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Characteristics of Morphometric Indicators of The Kidneys in Gestancial Pyelonephritis According to Pregnancy Parity

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Abstract: Basically, the morphometric parameters of the cells and fibrous structures of the kidney in the morphofunctionally actively stained areas were taken as the basis for expressing the trajectory of the values measured during the morphometry process within a certain range by numbers. The specific features of the morphometric parameters of the parenchymal and mesenchymal structures of the kidneys of 40 women who died from gestational pyelonephritis, who underwent autopsy at the Republican pathologoanatomical center of Uzbekistan, were studied using the Hamamatsu (QuPath-0.4.0, NanoZoomer Digital Pathology Image) morphometric software. To determine the morphometric parameters, the location, size, area occupied, size of cells, width of blood vessels, diameter, perimeter, volume of lumens in a given volume and other indicators were obtained. In the study, the superiority of all morphofunctional parameters over the control group was up to 1.35 times in the I-pregnancy, up to 1.2 times in the II-pregnancy, which was explained by the weakness of morphological adaptation mechanisms, a decrease in the age-related reactivity of vascular components.

Keywords: Borphometry, kidney, gestational pyelonephritis, pregnancy.

Introduction: According to the WHO (2022), pregnant women make up an average of 11.7% of the world's population. During the second and third trimesters of pregnancy, the development of morphofunctional obstructions in the urinary system can occur, leading to compression of the ureters coming from the kidneys. This causes urinary stasis and, with the addition of infectious agents, results in the development of gestational pyelonephritis [1, 2, 6].

The incidence rate of gestational pyelonephritis corresponds to the number of pregnancies and births and is observed in approximately 2–4% of all pregnant women in the United States and European countries, around 2–3% in Japan, South Korea, and India, and on average 2–10% in CIS countries and the Russian Federation. In the Republic of Uzbekistan, this indicator averages 10–18%. The development of gestational pyelonephritis during childbirth and the postpartum period accounts for approximately 6–25%, underscoring the urgency of the problem.

The mortality rate due to kidney complications arising during pregnancy and the postpartum period is on average 1–3% per 1000 pregnant women [3, 4, 5].

Research aim and objectives

To study the changes in renal morphometric parameters in gestational pyelonephritis depending on pregnancy parity.

METHODS

The study was conducted at the Republican Center of Pathological Anatomy between 2020 and 2023 and involved 40 women who died during pregnancy due to renal pathologies. The specific morphometric characteristics of the renal parenchyma and mesenchymal structures in cases of gestational pyelonephritis were analyzed using the Hamamatsu (QuPath-0.4.0, NanoZoomer Digital Pathology Image) morphometric software.

RESULTS

For morphometric examination, kidney tissue samples were obtained from the autopsies of patients who suddenly died of myocardial infarction (control group, n=17). As the experimental group, kidney tissue samples were taken from autopsies of women of various reproductive ages who died during pregnancy due to acute renal diseases. The prepared kidney tissue materials were scanned using the NanoZoomer, and microimages were obtained.

Morphometric parameters were determined based on cellular localization, volume, occupied area, size, width, diameter, perimeter, lumen volume of blood vessels, and other relevant indicators within a defined volume.

Specifically, morphometric analysis identified dystrophic changes in the functional active areas of the renal parenchymal components, while inflammatory changes were observed in the mesenchymal parts, such as the glomeruli and tubules, which serve as key indicators of pathological alterations.

Our study revealed distinctive features of the examined tissue, including the complete integrity of all glomerular blood vessels, a 17–28% increase in glomerular weight compared to the control group, focal detachment in the epithelium of proximal and distal tubules, presence of coarse proteinaceous inclusions in the cytoplasm, massive multifocal desquamation in the epithelium, and nuclei exhibiting karyopyknosis, karyorrhexis, and karyolysis due to necrobiosis. Additionally, thickening of the basal membrane of proximal tubules, accumulation of coarse homogeneous proteinaceous substrate in the lumen of distal tubules, massive congestion of peritubular capillaries, diapadesis hemorrhages, and a significant decrease in reabsorption capacity of proximal tubules were observed.

Morphometrically, the changes associated with gestational pyelonephritis were studied according to the number of pregnancies.

Table 3.1.

