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Review Article

Urolithiasis in Children: Etiopathogenesis of Kidney Stone Disease and Extracorporeal Shockwave Lithotripsy

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Abstract

The fact that urolithiasis becomes more common among infants is frustrating [1]. Bilateral process is observed in 15-30% of patients according to the literature. Kidney stone disease (KSD, also known as urolithiasis) is a pretty tricky disease, apart from its high incidence it has a tendency to recurrence. Such patients usually have severe course of disease, development of serious complications, that in turn can lead to chronic renal failure (CRF).

Nowadays laparoscopy and retroperitoneoscopy are rarely used for removal of calculi from kidneys and ureters. Such combined methods as percutaneous lithocenosis with ureterorenoscopy (endoscopic combined intrarenal surgery (ECIRS)) are used more often. This procedure involves less postoperative complications, reduces hospital stay and recovery time, improves cosmetic results and would not disgrace the traditional surgery in functional results, if compared with open surgery methods for calculi extraction [2]. The number of open surgeries has significantly reduced, it can be used as the last method when all other minimally invasive procedures have no positive effect.

Both transurethral and percutaneous endoscopic lithotripsy should not be opposed to extracorporeal shockwave lithotripsy (ESWL) because these methods complement each other in 18-27% of cases. Whereas endoscopic surgeries allow not only to remove the calculus, but also to eliminate simultaneously the cause of lithogenesis (internal urethrotomy, ureterocele dissection, ligature removal, etc.) [3].

The extracorporeal lithotripsy is currently the least invasive method of calculus removal. Such factors as calculus density and composition would be important in choosing the treatment method.

Keywords: Kidney Stone Disease; Chronic Renal Failure; Extracorporeal Shockwave Lithotripsy; Etiopathogenetic Principles; Calculus Removal

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Abbreviations

ASQ: Acoustic Structure Quantification; DECT: Dual-energy Computed Tomography; ECIRS: Endoscopic Combined Intrarenal Surgery; EOIC: Electron-Optical Image Converter; ESWL: Extracorporeal Shockwave Lithotripsy; GIT: Gastro-intestinal Tract; GSI: Gemstone Spectral Imaging; HU: Hounsfield Units; KSD: Kidney Stone Disease; MHC: Major Histocompatibility Complex; MSCT: Multispiral Computed Tomography; PCNL: Percutaneous Nepholitholapaxy; URS: Ureterorenoscopy

Introduction

Kidney stone disease (KSD) is well known nosology. Urinary calculi maintained and were already found in embalmed and buried nearly 7000 years ago bodies. It is generally known that Hippocrates, who lived in 400 years BC, was the first person described renal colic and suggested to manage it with thermal procedures. He has also recommended renal water loads for such patients. It should be noted that this recommendation is still relevant [4]. Roman surgeon and philosopher Galen thought that the process of calculus formation is inseparably associated with the climate, diet, race, alcohol intake, and water composition. It is generally recognized that the most crucial factor for the KSD development is salt excess in the body.

The first successful extracorporeal shockwave lithotripsy (ESWL) was performed in the urological clinic of Ludwig-Maximilian University, Munich, in 1980.

The advantages of ESWL are: low organ (first of all, renal parenchyma) traumatization, efficient calculus destruction (even for big staghorn), relatively short duration of lithotripsy session, low percentage of complications, and possible outpatient management in older children [5].

If you prioritise this method, you should understand that there are several predictors of success for favorable outcomes, such as: size, density, localization and composition of the calculus, distance from the body surface to the calculus, and lithotriptor type. The understanding of calculus composition and density before choosing the treatment method will greatly facilitate your work and allow you to choose correct tactics that can affect the KSD treatment outcomes. Therefore, such indices as calculus density and composition are also crucial while choosing the ESWL method [6].

