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Morphometric Parameters of Venous Vessels in Human Kidneys during Aging according to Computed Tomography Data

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Abstract

The purpose of the study was to review the morphometric parameters of the venous vessels in human kidneys in mature, elderly, and senile ages. To study the variant anatomy and determine the morphometric characteristics of the extra-organ part of the venous vessels of the kidneys, computed tomograms in the coronal projection of 111 men and women were used. To study age-related characteristics, the most common variant of the formation of renal veins (from the superior and inferior polar vessels) was chosen, followed by the study of the frontal diameters of the renal veins and the frontal diameters of the polar veins.
It was found that the mean diameters of the left and right renal veins were more prevalent in males than in females. Age-related changes in the morphometric parameters of the renal venous vessels consist in an increase in these values in the first (20–34 years) and the second (34–59 years) mature periods (at $p \leq 0.05$). However, in the elderly and senile periods of ontogenesis, statistically, significant changes are generally not observed. The renal vein and the venous vessels forming it in the mature, elderly, and senile periods of ontogenesis are characterized by an asymmetry of diameters, angles of fusion of the polar vessels, and their lengths (at $p \leq 0.05$). Sex-based differences in the morphometric parameters of the renal veins and the venous vessels that form them consist in an insignificant prevalence of these parameters in males than in females.

Keywords: Kidney, Renal vein, Computed tomography, Morphometry

Introduction

Currently, in the scientific literature, there is no unequivocal opinion regarding issues related to the diameters of the renal veins, the knowledge of which is of great clinical importance (Tarabarko, 1995; Kvyatkovskaya *et al.*, 2000; Barabanov, 2001; Shumakov, 2005; Mochalov, 2006; Kostilenko & Azmi, 2008; Wang *et al.*, 2008; Monina, 2014; Kafarov *et al.*, 2015; Kafarov *et al.*, 2017; Girgenti *et al.*, 2019; Jannatbabaei *et al.*, 2019; Jiang *et al.*, 2019; Kafarov *et al.*, 2019; Russell *et al.*, 2019; Fulop *et al.*, 2020; Xu *et al.*, 2021).

The need to study the morphometric characteristics of renal venous vessels is explained by the demands of bypass surgery (Tarabarko, 1995; Shumakov, 2005; Monina, 2014; Alsulaimani & Al-wayili, 2019; Meng & Mu, 2020). Thus, according to certain authors, the percentage of successfully performed organ-preserving surgical interventions in localized renal cell carcinoma does not exceed 40%, where the main attention is directed to the structural features of the renal vascular bed, and its morphometric and hemodynamic features (Monina, 2014; Bonilla *et al.*, 2020). Besides, the same authors, studying age-related changes in the blood vessels of the kidneys, have noted that in children the diameter of the renal vein is small compared to the renal artery, and gradually increases with age (Elwy *et al.*, 2019; Red-Horse & Siekmann, 2019; Cacciapuoti, 2020; Fulop *et al.*, 2020).

The anatomical and biophysical features of human renal venous vessels are discussed in the works of A.V. Ayvazyan (Russell *et al.*, 2019). He investigated about 400 vessels of the kidneys, measuring the length of the renal vessels, the diameters of their lumens, the thickness of the walls of the vessels, the degree of vascular extensibility, and the load force required for their rupture (Alsulaimani & Al-wayili, 2019; Elwy *et al.*, 2019). When comparing the diameters of the renal veins with the arteries, he observed the following pattern: the inner diameter of the renal vein in the wall of the inferior vena cava was 1–2 mm larger than the diameter of its middle lumen. Besides, he found that the average diameters of the main renal venous vessels are 1.3–1.4 mm larger than the average diameters of the renal arteries.