Morphometric Parameters (number and micrometers) of Renal Injury Areas in Gestational Pyelonephritis

Studied Parameters		Control Group	I Trimester	II Trimester	III Trimester	R ≤ 0.01
Average diameter of renal glomeruli		166.8±1.1	209.3±1.1	191.1±1.01	173.2±1.1	0.01
Glomerular perimeter		256.7±1.03	343±1.05	314.5±1.1	293.1±1.21	0.01
Area occupied by the glomerular tuft (15000 μm²)		10365±5.61	12281±3.25	10995±8.3	10725±2.92	0.01
Shumlyansky–Bowman space		18.31±1.01	15.21±1.01	17.42±0.97	18.21±1.01	
Proximal	121.12±5.01	162.11±8.16	152.5±7.13	135.31±5.21	0.01	

tubule diameter Proximal tubule lumen diameter Proximal tubule perimeter Proximal tubule area (µm²)	43.01±0.01	36.2±1.01	37.1±1.01	39.2±1.01	0.01	
	243.12±1.65	284.15±1.16	265.31±1.32	251.42±1.2	0.01	
	716.48±312.65	774.1±1.12	745.1±1.76	725.1±1.1	0.01	
Distal tubule diameter	61.12±1.4	84.36±12.5	78.14±1.6	68.11±1.3	0.01	
Collecting duct lumen diameter	31.16±6.59	42.18±6.25	39.7±1.4	34.01±1.06	0.01	
Collecting duct perimeter	121.24±2.8	169.72±25.1	156.28±3.2	136.21±2.6	0.01	
Collecting duct area (µm²)	1299.97±22.84	1559.96±23.4	1374.13±11.15	1274.29±12.52	0.01	

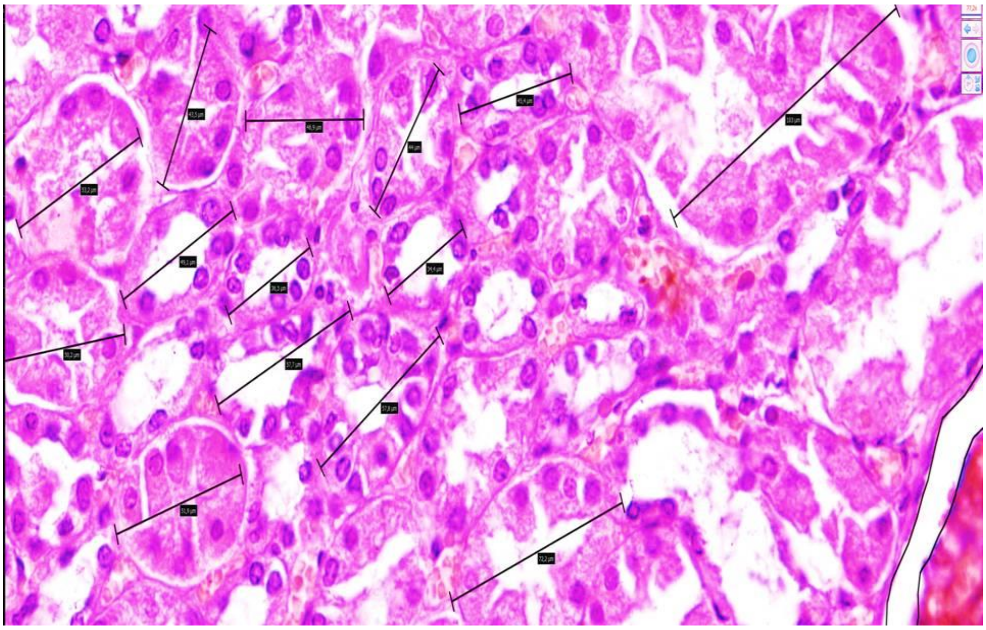

Figure 1. In the image, centrally located dilated tubules appear irregularly oval in shape and have undergone compressive deformation. Scanned using NanoZoomer. Staining: H&E. Size: 20×10.

The average diameter of the renal glomeruli in the control group was 166.8±1.1 µm. In comparison, this parameter increased to 209.3±1.1 µm in the kidneys of the first group of pregnant women with gestational pyelonephritis during the first trimester, showing a 1.25-fold increase. These changes correspond to the morphological signs described above, particularly the vascular response within the glomerular capillary network. The observed increase in filtration, marked vasodilation, and enlargement of the glomeruli confirm that these alterations are most pronounced in gestational pyelonephritis occurring during the first trimester.

In the second trimester, this indicator measured 191.1±1.01 µm. From an age-related perspective, this is explained by a reduction in vascular elasticity, and compared to the first-trimester group, vessels became more fragile and thickened. As a result, the extent of vasodilation was less pronounced. Nevertheless, this parameter was still 1.15 times higher than that of the control group, confirming its significance.