Theory

Etiopathogenetic principles of kidney stone disease

Currently there is no single cause of kidney stone disease. This disease is polyetiological, thus, it is possible to identify several possible major causes of its development: genetic disposition, urodynamic infringement, congenital enzymopathies, geographical location (endemic zones) [7]. Despite all above-mentioned factors, the leading theory of calculi development is urinary supersaturation with lithogenic ions. This theory is over a century old, but it is still relevant. There is another widespread so-called theory of struvite calculus development due to microbial products in the urinary tract. We would like to emphasize that it is relating foremost to *Proteus mirabilis* and *Proteus rettgeri*. Contamination by *Proteus* spp bacteria causes urea degradation driven by urease, this leads to ammonia release and to changes in urine pH (urinary alkalinizing). Water composition, nutritional quality and characteristics of consumed products also play its roles in calculi development in the urinary tract, for sure. Lithogenesis is more often caused by only one factor, rarely by several factors but only in case of pathogenic conditions.

All calculi developed in the urinary tract have its own characteristics: size, radiopacity, chemical composition. This data along with information on the calculi location and the pelvicalyceal system and ureters sizes are necessary for the specialist to determine the tactics of further treatment, as well as appropriate metaphylaxis in order to prevent recurrence [8].

It is known that urolithiasis can be secondary, usually due to urodynamic infringements. Also, urolithiasis is almost inevitable when the child has any abnormalities in kidneys shape and localization.

Urodynamic infringement will increase the urinary salts concentration and slow down the evacuation of pathogenic bacteria, all together it can lead to development of KSD of phosphate nature. Secondary urinary tract infection will only aggravate the disease course since it can facilitate calculus rapid growth and not just that. Some authors point out certain difficulties in the management of calcium oxalate monohydrate calculus with high concentrations of Zn, Mg, and Mn [9].

Nowadays, science know many syndromes and pathological conditions accompanied with the urinary tract calculi, such as:

leukemia, congenital or acquired nephropathy, gout, primary hyperparathyroidism, Lesch-Nyhan syndrome (hyperuricemia), de Toni-Debre-Fanconi syndrome, etc.

There is also a correlation between lithogenic processes and age. This is due to the childhood features and the development of general pathological processes: regulating mechanisms instability (particularly nervous and endocrine), immature immune tissue, metabolic processes lability, etc.

Endogenic factors of KSD are pathological conditions of digestive system organs when absorption of lithogenic substances in the gastro-intestinal tract (GIT) can increase. 1,25-dihydrocholecalciferol regulates calcium and phosphorus absorption in the intestine. Kidneys start to produce it in case of calcium loss and hypophosphatemia. We should also pay attention to the prostaglandins, that are produced in renal medulla and renal cortex, and their role in calcium and sodium circulation and excretion.

Another major lithogenic factor is urine pH that determines sedimentation of urinary salts and proteolytic enzymes activity. Effective upkeep of blood acid-base balance depends on daily range of urine pH, that is the indicator of kidneys functioning on acid and alkaline radicals' production in the body. It should be emphasized that urine pH increase is directly associated with urea hydrolysis by bacterial enzyme urease, since it triggers the bicarbonate, carbonate and ammonium formation. Proteins that change urine pH are oncotically active substances and chemical reactions catalysts. Carbonic anhydrase deficiency in nephron epithelial cells leads to decrease in hydrogen ion secretion. Sedentary lifestyle is also accompanied by different amount of calcium urinary excretion [10].

Nowadays, the issue of urolithiasis genetic inheritance is increasingly drawing researchers' attention. Familial history of urolithiasis was revealed in 2-12.5% cases, according to the literature.

It has been proven that the dietary factor is also significant in the urolithiasis development. It became the reason for explaining the disease cases in family members with the same nutritional conditions.

Modern immunogeneticists believe that individual sensitivity to different pathogenic factors is defined by the features of the tissues biochemical structure determined by the MHC-system (major histocompatibility complex).

On the other hand, it is known that some pathological conditions can be genetically determined, such as: skeletal system disorders, thyrotoxicosis, calcium and uric acid metabolism disorders. All of them are causing factors of lithogenesis.

A number of physical and chemical processes in the organism affect the lithogenesis mechanism. This mechanism itself has several stages, from urine supersaturation with salts to the enucleation phase. The accumulation of crystals leads to the growth of the calculus itself up to clinically significant sizes if nothing interferes with it or there are no mechanisms of crystal growth inhibiting.

The major metabolic disorders in patients with urolithiasis are the following: hyperuricuria, hyperuricemia, hypercalciuria, hyperoxaluria, hyperphosphaturia and change in urine acidification [11]. Such metabolic disorders are based on both environmental and endogenous causes, though, their interaction may be revealed as well [12]. 25% of patients with urolithiasis have uraturia, typically, it is the result of impaired synthesis of purine nucleotides. For the present, the significant role in the urinary calculi formation is assigned to the hereditary defects of the enzyme system, for example, deficiency or excess of hypoxanthine-guanine phosphoribosyltransferase.

The increased uric acid formation almost always happens due to nucleotide degradation, including cases with pyelonephritis. The inflammatory process activity directly affects uraturia state. It has been proven thus far that animal proteins increase uric acid levels in urine and serum, thereby, showing the correlation between uric acid metabolism and state of lipid and carbohydrate metabolism.

Genetically determined primary hyperoxaluria develops at glycine and glyoxylic acid metabolism disturbances. Ketoglutarate-glyoxylate-carboligase deficiency increases the synthesis of glyoxylate and oxalates. The absence or deficiency of D-glycerate dehydrogenase, in turn, leads to increased release of D-glycerate and oxalates. Several physicochemical mechanisms are involved in lithogenesis, such as: CaOx supersaturation and crystal nucleation, crystal growth and aggregation. Conditions that initiate calcium oxalate supersaturation lead to the risk of calculi formation.

Secondary hyperoxaluria that develops due to small intestine dysfunction is also rather significant. It leads to impaired fatty acids absorption. Fatty acids form compounds with calcium and disrupt intestinal balance of calcium oxalate enhancing its effect. Also, vitamin C can aggravate the hyperoxaluria course as an oxalic acid precursor.

Hyperphosphaturia also plays a certain role in the pathogenesis of KSD. Major part of inorganic phosphate in the glomerular filtrate is reabsorbed in the proximal renal tubules. Hyperexcretion of inorganic phosphate may also occur in patients with phosphate diabetes (anomaly with decreased phosphorus reabsorption in proximal renal tubules).

Climatic, environmental and food exogenous factors (nitrates, hydrocarbonates, sulfates and other compounds from mineral fertilizers and pesticides), that enter the body with water and food, can have either direct or indirect toxic effect on the human body causing metabolic disorders in biological environments [13]. Finally, they can cause nephron dysfunction and, particularly, its tubular apparatus (tubulopathies). Further on it can be accompanied with increased levels of lithogenesis substances in serum and urine.

The increased levels of lithogenesis substances in serum and its further logic hypersecretion with kidneys lead to urine supersaturation. Finally, it leads to salts and microlites crystallization. In return crystals and microlites create conditions for further calculi development.

Nevertheless, there are some other factors that are crucial for urolithiasis development. It is known that there is a range of substances affecting the urine colloidal stability and maintaining salts in dissolved state and countering its crystallization. Such substances as xanthine, sodium chloride, magnesium, hippuric acid, citrates, inorganic pyrophosphate, ions, manganese, cobalt, etc., are classified as substances maintaining urine salts in dissolved state and countering its sedimentation [14]. It should be noted that they can counter crystallization even in low concentrations, whereas in patients with urolithiasis they are present in low concentrations or absent completely.

Early diagnosis of urolithiasis in children

Nowadays, there are no problems with diagnosis at the early stage of the disease. Recent researches in the field of biochemistry, biophysics and physicochemical sciences have significantly improved the diagnosis of urolithiasis at early stages, as well as general understanding of disease etiopathogenesis.

Urolithiasis diagnosis is based on the analysis of typical symptoms, physical examination, and laboratory and radiological data. The importance is not only in the presence of a calculus itself, its size and localization, but also in the predisposing causes of the recurrence. Studies have shown that the formation of calculus of a certain chemical composition depends mostly on the urine acid-base balance.

At suspicion on KSD the most objective diagnosis methods are ultrasound investigation, clinical and laboratory examination of urinary tract and plain abdominal radiography. We can confirm the calculus presence via X-ray in 85% of cases, but we need to keep in mind that there are low-contrast and radiolucent calculi. The calculus radiological contrast depends on its chemical composition. Earlier calculus chemical composition was indirectly estimated according to pH-metry of the first morning portion of urine, though some authors do not count this method as accurate enough. Several years ago, the calculus composition was determined via X-ray phase analysis, and it is the most pressing method even today. Keep in mind that this method can be implemented only after extraction of calculus via any method like ESWL, percutaneous nephrolitholapaxy (PCNL), or major abdominal surgery. However, modern technologies suggest us methods for estimation of the calculus chemical composition even at the preoperative stage. It is crucial for specialists to understand the calculus composition at the preoperative stage. Dual-energy computed tomography (DECT) allows us to estimate the calculus composition during the diagnosis stage [15].

