ADAPTATION PROCESSES IN A SINGLE KIDNEY AT THE ORGANIC, TISSUE, CELLULAR AND SUBCELLULAR LEVELS

RESEARCH GROUP:

Pivtorak Volodymyr
MD, PhD, DSc, Professor, Head of the Department of Clinical Anatomy and Operative Surgery,
National M. I. Pirogov Memorial Medical University, Vinnytsia, Ukraine

Monastyrskiy Volodymyr
MD, PhD, DSc, Associate Professor, Department Surgery Faculty of Postgraduate Education
National M. I. Pirogov Memorial Medical University, Vinnytsia, Ukraine

Pivtorak Kateryna
MD, PhD, DSc, Associate Professor, Department of Clinical Pharmacy and Clinical Pharmacology
National M. I. Pirogov Memorial Medical University, Vinnytsia, Ukraine

Bulko Mykola
MD, PhD, Associate Professor, Department of Clinical Anatomy and Operative Surgery
National M. I. Pirogov Memorial Medical University, Vinnytsia, Ukraine

Summary. Adaptive processes in a single kidney after nephrectomy are manifested in the early stages of compensatory hypertrophy of the remaining kidney. Changes in kidney size (length, width, thickness) were determined. The results of studies have shown that the width of the kidney, not length, is a predictor of renal failure. Renal volume has been shown to be the optimal parameter for predicting renal function. Microscopic and submicroscopic changes of structural components of nephrons at different times after nephrectomy are described.

Keywords: single kidney, adaptive-compensatory changes, compensatory hypertrophy, structured illumination microscopy, electron microscopy.

It has been established [1] that many factors affect renal function after nephrectomy or resection of the kidney. There are preoperative factors such as hypertension, diabetes, urolithiasis, obesity, metabolic syndrome, etc.; intrasurgical factors (surgical technique, surgeon’s experience, duration of operation, etc.); and post-surgical factors (control of existing diseases, change of lifestyle, diet, etc.).
A number of studies have shown that body weight and body mass index are independent predictors of chronic kidney disease after nephrectomy [2, 3]. It was found that the greater the mass of the kidney, the greater the predictability of survival after nephrectomy in the elderly [4]. Normal renal aging is characterized by progressive nephrosclerosis with loss of glomerular function and decreased overall renal function, as determined by glomerular filtration rate (GFR). To some extent, the decrease in the volume of the renal cortex from nephrosclerosis is compensated by nephron hypertrophy. However, when patients are older than 50 years, this compensation becomes less adequate, and the total kidney volume begins to decrease [5]. In healthy adults under the age of 65, the volume of the renal parenchyma is determined by body size and sex and is closely related to GFR. This indicates that the volume of the renal parenchyma varies depending on metabolism and is closely related to renal function [6].

According to researchers, after nephrectomy, the renal function of the contralateral kidney is reduced in patients regardless of the choice of access (open, laparoscopic) [7] and depends on the extent of loss of the renal parenchyma [8]. Compensatory hypertrophy and increased filtration at the level of the individual nephron leads to normalization of GFR. However, over time, these same compensatory mechanisms may contribute to kidney damage and hypertension [9].

Kidney volume is considered to be the most accurate measure of kidney size. Recent studies have shown that renal volume is the optimal parameter for predicting renal function [10, 11]. Changing the size of the kidneys from one examination to another can be an important indicator of the presence or progression of the disease. An increase in kidney volume was observed to a greater extent after nephrectomy than after kidney resection [12].

According to the scientific literature, kidney length directly correlates with creatinine clearance [13], and kidney width better reflects the influence of environmental factors than kidney length. Research shows that kidney width, not length, is a predictor of renal failure [14]. According to the literature, there is a dependence of renal function on its size [15].

Using computed tomography, we found that in patients with a single kidney after nephrectomy, kidney size and kidney volume were statistically significantly larger than in patients without kidney disease [16].

One of the hypotheses of early preclinical mechanisms of single kidney pathology in the postoperative period is systemic distress syndrome, which leads to a "vicious circle", which significantly reduces the functional reserve of renal tissue [17].

Histological studies showed that on the 7th day after the experimental nephrectomy in the kidneys of young and mature animals on the background of vascular reorganization there are changes in all components of the nephrons. In the cortical substance, most renal corpuscles are hypertrophied, they have a blood supply to the hemocapillaries of the vascular glomeruli. The lumens of the capsules are also enlarged, compared with the renal corpuscles of animals of the intact group [18].