According to some authors, it has been established that with age, the diameters of human renal venous vessels increase and in adults, the diameters at the site of infusion into the inferior vena cava are 14-16 mm on the left and 12-14 mm on the right; whereas in children they are 8 mm on the left and 5 mm on the right (Barabanov, 2001; Fulop *et al.*, 2020). The largest diameter of the renal vein, according to these authors, was 23 mm, and the smallest 4.3 mm. It was found that the largest internal diameter of the renal vein was 13 mm (174 cases), and the smallest diameter equaled 8 mm (20 cases).

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Several authors have measured the internal diameters of venous and arterial vessels using polychrome corrosive kidney preparations (Mochalov, 2006; Kafarov *et al.*, 2017). Besides, they measured the diameters of the renal vessels in patients by the method of ultrasound scanning. After a comparative analysis of the morphometric data of corrosive preparations, it was found that the diameter of the renal vein in the area of the renal hilum averaged 8.7 ± 0.6 mm (from 5.3 mm to 12.6 mm). According to the data of duplex scanning, the average diameter of the renal vein differed from the morphometric data of corrosive preparations and was 5.9 ± 0.4 mm (from 3.4 mm to 8.5 mm). The diameter of its venous tributaries in the renal sinus averaged 2.9 ± 0.1 mm (from 2.0 mm to 3.5 mm) (Kafarov *et al.*, 2017).

Thus, the analysis of the literature has shown that even though the study of renal venous vessels is currently receiving more and more attention, there is still no consensus regarding the morphometric parameters of renal veins (Kafarov *et al.*, 2015; Kafarov *et al.*, 2017; Jannatbabaei *et al.*, 2019; Jiang *et al.*, 2019; Xu *et al.*, 2021). The lack of a unified point of view among researchers is explained, in our opinion, by, firstly, significant variability of the venous bed of the kidney, secondly, insufficient attention to this link in the vascular bed of the kidney, thirdly, the difference in the morphometric parameters of various research methods (some morphometric parameters of vessels obtained on two-dimensional (2D) section matrices after three-dimensional (3D) modeling or after 3D reconstruction may change), and fourthly, by the need to systematize the available data and develop new, more informative approaches to studying the morphometric parameters of venous vessels of this organ (Kvyatkovskaya *et al.*, 2000; Wang *et al.*, 2008).

The study aimed to review the morphometric parameters of the venous vessels in human kidneys in mature, elderly, and senile ages according to the data of computed tomography studies on 2D section matrices.

Materials and Methods

To determine the morphometric characteristics of the extra-organ part of the renal venous vessels, we used computed tomograms in the coronal projection of 111 men and women, obtained on a LightSpeed VCT computed tomography (OOO Diagnostic Center Zdorovye, Grozny). To study the age-related characteristics of the morphometric parameters of the renal venous vessels on computed tomograms, we selected the most common variant of the formation of the renal veins (from the superior and inferior polar vessels), followed by the study of the frontal diameters of the renal veins, the frontal diameters of the polar veins, the lengths of the polar veins and the angles of their confluence.

All the material obtained and the data of instrumental research methods were processed by the methods of variational and nonparametric statistics on a workstation with an Intel Core2Duo T5250 1.5 GHz processor, RAM up to 2GB on the Windows 7 platform. In the course of the study, we used the Excel application package from Microsoft Office 2007. The degree of research accuracy is determined by the probability of an error-free forecast less than or equal to 0.95%; significance level $p \leq 0.05$; for features with a normal distribution, Student's t = 2 test was used, for features with a distribution other than normal, we used the nonparametric Wilcoxon U-test (Mann-Whitney) with the same level of significance.

Results and Discussion

The analysis of morphometric parameters obtained by computed tomography (2D sections) revealed a change in the diameter of the renal veins at the stages of ontogenesis.