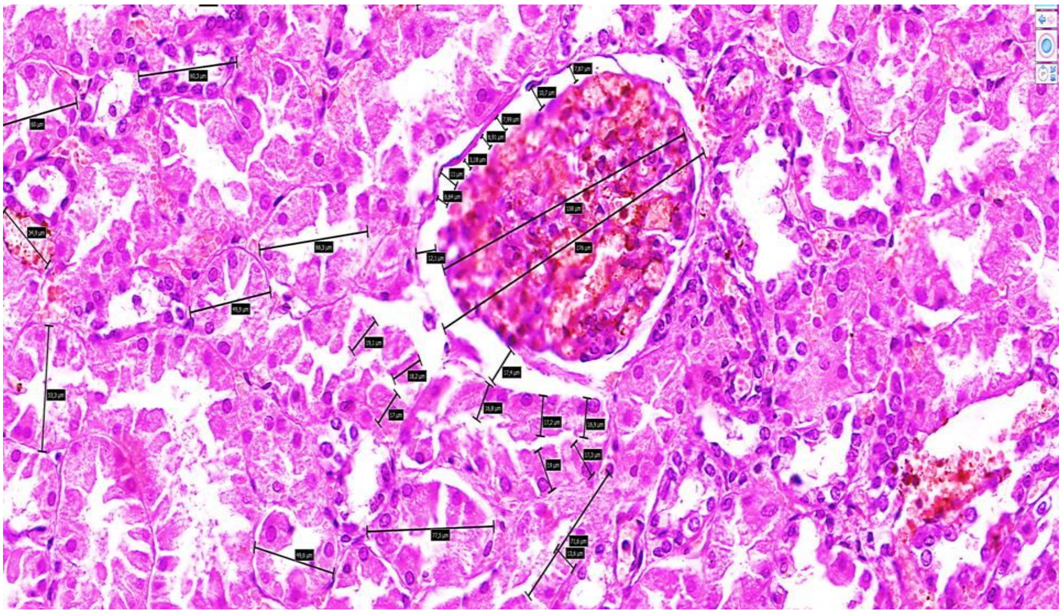

Figure 2. Graphical representation of the average perimeter of the Shumlyansky–Bowman's space of the renal glomerulus. Scanned using NanoZoomer. Staining: H&E. Size: 20×10.

In the third trimester, the same parameter measured 173.2±1.1 µm. This value can be explained by age-related changes, such as a marked reduction in vascular elasticity, increased fragility of blood vessels compared to groups I and II, and a decrease in elastic fibers within the vessel walls. Additionally, reduced reabsorption capacity in the renal tubules contributes to this finding. The parameter was 1.03 times higher than that of the control group, confirming its significance.

As for the glomerular perimeter, it was 256.7±1.03 µm in the control group, while in the first trimester group, it increased to 343±1.05 µm. This represents a 1.34-fold increase, indicating significant vascular congestion within the glomeruli and intensified filtration processes, which in turn led to the expansion of Bowman's space, thus supporting the observed morphological findings.