Microscopically, changes in the proximal and distal tortuous tubules of the nephrons in the kidneys of young and mature animals are detected. The lumens of
tortuous tubules and collecting tubules increase in comparison with the kidneys of intact animals. There is swelling and enlightenment of the apical areas of epitheliocytes, especially the distal nephrons. Expansion of lumens and blood supply of hemocapillaries of a peritubular grid is noted.

Microscopically, hypertrophied renal corpuscles are observed on semi-thin sections of the cortical substance of the kidneys of young and mature animals on the 7th day after nephrectomy. In their vascular glomeruli, some blood capillaries have wide lumens, which are filled with blood, there are shaped elements of blood, mainly erythrocytes [19].

Electron microscopic examination of the nephrons of the kidneys of young animals in these terms of the experiment after nephrectomy found that the epitheliocytes of the proximal and distal tubules have rounded nuclei with clear contours of the cariolema and well-defined nuclear pores. Some nuclei have large nucleoli. In the cytoplasm of epitheliocytes, more often in the basal areas, there are hypertrophied mitochondria whose cristae are partially reduced. The basement membrane is clear, the folds of the plasmolemma are well defined. Protein inclusions are found in the epitheliocytes of the proximal tubules, they are osmophilic and different in size. On the apical surface of such cells microvilli are densely arranged, elongated, but in some areas there is fragmentation and destruction [20].

Microscopic and submicroscopic data of the structure of a single kidney correspond to the data of other researchers [21]. Recently, the state of stress of the endoplasmic reticulum as a general link in the pathogenesis of many human diseases is increasingly discussed. This regulatory mechanism allows the cell to adapt to metabolic changes in the environment. The involvement of endoplasmic reticulum stress in the development of renal pathology is indicated by the high degree of apoptosis found in this organ. Apoptosis in the kidney disrupts all parts of the nephron, including glomerular podocytes, mesangial cells, and tubular epithelium. The role of endoplasmic reticulum stress was first identified in the maintenance of proteostasis. It has been shown that endoplasmic reticulum stress is also crucial for the regulation of lipid homeostasis, membrane metabolism and autophagy [22]. Stress of the endoplasmic reticulum initiates the internal signaling network, the deployed protein response, one of the components of a multiple and complex system of cellular signaling processes, which leads to serious changes in the profiles of transcription factors. In male rats, modeling the development of urolithiasis showed a possible effect of these changes on the formation of nephrolithiasis. At the same time, the vacuolation of tubular epitheliocytes visible under light-optical observation was observed, which was detected electronically and microscopically by the expansion of the granular endoplasmic reticulum tanks and the formation of vacuoles of different sizes. Their content was electron-light flaky, on the surface of the membranes were determined by unevenly spaced ribosomes. There were moderate changes in mitochondria in the form of edema, violation of the integrity of the inner membrane and the correct location of the cristae. The cytoplasm of the cells and some enlarged mitochondria contained small electron-dense calcium deposits. The endoplasmic reticulum of such cells has been significantly expanded. It has been shown that the accumulation of dysfunctional mitochondria after nephrectomy can cause pathological changes in the pathways of
biosynthesis, energy production and activation of regulatory pathways of apoptosis, thereby contributing to the development of chronic kidney disease [23]. Recent studies [24] have shown that after nephrectomy of the right kidney under general anesthesia, male Wistar rats protect kidney cells through the mechanism of microRNAs that regulate phosphorylation of protein kinase B, and it directly promotes cell protection.

Changes in the topographic and anatomical position of a single kidney are quite common. Thus, according to the literature, ultrasound observation revealed deviations from the normal position of the single kidney in the sagittal plane in 43% of patients. Urologists find numerous rotations of a single kidney and its nephrophtosis [25]. To systematize and identify patterns of changes in the position of the kidney, after removal of the contralateral, we set the task of mathematical modeling to determine possible deviations of the position of the kidney with increasing mass, which is observed due to its hypertrophy [26]. It is proved that with increasing kidney mass, provided that the width, length and thickness of the kidney increases proportionally, the movement of the kidney is due to its rotation in the plane of material symmetry clockwise.

Conclusion.

Adaptation processes in a single kidney after nephrectomy are manifested at the organ, tissue, cellular and subcellular levels. An increase in kidney mass and volume, growth of structural components of the nephron (most intense in the immediate postoperative period). Vascular glomeruli of the renal corpuscles are characterized by dilated, blood-filled lumens of hemocapillaries.

References:


