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Possibilities of Ultrasound Diagnostics of Urolithiasis

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Relevance. Urolithiasis (UCD) is one of the most common urological diseases and ranks second in the world after inflammatory nonspecific diseases of the kidneys and urinary tract. Its share among all urological diseases is about 40%. In 70% of patients, ICD is diagnosed at the age of 30–60 years, and there is a predominance of males. The increase in morbidity, the severity of complications, the tendency to relapse, and the predominant affection of young and most able-bodied people make the diagnosis and treatment of nephrolithiasis one of the most important problems of urology. Urolithiasis is a metabolic disease caused by various exogenous and/or endogenous factors, often has a hereditary nature and is determined by the presence of a calculus in the urinary system.

Purpose of the study. The causes and mechanism of stone formation remain open in urology. Study of morphofunctional changes kidney with ultrasound.

Materials and methods of research. There is still no definitive theory for the development of urolithiasis. The main theories of lithogenesis come down to the leading role of such factors as an increase in the level of lithogenic ions, a deficiency of inhibitors of crystallization and crystal aggregation, the presence of stone formation activators in the urine, and local changes in the kidneys.

Research results. Mortality in urolithiasis has decreased significantly over the past decades due to the widespread introduction of modern treatment methods into clinical practice: extracorporeal lithotripsy (ESWL), contact lithotripsy (CLT), and puncture nephrolitholapaxy. However, ESWL is always accompanied by kidney injury. In severe cases, the formation of intraparenchymal, subcapsular or perinephric hematomas is possible, leading to sclerosis of the renal tissue and decreased renal function [1]. The main symptoms of urolithiasis are pain, hematuria, dysuria and stone passage. One of the manifestations of urolithiasis is renal colic, which is caused by occlusion of the ureter, resulting in increased intracavitary pressure, impaired intrarenal blood flow with pronounced edema of the renal parenchyma. In the first four hours after the onset of obstruction, an increase in renal blood flow is observed as a result of preglomerular vasodilation of the renal vessels. After four hours, blood flow decreases and pressure in the ureter increases due to postglomerular vasoconstriction. Increased pressure in the ureter activates the renin-angiotensin system and increases the level of vasoconstrictors, which is manifested by a decrease in renal blood flow and pressure in the urinary tract due to narrowing of the afferent arterioles [6]. Timely and accurate diagnosis of urolithiasis allows one to avoid complications of the disease. Radiation diagnostic methods: ultrasound, x-ray, radionuclide, magnetic resonance imaging.

At present, when extracorporeal lithotripsy, contact lithotripsy, and nephrolitholapaxy are widely used in urological practice, the question of developing a diagnostic algorithm that allows choosing the optimal method for stone removal remains open. Ultrasound diagnostics using B-mode plays a vital role in identifying a calculus, determining its location, size and complications that have developed. The use of color and power Doppler makes it possible to assess uro- and hemodynamic disturbances. An important advantage of the method is its non-invasiveness, the absence of radiation exposure and the development of allergic reactions. The use of ultrasound makes it indispensable for studying the dynamics of the early and late postoperative period. The use of B-mode ultrasound allows one to evaluate both direct and indirect signs of renal obstruction. An assessment of indirect signs showed that the degree of expansion in ureterectasia was directly dependent on the duration of the presence of the stone and the concomitant inflammatory process. Difficulties in diagnosing ultrasound signs of obstruction arise when examining obese patients and when conducting research after relieving an attack of renal colic [8]. A direct ultrasound sign of nephro- and ureterolithiasis is an echo-positive structure in the renal cavity system and/or in the lumen of the ureter with an acoustic shadow. In the studies of Yu.Yu. Migushova, the appearance of an acoustic shadow depended on the size of the stone. Thus, the acoustic shadow was reliably detected with stone sizes of 4 mm and larger. At smaller sizes, the acoustic shadow, as a rule, was not detected. To visualize it, clarifying ultrasound with an intracorporeal sensor was used, and in the presence of a stone, an acoustic shadow was usually detected, which made it possible to carry out a differential diagnosis between a stone, strictures and other pathology. The diagnostic capabilities of ultrasound for lower ureteral stones turned out to be the highest [8]. Ultrasonography can be considered an informative method in the assessment of renal colic. In some cases, with a "mute" kidney, it becomes the only acceptable way to interpret the situation. If obstruction of the upper urinary tract is suspected, it should become the primary diagnostic technique in the clinical program, and its data can justify the entire complex of further examination and determination of treatment tactics [9]. Improvements in ultrasound technology, as well as the use of ultrasound contrast agents (Levovist, Sonovista, etc.) make it possible to trace the branching of the renal artery down to the subcapsular sections. With the help of intravenously administered echo contrast agents, it is possible to study the true perfusion of the organ and identify areas of ischemia or destruction at the earliest manifestations. Analysis of the spectral Doppler curve is carried out taking into account qualitative and quantitative indicators, which in turn are divided into angle-dependent and angle-independent. There is a redistribution of blood from the cortex to the medulla. Arteriovenous shunts develop, and subsequently the death of the renal glomeruli occurs. As a result of intracavitary hypertension, edema of the renal parenchyma develops, and venous outflow from the kidney becomes difficult. This situation has been little studied in the literature, and it seems advisable to conduct a special study of this problem.

According to some authors, the most valuable data comes from a comparative assessment of blood flow in the affected and healthy kidney [2-3]. In the work of E.V. Olshanskaya revealed a statistically significant increase in the resistance index on the colic side and a difference in resistance indexes of more than 0.05 between the kidneys, and also, according to radiothermometry, the difference in temperature indicators of the kidneys was more than 0.3º C [4]. When performing ultrasound Dopplerography of the venous bed of the kidney, it is necessary to take into account the features of venous hemodynamics. Veins are characterized by inconstancy of pressure and blood flow in them, which depends on the suction action of the chest cavity, the "muscle pump" and the locking function of the venous valves. Being thin-walled, they are relatively easily compressed in pathological conditions associated with pressure on their wall from the outside. Blood enters the veins at a pressure of 8–12 mmHg. Art., which is 10–20% of the pressure in the aorta. The pressure and speed of blood flow in the central veins are influenced by cardiac contractions, namely, the difficulty of venous outflow into the right atrium during its contraction [12]. Due to the proximity of the venous and arterial vessels in the veins, transmitted arterial pulsation can be recorded. The pressure and speed of blood flow in large veins are associated with the respiratory cycle. In most veins, blood flow decreases during inhalation and increases during exhalation. In connection with the above, fluctuations in blood flow velocity recorded in the veins have a different semantic meaning than in the arteries. For this reason, the determination of indices characterizing velocity fluctuations synchronous with the cardiac cycle is not informative and is not carried out. Therefore, the number of indicators for characterizing venous blood flow is limited [12]. The complete absence of phasicity of the Doppler curve corresponding to the phases of systole and diastole, as well as the lack of synchronization with breathing are signs of pathology - impaired venous patency, elasticity of the vascular wall, etc.

When studying pathological conditions in organs associated with impaired blood outflow, we consider it advisable to introduce indices that link Doppler characteristics of arterial and venous blood flow and reflect primarily venous stasis in the organ [12].

When analyzing the effect of congenital changes in the renal veins on the likelihood of developing urolithiasis, the indicators were not statistically significant due to the rarity of these anomalies [5]. To assess parenchymal blood flow during hydronephrotic transformation of varying degrees, pharmacodopplerography was performed. The use of pharmacoechography in the immediate postoperative period as a control study makes it possible to timely identify disturbances in the urodynamics of the upper urinary tract and determine the necessary method of drug or instrumental correction, which is the prevention of the development of complications [8].

The inflammatory process accompanying these factors in varying degrees of activity also affects the state of blood flow.

The urodynamics of the upper urinary tract (UTT) is impaired in urolithiasis. To diagnose urinary passage disorders, a subtle understanding of urodynamic processes is necessary. However, to date there is no consensus on the regulation of the physiological activity of the upper urinary tract and, in this regard, several different theories remain relevant.

Thus, the functioning of the upper urinary tract appears to be a complex multi-level process. Severe hydronephrosis and ureteral strictures are risk factors that contribute to a complicated course after DLT.

With ultrasound scanning, the kidneys have a bean-shaped shape, an intense echo signal from the capsule, surrounded by echo-negative perinephric tissue. The renal parenchyma is isoechoic. The pyramids, forming the medulla of the kidneys, have less echogenicity than the cortex. The thickness of the kidney parenchyma is on average 12–18 mm. The central complex corresponds to the renal sinus, is represented by the renal collecting system, blood and lymphatic vessels, nerves, adipose and fibrous tissue and looks like a hyperechoic zone due to the presence of fatty tissue. The pyelocaliceal system in healthy individuals is practically not visualized [3]. The use of B-mode during an ultrasound examination allows one to evaluate both direct and indirect signs of renal obstruction. A direct ultrasound sign of nephro- and ureterolithiasis is an echo-positive structure in the renal cavity system and/or in the lumen of the ureter with an acoustic shadow. Thus, the acoustic shadow was reliably detected when the stone size was 4 mm or more. At smaller sizes, the acoustic shadow, as a rule, was not detected. To visualize it, clarifying ultrasound with an intracorporeal sensor was used. As a rule, in the presence of a stone, an acoustic shadow was detected, which made it possible to make a differential diagnosis between the stone, strictures and other pathology. In the presence of obstructive syndrome, expansion of the renal cavity system and reduced echogenicity of the renal parenchyma due to edema and venous stasis are also detected. Perinephric tissue may also be edematous. The kidneys are highly perfused organs. About 1200 ml of blood passes through the renal vessels per minute. The kidneys are fed by the right and left renal arteries, which arise from the abdominal aorta at the level of the L1-L3 vertebrae. The left renal artery arises just below the right. The main trunk of the renal artery divides into a thick anterior and thinner posterior branches located within the renal sinus. Segmental branches originate from the main branches, which enter the renal parenchyma and pass between the pyramids of the kidney. There are two ventral, one dorsal and two polar segmental arteries, but their structure is variable. The arteries entering the kidney parenchyma are called interlobar. At the base of the pyramids, the interlobar arteries are divided into arcuate ones that do not anastomose with each other. Interlobular arteries, and then intralobular ones, extend to the renal cortex. The afferent arteries of the glomeruli begin from the intralobular arteries, and a capillary network is formed, which accounts for 86% of the vascular merchandis, and the medullary substance accounts for 14%. The outflow from the kidney begins with cortical veins, which gather into interlobular, then into arcuate veins. Straight venules of the medullary substance flow into the arcuate veins, through which outflow occurs from the tubular structures of the kidney pyramids. At the level of the base of each papilla, the arcuate veins are connected with the wide fornicale veins, which surround the minor calyces. The fornic veins of adjacent calyces are connected to each other, as well as to the arcuate and interlobular veins. The arcuate veins unite and form interlobar veins, which pass into the interstitium between the pyramids of the kidney and then merge into segmental vessels. The superior, middle and inferior segmental branches merge to form the main trunk of the renal artery. The right renal vein is 1.5–2.5 cm long and joins the inferior vena cava at the level of L1-L2. The left renal vein is 6–8 cm long and the angle of its entry into the lower hemivenous is more acute. The hemodynamics of the kidney depends on the state of the shunts, which are located at the level of the glomeruli, in the columns of Bertini, the pyramids of the kidney, and in the renal sinus [1].

Using this method, it is possible to obtain qualitative and quantitative differences in ureteral emission curves in healthy individuals depending on the level of diuresis and the degree of bladder filling. The method non-invasively allows you to determine separate diuresis of each kidney [13]. Registration of ureteral emissions can be carried out using both external and transvaginal or transrectal sensors [13]. According to a number of authors [13, 25], only the speed and frequency of the discharge are informative for diagnosing urodynamic disorders. Considering the role of individual factors in compensating for urodynamic disorders, it should be noted that the pressure in the renal pelvis when the obstructive factor is localized in the upper third of the ureter increases in proportion to the degree of obstruction and in accordance with its compensation by intrarenal mechanisms. Such mechanisms are pelvicalyceal reabsorption, pyelorenal, pyelovenous, pyelolymphatic refluxes. Compensation for increased pressure can also occur as a result of dilatation of the collecting system and ureter [28].

Thus, according to a number of authors, in patients with a stone in the ureter, the maximum number of emissions did not exceed 3 per minute (normally 4–7), the absence of emissions or their significant asymmetry relative to the opposite side is highly likely to indicate obstruction of the upper urinary tract. The flow spectrum in the presence of a stone in the ureter differs significantly from the normal flow spectrum: the curve is devoid of characteristic peaks and is represented by a monophasic low-amplitude curve with low flow acceleration, the so-called “venous spectrum”.

CONCLUSIONS. Thus, the algorithm for studying the urodynamics of UMP should begin with ultrasound in parallel with Doppler ultrasound. A comprehensive ultrasound examination of patients with obstructive uropathy, taking into account the conditions of hemo- and urodynamics, allows not only to establish the presence of obstruction and its nature (complete or incomplete), but also to assess the functional state of the kidney and upper urinary tract, which is necessary to select adequate treatment tactics. Scanning must be carried out polypositionally, which allows you to get a complete picture of all parts of the kidneys and upper urinary tract.

Thus, the presence of a hyperechoic structure in the renal cavity system of more than 0.4 cm with an acoustic shadow behind it indicates the presence of a calculus. Expansion of the renal cavity system and the absence of emissions or their significant asymmetry relative to the opposite side indicates obstruction of the upper urinary tract. Changes in renal blood flow in patients with urolithiasis depend on the nature of the urodynamic disturbance, the location and size of the stone, the duration of the disease, the presence of complications, and the age of the patient. The inflammatory process accompanying the above factors in varying degrees of activity also affects the state of blood flow. Assessment of Doppler indicators of renal blood flow and ureteral emissions together increases the information content of the method.

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