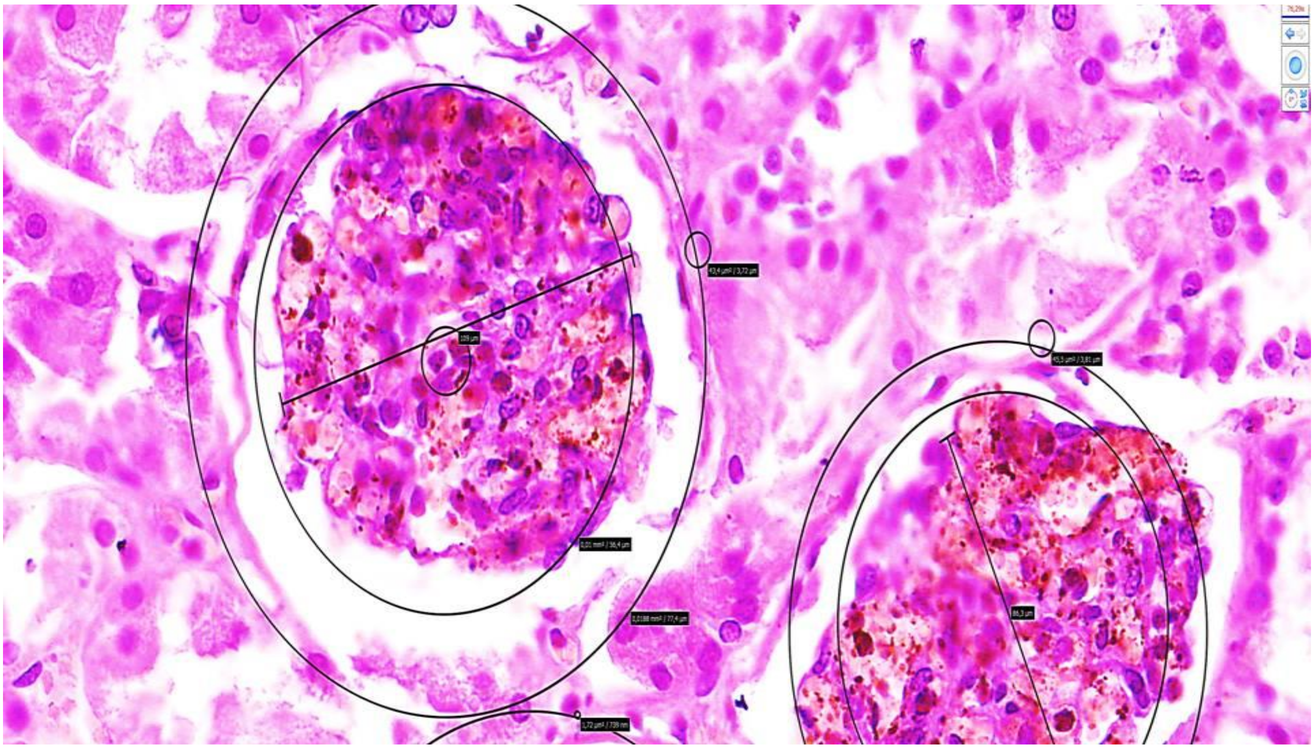

Figure 3. The renal glomerulus with illustrated epimetric and perimetric measurements of the Shumlyansky–Bowman's space, showing one-quarter of the segmental diagonal diameter. Scanned using NanoZoomer. Staining: H&E. Size: 20×10.

In the second group (i.e., during the second trimester of pregnancy), the perimeter of the renal glomeruli was 314.5±1.1 µm, showing a 1.22-fold enlargement. This enlargement is explained by damage to the glomeruli during chemotherapeutic treatment for gestational pyelonephritis and by an increase in filtration parameters.

In the third group (i.e., third trimester of pregnancy), the glomerular perimeter measured 293.1±1.21 µm, which is 1.14 times greater than in the control group. This finding indicates a reduced adaptive response in this stage of pregnancy.

The next morphometric indicator is the average area occupied by the glomerular tuft (15000 µm²). In the control group, this area was 10365±5.61 µm², whereas in the first trimester, it increased to 12281±3.25 µm², confirming the results observed in the other morphometric measurements. In terms of the proportion of the glomerulus occupied by the capillary tuft, 69.1% of the area was occupied in the control group, compared to 82% in the first group. This indicates pronounced vascular dilation and elevated filtration capacity, as well as ongoing vascular damage occurring in parallel. These findings collectively support the notion that renal insufficiency may develop following any course of chemotherapeutic treatment

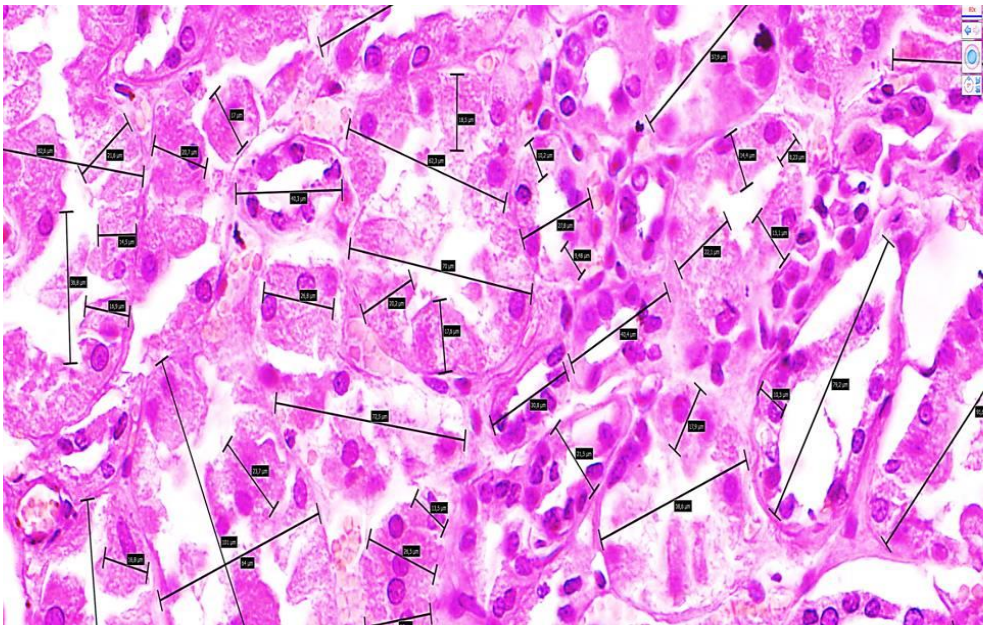

Figure 4. Morphogram showing the perimeter, external diameter, and internal (luminal) diameter of the proximal and distal renal tubules. Scanned using NanoZoomer. Staining: H&E. Size: 20×10.