The study found that in males, in the first mature period (20–34 years), the average diameter of the right renal vein was 11.7 ± 0.2 mm, (Cv = 2.4%), and the diameter of the left renal vein was 12.4 ± 0.3 mm, (Cv = 3.1%). It was observed that by the end of the second mature period (34 - 59 years) the diameter of the right renal vein reached 13.2 ± 0.3 mm, (Cv = 2.2%), and that of the left vein equaled 13.6 ± 0.2 mm (Cv = 0.6%). Further, the study showed that in the senile period this parameter increased to 14.1 ± 0.2 mm on the right, (Cv = 0.6%) and 14.5 ± 0.2 mm on the left, (Cv = 1.1 %).

Thus, the analysis showed that at all stages of ontogenesis, the diameter of the left renal vein was slightly larger than that of the right vein (Kafarov *et al.*, 2019).

We found different age-related dynamics of the renal vein diameters in females. Thus, according to computed tomography, at the age of 20–34 years, the average diameter of the right renal vein in females equaled 10.5 ± 0.2 mm, (Cv = 1.6%), and the diameter of the left vein amounted to 11.7 ± 0.3 mm, (Cv = 3.4%). It was found that at the stages of ontogenesis in females there was a fluctuation in the diameters of the right and left renal veins, amounting to 12.3 ± 0.3 mm in the right renal vein by the end of the second mature period, (Cv = 3.1%), and to 12.6 ± 0.3 mm in the left renal vein, (Cv = 1.5%).

By the senile period (75–89 years), the diameter of the right renal vein reached 13.6 ± 0.2 mm, (Cv = 0.6%), and the diameter of the left renal vein equaled 14.1 ± 0.2 mm, (Cv = 2.2%). Morphometric analysis of the dynamics of the diameters of the superior and inferior polar venous vessels also did not reveal significant sex-based differences. Thus, in the first mature period in males (20–34 years), the average diameter of the inferior polar vessel of the right renal vein was 8.3 ± 0.2 mm, (Cv = 1.3%), and the diameter of the superior polar vessel was 8.5 ± 0.2 mm, (Cv = 1.2%).

It was observed that by the elderly period (60–74 years) the diameters of the veins increased in the inferior polar vessel up to 8.6 ± 0.2 mm, (Cv = 1.2%), and in the superior polar vessel up to 9.4 ± 0.2 mm, (Cv = 1.1%). Further, the study showed that by the senile period, the diameters of the polar veins in males reached 9.7 ± 0.1 mm in the superior polar vein and 8.7 ± 0.08 mm in the inferior one, (Cv = 1, 2%) and (Cv = 0.8%), respectively.

Morphometric analysis of the dynamics of the diameters of the left polar vessels according to our study showed that in the first mature period (20–34 years), the diameter of the inferior polar vessel of the left renal vein was 8.5 ± 0.1 mm (Cv = 2.2%), and the diameter of the superior vessel was 8.6 ± 0.2 mm (Cv = 3.3%). Further, the study showed that in the second mature period, the pole diameters equaled 9.1 ± 0.2 mm (Cv = 1.2%) in the inferior polar vessel and 9.3 ± 0.06 mm in the superior polar vessel (Cv = 0.8 %).

In the senile period, the diameter of the superior polar vessel was 9.4 ± 0.3 mm (Cv = 2.2%), and that of the inferior polar vessel was 9.2 ± 0.2 mm (Cv = 1.7%).

In females, aged (20–34 years), the average diameter of the inferior polar vessel of the right renal vein was 8.3 ± 0.2 mm (Cv = 1.3%), and in the superior polar vessel, it equaled 8.4 ± 0.3 mm (Cv = 2.4%).

In the elderly period (55–74 years), the diameters of the polar veins were 8.7 ± 0.3 mm in the inferior polar vessel (Cv = 2.3%), and 9.3 ± 0.3 mm in the superior polar vessel (Cv = 2.2%).

Further, during the study, we found that in the senile period the diameters of the polar veins increased to 9.4 ± 0.2 mm in the superior polar vein (Cv = 1.1%) and 9.2 ± 0.2 mm in the inferior one, respectively (Cv = 3.2%).

