cases, the renal vein is formed from the superior pole, inferior pole and dorsal central veins. The value of the diameter of the renal vein averaged 9.1±1.0 mm. The fusion angle of the upper and lower pole veins averaged 18.1±0.9°. The confluence angle of the upper pole and dorsal central veins was 29.3±1.4°. The fusion angle of the dorsal central and lower pole veins averaged 28.1±1.4°. The length of the superior pole vein was on average 21.1±0.1 mm, while the diameter was 8.4±0.4 mm. The length of the dorsal central vein averaged 12.8±0.6 mm, and the average value of its diameter was 5.5±0.2 mm. The length of the inferior pole vein averaged 14.8±0.7 mm, while its diameter averaged 8.1±0.4 mm.

Analysis of x-ray diffraction patterns showed that in 18% of cases, the shadow of the dorsal central vein was visualized as the central one (orthogonal principle of the depth of location), located in the same plane with the rest of the veins. The average diameter of the renal vein was 9.4±0.4 mm. The fusion angle of the upper and lower pole veins averaged 17.2±0.8°. The fusion angle of the upper pole and dorsal central veins was on average 13.2±0.6°, and the dorsal central and lower pole veins 14.1±0.6°. The length of the superior pole vein was, on average, 20.2±1.0 mm, and its diameter 8.7±0.4 mm, which did not significantly differ from that on corrosion preparations. The length of the dorsal central vein averaged 9.3±0.4 mm, and its average diameter was 5.8±0.2 mm. The length of the inferior pole vein was on average 13.1±0.6 mm, and its average diameter was 8.5±0.4 mm.

According to the analysis of computed tomograms (spiral pitch 1.0 mm), it was revealed that the average values of their morphometry data did not differ significantly from those on corrosive preparations. However, analysis of computed tomograms from the same corrosive preparations (2.5 mm pitch) showed significant differences in morphometric parameters and the appearance of non-existent parts. So, in 6.2% of cases, a central vein and insufficient visualization of interlobar and arc veins were visualized on computed tomograms. The diameter of the renal vein was on average 11.3±0.5

mm. The fusion angle of the upper and lower pole veins was on average 17.1±0.8°. The confluence angle of the upper pole and dorsal central veins was 27.3±1.3°. The fusion angle of the dorsal central and lower pole veins averaged 26.4±1.3°, which was significantly different from morphometry data on corrosion preparations. On average, the length of the superior pole vein was less than on corrosive preparations and was 19.4±0.9 mm, and its diameter was 10.2±0.5 mm. The length of the dorsal central vein was also less and amounted to 10.4±0.5 mm, while its diameter was on average equal to 7.1±0.3 mm. The length of the inferior pole vein was on average 12.3±0.6 mm, while its average diameter was 10.3±0.5 mm. A comparative analysis of morphometry data showed that the degree of similarity was: simPhi - (3D, 2D) - 79.1%, simPhi - (3D, CT1) - 99.8%, simPhi - (3D, CT2.5) - 95.5 %, simLen - (3D, 2D) - 70.2%, simLen - (3D, KT1) - 99.7%, simLen - (3D, KT2.5) - 93.0%, sim - (3D, 2D) - 55.5%, sim - (3D, KT1) - 99.6%, sim - (3D, KT2.5) - 88.8%.

In 4.2% of cases, renal veins are formed from the ventral, dorsal and lower pole veins. In 13.0% of cases on X-ray diffraction patterns from the same corrosive preparations, the ventral veins were visualized as upper pole, dorsal veins as central (the principle of location depth). On x-ray angiograms, these veins were falsely projected in the frontal plane in the form of an upper pole, central and lower pole vein. In 16.0% of cases, when the veins are located in the same projection, the shadows are subtracted, and the ventral and dorsal veins overlap each other, which creates the false impression of a single venous trunk (the principle of competing lines).

Discussion

Based on the researches, it was established that certain options appear on the radiograph[10], which is consistent with the opinion of a authors' number[16]. According to the results of our research, variants were observed, as a rule, where the shadows of the kidneys veins were projected in the same geometric plane[11]. In axonometry, they are called competing lines, giving a single shadow in one plane[16]. If a separate image element (a section of a kidney vein) was an object of perception, then options in a planar projection were visualized relative to the depth of the venous vessels[7]. On radiographs of corrosive preparations of the veins of the kidney, the true parameters (angles of fusion of the veins, lengths of the kidneys veins and their diameters) were distorted. Analysis of computed tomograms with a helix pitch of 1.0 and 2.5 mm, followed by 3D modeling, revealed possible distortions of the spatial organization of the venous vessels of the kidneys, which depend on the helix pitch (changes in diameters, angles of vascular fusion). According to the study, after 3D - modeling, computed tomograms do not contain some important anatomical structures for diagnosis, and sometimes artificially formed parts appear in the form of additional (non-existent) venous vessels[4], which we met in 28.6% of cases and is consistent with data from several authors[10].

Conclusion

A comparative assessment of the spatial characteristics of the kidney veins in planar projection, in stereo projection, and according to the results of computed tomography with increments of 1.0 and 2.5 mm after 3D modeling showed that the highest degree of the parameters similarity was found between corrosion preparations and computed tomograms of kidney veins with a spiral pitch 1.0 mm, which was equal to 98.0%.

Studies have shown that the informational content of x-ray examination of the kidneys veins depends on the options for the formation and location of blood vessels in the gates of the kidney relative to the frontal, horizontal and sagittal planes. The informativeness of computed tomography studies does not depend on the options for the formation of renal veins, it determines the step of the spiral.

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