Ultrasound methods are widely used for urological condition diagnosis, KSD included. So-called distal acoustic shadow is typical at ultrasound investigation. The calculus is more echogenic contrasted with the echodense area, so it will allow us to correctly determine its localization and sizes. Calculi can be revealed more conclusively in the enlarged pelvicalyceal system. In earlier years, ultrasound made it possible to determine calculi of clinically significant sizes, while smaller ones were much more difficult to determine. Today, modern ultrasonograph allows you to determine even the smallest calculus fragments, so you can reveal the presence of residual fragments after a ESWL session. Apart from tracking the calculus itself (it can be visualized on all scales), it is possible to get the image of the structures around the calculus and differentiate it from the calcinates. Another advantage of ultrasound is the absence of radiation hazards. In recent years, thanks to the widespread implementation of computed tomography and magnetic resonance imaging methods, the diagnosis of urolithiasis has reached higher quality levels. It allows us to determine even the smallest calculi in all parts of the urinary tract with great probability, regardless of its radiopacity [16].

Calculi classification

- Nowadays, there are many different calculi types according to their chemical composition. The most common calculi are: calcium-containing, urate, struvite and less often cystine.
- All urinary stones can be classified according to the following criteria: location, size, etiology, radiological characteristics, density, and mineralogical composition.
- The calculus can be located in the following anatomical structures of the urinary tract: upper, middle or lower calyx; pelvis; upper, middle or distal parts of the ureter; and bladder.
- The calculus size is indicated in millimeters or cubic centimeters in 1 or 2 dimensions. Based on the above, we can divide calculi into groups of <5 mm, 5-10 mm, 10-20 mm and> 20 mm.
- The genetic factors contributing to calculi development are: cystine (aminoaciduria characterized by impaired tubular reabsorption of dibasic amino acids: cystine, ornithine, arginine, lysin); xanthine (xanthinuria due to hereditary xanthine oxidase deficiency); 2,8-dihydroxyadenine (inherited adenine phosphoribosyltransferase deficiency causing the adenine accumulation oxidized lately to 2,8-dihydroxyadenine).
- The presence of the following substances in the calculus structure indicates its infectious nature: magnesium and ammonium phosphate, apatite, and ammonium urate. Non-infectious calculi are: calcium oxalates, calcium phosphates and uric acid.
- Drug-induced calculi can develop in case of using medications promoting development of urinary calculi. Compounds that can crystallize in urine: amoxicillin/ampicillin, allopurinol/oxypurinol, ciprofloxacin, ceftriaxone, ephedrine, indinavir, sulphonamide, magnesium trisilicate, triamterene.
- Compounds that can affect urine composition: allopurinol, acetazolamide, ascorbic acid, calcium, furosemide, laxatives, aluminum and magnesium hydroxide, methoxyflurane, vitamin D.

Calculi are classified according to X-ray survey of the urinary tract. The Hounsfield scale (HU) is used for classification during multispiral computed tomography (MSCT) [17]. This X-ray attenuation scale is used for visual and quantitative estimation of structures density determined by computed tomography. There is the list of X-ray positive and X-ray negative calculi below.

X-ray positive calculus	Low radiopacity calculus	X-ray negative calculi
Calcium oxalate dihydrate	Magnesium and ammonium phosphate	Uric acid
Calcium oxalate monohydrate	Apatite	Ammonium urate
Calcium phosphate	Cysteine	Xanthine
		2,8-dihydroxyadenine
		Drug-induced calculi

Table 1: Classification on radiopacity depending on the calculus chemical composition.

As you can see from the table 1, X-ray positive calculi are mono- and dihydrate calcium oxalate and calculi consisting of calcium phosphate. Calculi with less radiopacity consist of magnesium and ammonium phosphate, apatite and cystine. X-ray negative calculi consist of uric acid, ammonium urate, 2,8-dihydroxyadenine and drug-induced calculi.