The analysis showed that in the left renal vein the age-related dynamics of the diameters of the polar veins were characterized by the fact that in the first mature period (20–34 years) this indicator in the inferior polar vessel was 8.3 ± 0.04 mm (Cv = 0.5%), and the diameter of the superior polar vessel was 8.6 ± 0.2 mm (Cv = 1.8%). In the elderly period (55–74 years) the diameters of the polar veins were 9.4 ± 0.1 mm in the superior pole vein (Cv = 1.0%) and 8.7 ± 0.2 mm in the inferior one (Cv = 1.5 %).

We saw that in the senile period, the diameter of the superior polar vessel was 9.6 ± 0.04 mm (Cv = 0.5%), and in the inferior polar vessel was 9.2 ± 0.2 mm (Cv = 1.4%).

Morphometric analysis of computed tomograms in coronal projection showed that the average lengths of the superior polar and inferior polar veins in both kidneys did not have significant differences, regardless of gender. Along with this, at the stages of ontogenesis, we observed a change in the length of the polar veins of the kidney. Thus, in males, in the first mature period (20–34 years), the average length of the inferior polar vessel on the right was 24.3 ± 0.4 mm (Cv = 2.1%), and the length of the superior polar vessel was 23.7 ± 0.4 mm (Cv = 2.4%). By the elderly period, the length of the polar vessels reached 26.3 ± 0.3 mm at the inferior polar vessel (Cv = 1.3%), and 27.4 ± 0.3 mm at the superior polar vessel (Cv = 0.7%).

In the course of the study, we saw that in the senile period (75–89 years) the vein diameters increased to 27.4 ± 0.2 mm at the superior polar vein (Cv = 0.3%) and up to 28.2 ± 0.1 mm at the inferior polar vein (Cv = 0.8%). In males, the dynamics of the length of the polar vessels of the left kidney were characterized by the fact that in the first mature period (22–30 years) the length of the inferior polar vessel was 22.6 ± 0.6 mm (Cv = 3.2%), and the length of the superior polar vessel was 23.6 ± 0.6 mm (Cv = 3.1%).

It was further established that in the elderly period (60-74 years) the length of the polar veins was 27.5 ± 0.2 mm (Cv = 0.7%) in the superior polar vessel and 26.2 ± 0.3 mm (Cv = 1.6%) in the inferior one. By the senile period, the length reached 27.6 ± 0.3 mm (Cv = 1.6%) in the superior polar vein and 26.4 ± 0.2 mm (Cv = 0.6%) in the inferior one, respectively.

Morphometric analysis of computed tomograms of venous vessels in coronal projection showed that the mean angles of fusion of the polar vessels of the right and left renal veins did not have significant sex-based differences. Along with this, in the studied periods of ontogenesis, we noted an increase in the angles of fusion of the polar veins of the kidney. Thus, in the first mature period in males (20–34 years), the average angles of fusion of the superior polar and inferior polar vessels of the right and left kidneys were 12.6 ± 0.2 ° (Cv = 2.6%) and 12.8 ± 0.2 ° (Cv = 2.4%), respectively.

Studies showed that by the end of the second mature period (34–59 years), the angle of fusion of the right superior and inferior polar venous vessels was 14.2 ± 0.2° (Cv = 0.8%), and the angle of the left one equaled 14.8 ± 0.2° (Cv = 0.7%). It was found that by the senile period this parameter increased to 14.7 ± 0.2° (Cv = 0.7%) on the right and up to 15.3 ± 0.4° (Cv = 3.4%) on the left.

In females in the age period of 22-30 years, the average angle of fusion of the right superior polar and inferior polar venous vessels was 12.3 ± 0.4° (Cv = 4.1%), and the angle of fusion on the left was 12.5 ± 0.5 ° (Cv = 4.7%).