In the second group (i.e., second trimester of pregnancy), the area occupied by the glomerular tuft was 10,995±8.3 µm², comprising 73.3% of the total glomerular area (15,000 µm²). Compared to the control group, this represents a 4.2% increase, although statistically of low significance.

In the third group (third trimester), the tuft area measured 10,725±2.92 µm², accounting for 71.5% of the total, which is very close to the control group and statistically not significant, indicating that vascular reactivity in the glomeruli during this period does not differ substantially from the baseline.

The next stage of examination focused on the Shumlyansky–Bowman's space, which is critical for evaluating the morphofunctional characteristics of the glomeruli. In the control group, the average width of this space was 18.31±1.01 µm, while in the first trimester group, it decreased to 15.21±1.01 µm, indicating a narrowing of Bowman's space. This is interpreted as a result of the marked enlargement of the capillary tuft and vascular hyperemia, reducing the available space. This reflects a 1.2-fold decrease.

In the second trimester, the Bowman's space measured 17.42±0.97 µm, showing a 10.5% reduction compared to the control group, which was considered statistically less significant.

In the third trimester, the measurement was 18.21±1.01 µm, with no meaningful difference from the control group. This suggests that the structure and function of the glomerular tuft and Bowman's space remained largely intact.

Subsequent morphometric analysis involved measurements of renal tubules in various projections, comparing them to the control group.

For the proximal tubules, the average diameter in the control group was 121.12±5.01 µm, while in the first trimester, it expanded to 162.11±8.16 µm, showing a 1.2-fold increase. This can be attributed to increased filtration activity, enhanced reabsorption, and the development of dystrophic changes in tubular epithelium, leading to cellular swelling and tubular dilation.

In the second trimester, the proximal tubule diameter reached 152.5±7.13 µm, 1.15 times larger than the control group. This reflects ongoing epithelial damage, with histological evidence (at 200× magnification) of dystrophic changes, including hyaline droplet degeneration and hydropic degeneration. Notable findings included epithelial detachment, cellular desquamation, and karyolysis-like foci.

In the third trimester, the proximal tubule diameter was 135.31±5.21 µm, 1.12 times larger than in the control group, and was considered statistically significant. This enlargement is attributed to various degrees of epithelial swelling.

The inner diameter of the proximal tubules in the control group was 43.01±0.01 µm. In the first trimester, this reduced to 36.2±1.01 µm, a 1.2-fold decrease, primarily due to enlargement of epithelial cells. In the second trimester, the diameter was 37.1±1.01 µm, indicating a 1.15-fold reduction, with less pronounced changes with age.

In the third trimester, the inner diameter was 39.2±1.01 µm, showing a 1.1-fold decrease compared to the control group, but this difference was not statistically significant.

Regarding the distal tubule diameter, it measured 61.12±1.4 µm in the control group, while in the first trimester, it reached 84.36±12.50 µm. This increase reflects tubular enlargement and corresponds with the presence of dystrophic and necrobiotic changes in the epithelium.

In the second trimester, the distal tubule diameter was 78.14±1.6 µm, 1.3 times larger than in the control group. In older individuals (ages 60–74), this measurement averaged 68.11±1.3 µm, which is 1.11 times larger than controls, although the difference was statistically insignificant. These findings indicate that age-related reductions in adaptive capacity contribute to a lesser degree of change in the distal tubules

CONCLUSIONS

Multiplex morphometric studies revealed that age-related renal damage indicators were significantly elevated in all study groups compared to the control group. In the first trimester of pregnancy, morphofunctional parameters were markedly elevated, with more pronounced damage observed. On average, the size of all renal components increased by up to 1.35 times relative to the control group, reflecting vascular dilation and overall morphological dominance of injury features, making this the most affected group.

In the second trimester, these parameters were, on average, up to 1.2 times higher than in the control group. This was explained by weaker rapid morphological adaptation mechanisms and a decline in vascular component responsiveness due to age-related changes. In this group, renal damage indicators showed 10–15% variability compared to the control group, confirming moderate but notable pathological differences.

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