All calculi can also be classified by density. Radiological density is measured in Hounsfield units (HU) and can be divided in 4 groups as shown in table 2.

Regarding the calculus mineralogical composition, we should remember that one of the major aspects of calculi development is metabolic disorders. Accurate calculus analysis regarding the revealed metabolic disorder determines the tactics of further decisions on metaphylaxis. We frequently can see calculi of mixed type,

№	Density indication	Density value	Unit of measure
1	P	Up to 500 U	HU
2	P	501-1000 U	HU
3	P	1001-1500 U	HU
4	P	> 1500 U	HU

Table 2: Calculi classification according to radiological density.

that is a combination of different substances (minerals). The most crucial is to identify the calculus predominant substance.

Table 3 presents the calculus chemical composition and the corresponding mineral.

Chemical composition	Mineral
Calcium hydrogen phosphate	Brushite
Calcium oxalate dihydrate	Weddellite
Uric acid dihydrate	Uricite
Carbonate apatite (phosphate)	Dahllite
Calcium oxalate monohydrate	Whewellite
Magnesium and ammonium phosphate	Struvite
2,8-dihydroxyadenine	-
Xanthine	-
Ammonium urate	-
Cystine	-
Drug-induced calculi	-

Table 3: Calculi mineralogical composition.

Discussion

There are various approaches and methods (surgical and conservative) of patients with urolithiasis management in modern urology. Some authors point up the positive effects of phytotherapy in calcium oxalate urolithiasis. However, every treatment method has its own indications and contraindications [18,19].

Extracorporeal shockwave lithotripsy

Today, the specialists working with urolithiasis have a wide range of great opportunities thanks to modern equipment. Most notably this is extracorporeal shockwave lithotripsy, which was somewhat sidestepped by another method of calculus destruction (contact lithotripsy), although, some authors consider ESWL as a method of monotherapy [20,21]. It should be noted that some foreign authors suggest performing ESWL as early as possible in case if the patient has renal colic [22]. ESWL can be used in infants too [23]. Moreover, this method allows to destroy calculi in almost any section of the upper urinary tract [24].

Earlier it was almost impossible to estimate the calculus density, but now the use of computed tomography and special programs make such assessment real and accurate. The density estimation can be a predictor for ESWL outcomes [25]. One of such programs is dual-energy computed tomography and is called “Gemstone” Gemstone spectral imaging (GSI).

It has become possible, with use of this program (GSI), to perform the analysis of urinary calculi composition already at the preoperative period, thus, we can predict the possible ESWL efficacy.

Ferrandino., *et al*. has used raw data on attenuation value obtained from DECT without converting into HU. The researchers were able to determine calculi groups that differ by chemical composition: brushite, calcium phosphate, calcium oxalate, struvite, cystine and uric acid [26].

Uric acid and calcium oxalate dihydrate calculi can be fragmented easier than calcium oxalate monohydrate calculi, while cystine calculi are the most difficult to destroy via ESWL method.

Generally speaking, calculi from 1 cm to 2 cm in diameter and attenuation value >1000 HU are assumed to have unfavorable outcome of ESWL. Calculi destruction with ESWL was reported in 55% of cases (and lower) for calculi with attenuation value >1000 HU, in 86% of cases at 500-1000 HU, and in 100% of cases at <500 HU. Similar study of 112 patients with 5-20 mm calculi has shown linear association between attenuation value (HU) and number of ESWL sessions required for calculi removal [27]. When we have started using the value of 750 HU as cut-off level, the release from calculi was revealed in 65% of patients with high attenuation values and in 90% of patients with lower attenuation values 3 months after treatment. However, there is no consensus on using CT attenuation value for estimation of calculi fragility [28].

Ng., *et al*. has created a simple scoring system based on tree calculus characteristics obtained from CT: calculus volume <0.2 cm^3, attenuation value <593 HU, distance from the body surface <9.2 cm. The frequency of complete calculi removal in patients who had 0, 1, 2 or 3 of these factors were 18%, 48%, 73% and 100%, respectively ($p < 0.001$). Similarly, Ng., *et al*. has shown that the rate of complete calculi removal after ESWL was 91%, if the CT attenuation value was <900 HU and distance from the body surface <9 cm. Whereas, for calculi with attenuation value >900 HU and a distance from the body surface > 9 cm this rate has decreased up to 41% [29].