It was found that by the senile period the average angle of the fusion of the polar veins reached up to 14.5 ± 0.4° (Cv = 2.7%) in the left renal vein and 14.2 ± 0.2° (Cv = 0.7%) in the right one.

Thus, the morphometric analysis of the computed tomography data showed that during ontogenesis the average diameters of the right and left renal veins increased both in males (from 11.8 ± 0.2 mm (Cv = 2.4%) in the first mature period of ontogenesis to 14.2 ± 0.2 mm (Cv = 0.6%) in the senile period on the right and from 12.4 ± 0.3 mm (Cv = 3.1%) to 14.7 ± 0.1 mm (Cv = 1.0%), respectively, on the left, at $p \le 0.05$), and in females (from 10.7 ± 0.3 mm (Cv = 1.6%) in the first mature period of ontogenesis to 13.8 ± 0, 2 mm (Cv = 0.8%) in the senile period on the right and from 11.9 ± 0.5 mm (Cv = 3.5%) to 14.3 ± 0.4 mm (Cv = 2.2%), on the left, respectively, at $p \le 0.05$).

It should be noted that bilateral asymmetry of the renal veins with this research method was revealed in males in mature, elderly, and senile age periods, and in females in the first mature and senile periods of ontogenesis (Kostilenko & Azmi, 2008; Kafarov *et al.*, 2019).

It was found that in all age periods studied by us, the average diameter of the renal vein in males prevailed over that in females, but without a significant difference (Kostilenko & Azmi, 2008; Girgenti *et al.*, 2019; Kafarov *et al.*, 2019).

Further, the study found that in males the average diameter of the superior polar venous vessel on the right significantly exceeded the average diameter of the inferior polar vessel in the elderly (9.6 ± 0.2 mm (Cv = 1.1%) and 8.8 ± 0.1 mm (Cv = 1.2%), respectively) and senile (9.8 ± 0.2 mm (Cv = 1.1%) and 8.9 ± 0.07 mm (Cv = 0.8%), respectively) periods of ontogenesis at $p \leq 0.05$. On the left, no significant differences were found between the diameters of the superior and inferior polar veins.

In females, a different dynamics of the diameters of the superior and inferior polar venous vessels was noted, where on the right there was no significant difference between the diameters, and on the left, the average diameter of the superior polar vessel prevailed over the diameter of the inferior polar one in the mature (9.3 ± 0.04 mm (Cv = 0, 7%) and 8.4 ± 0.04 mm (Cv = 0.6%), respectively), elderly (9.6 ± 0.2 mm (Cv = 1.1%) and 8.7 ± 0.2 mm (Cv = 1.7%), respectively) and senile (9.8 ± 0.04 mm (Cv = 0.7%) and 9.2 ± 0.2 mm (Cv = 1.6%), respectively) periods of ontogenesis at $p \leq 0.05$.

Conclusion

The analysis of the morphometric parameters of the renal venous vessels according to the computed tomography study on 2D section matrices in the coronal projection in the age-sex groups has shown that:

1. The average diameters of the main right and left renal veins are more prevalent in males than in females. In males, the average diameter of the main left renal vein reliably prevails over the diameter of the right one in the mature, elderly, and senile periods, and in females only in the first mature and senile periods.
2. In males, the average diameter of the superior polar venous vessel on the right reliably prevails over the inferior polar one in the elderly and senile periods, and on the left, the diameter of the superior polar venous vessel prevails without a significant difference.

In females, the diameter of the superior polar venous vessel on the right prevails over the inferior polar one without a significant difference, and on the left with a significant one;

3. The length of the superior polar venous vessel is greater than the length of the inferior polar one on the left with a significant difference, and on the right without a significant difference, regardless of gender;
4. In males, the mean angles of fusion of the superior and inferior polar venous vessels of the left kidney significantly prevail over that of the right one only in the elderly and senile periods.

In females, the angles of fusion of the polar venous vessels on the left prevail over the ones on the right, without a significant difference.

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