If we divide calculi into groups according to the radiological density, it can be mentioned that the ESWL was successful for calculi <900 HU in 94.4% of cases, compared to 57.1% for calculi >900 HU ($p < 0.05$). Most re-ESWL procedures were performed in cases with calculi density over 900 HU. It was revealed that in case of mean calculi density more than 1200-1500 HU the first ESWL session efficacy falls two-fold. The mean number of ESWL sessions for calculi with density up to 1100 HU was 1.0, while for density 1200-1600 HU - 2.2-2.5.

The most efficient ESWL is for removal of calculi with diameter <20 mm [30]. Observations have shown that complete removal of calculi with diameter of up to 10 mm can be achieved on average in 84-92% cases, with diameter of up to 20 mm - 77-81%, and finally with diameter >20 mm - 68-70%. The most optimal for performing ESWL are calculi with diameters from 15 to 20 mm. This is due to the fact that almost all lithotripters have lateral size of "working focal zone" of shock-wave impulse from 12 to 18 mm.

Direct control of calculus destruction during ESWL is one of the most crucial factors. Accurate estimation of destruction degree allows to change lithotripsy regimens, especially the energy magnitude of shock-wave impulses. This, in turn, allows us to shorten the procedure duration and consequently reduce the impact on renal parenchyma [31]. It is essential because shock-wave (during ESWL) not only destroys calculi, but also has certain effects on kidney tissues, on bloodstream, and can adversely impact the hearing [32]. Vascular endothelium lesions can lead to microcirculatory disorders and finally ischemia. The higher is the energy of shock-wave impulses, the more severe may be the outcomes for the renal parenchyma during lithotripsy. Such control of calculus destruction can be implemented via advanced ultrasound diagnostics. Modern ultrasonographs have embedded Acoustic Structure Quantification (ASQ) program [33]. It is now possible due to this new development to estimate calculus disintegration directly during lithotripsy sessions. It is the analogue of computed tomography which cannot be performed during the ESWL session. The method is based on the use of ASQ technique including three types of analysis: histograming of tissue uniformity, color staining of tissue (parametric inference), comparative analysis.

Acoustic Structure Quantification of calculus can be considered as an alternative to computed tomography which cannot be performed during the extracorporeal lithotripsy session. We can use other methods for removing calculi from the urinary tract, in case of negative results of ESWL [34].

The calculus density measured via the Hounsfield scale (HU) during unenhanced CT represents the predictor of ESWL efficacy in children, which is higher in cases with calculus density below 600 HU and 1000 HU. According to the results of two recent studies on the nomograms development, favorable factors for the removal of calculi after ESWL in children are: male sex, early age, small calculus size, single calculus, localization not in the lower pole, and primary treatment [35].

However, children may have some complications after ESWL, but they are generally small and transient. However, children may have some complications after ESWL, but they are generally small and transient. The most common complications are: renal colic, transient hydronephrosis, skin ecchymosis, urinary tract infections, steinstrasse ("stone street") development, sepsis, hemoptysis (rarely).

Percutaneous nephrolitholapaxy

Percutaneous nephrolitholapaxy is contact type lithotripsy, it is performed via puncture access (through skin, muscle tissues, kidney tissues) with a special needle under the control of ultrasound or electron-optical image converter (EOIC) [36,37]. The targeted calculus undergoes different exposures: compressed air, laser or ultrasound [38]. Laser lithotripsy is the most relevant because this type of energy allows to destroy calculi of any radiological density and composition [39,40]. Nephrostomy is applied for several days at the end of the surgery. The early postoperative period usually proceeds smoothly without any serious complications. This method is used as monotherapy mostly, however, it can be used as additional treatment [41]. It has been proven that percutaneous lithotripsy is more effective and successful in removal of the bulk of the staghorn calculus in one session than other treatment types.

Indications for percutaneous lithotripsy are: large renal calculi (>20 mm, and >10-15 mm if the calculus is located in the lower calyx), multiple renal calculi, large calculi of the upper ureter (>10 mm). Percutaneous lithotripsy is also indicated for treatment if extracorporeal lithotripsy is ineffective. Contraindications are: urinary tract infections, intestine interposition (on the way to the calculus), tumor in the area of access to the calculus, potentially malignant kidney tumor, as well as all contraindications to general anesthesia, including coagulation failure.

The most frequent complications of this method in children are: bleeding, febrile fever, postoperative infection, nephrostomy fistula maintaining. The frequency of bleeding requiring blood transfusion is less than 10% and correlates to calculus volume, surgery duration, needle guard size, and number of accesses [35].

Ureterorenoscopy

The aim of endourological surgery is to perform ureterorenoscopy (URS) and complete calculi removal [42-44]. Calculi can be extracted via endoscopic forceps or baskets. Forceps allow you to safely release calculus if it gets stuck in the ureter, but it takes longer to extract it than with baskets. Calculi that cannot be extracted as a single piece must be previously destroyed [45].

Stenting prior to the URS is optional for now. However, stenting facilitates ureteroscopy, increases the rate of complete calculi removal, and reduces complications rate [46]. A stent should be placed in patients with higher risk of complications (such as residual fragments, bleeding, perforation, urinary tract infections), and in all doubtful cases to avoid emergencies.

Transurethral lithotripsy

It is also a method of contact lithotripsy which involves calculus destruction (ultrasound, pneumatically, laser) using endoscopic equipment. The access to calculus is performed transuretrally regardless to its localization [47]. It is easier to use laser with smaller tools considering the smaller size of sensors, so this method is more preferable in children [35].

Lithoextraction methods are used in both cases. Fragments' removal is performed immediately in the process of destruction, we should not wait for their self-evacuation in the early or late postoperative period. Thus, modern endoscopic equipment is required, as well as special medical consumables such as baskets and forceps to remove small calculi and their fragments.

Open surgery

Enhancement of ESWL and endourological surgery (URS and PCNL) led to significant decrease in open surgeries indications. Now they are used as second- or third-line therapy and in complex cases. Intraoperative ultrasound scanning in B-mode and dopplerography makes it possible to determine nonvascular areas in renal parenchyma that are close to calculus or enlarged calyces. This allows to remove large staghorn calculi via multiple small radial nephrotomies without kidney function disturbance. In some cases traditional "open" accesses are inevitable. They are usually used in infants with large stones and/or in case of congenital obstruction of the urinary tract requiring surgical correction [35].

Nowadays laparoscopy and retroperitoneoscopy are rarely used for removal of calculi from kidneys and ureters [48]. Although, these methods involve less postoperative complications, reduces hospital stay and recovery time, improves cosmetic results and would not disgrace the traditional surgery in functional results, if compared with open surgery methods [17].

Conclusion

- Consequently, the less invasive method of calculus removal with high efficiency these days is ESWL.
- The ESWL method should be used only in strict medical indications: calculus density <1500 HU, patient's age from 8 months. The contraindications are: calculus density >1500 HU, patient's age below 8 months, cystine calculus.
- Children with urolithiasis who have undergone ESWL procedure require long-term follow-up with metaphylaxis and prevention of disease recurrence.
- The management of patients with urolithiasis must be carried out according to the physicochemical parameters of the calculus.
- Transurethral, percutaneous endoscopic lithotripsy and combined endoscopic intrarenal surgery should not be opposed to ESWL because these methods complement each other in 18-27% of cases. Whereas endoscopic combined intrarenal surgery allows not only to remove the calculus, but also to eliminate simultaneously the cause of lithogenesis with a minimally invasive method.

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Highlights

- The less invasive method of calculus removal with high efficiency these days is ESWL
- The ESWL method should be used only in strict medical indications: calculus density, patient's age from 8 months, location.
- Children with urolithiasis who have undergone ESWL procedure require long-term follow-up with metaphylaxis and prevention of disease recurrence
- The management of patients with urolithiasis must be carried out according to the physicochemical parameters of the calculus.
- Transurethral, percutaneous endoscopic lithotripsy and combined endoscopic intrarenal surgery should not be opposed to ESWL.

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