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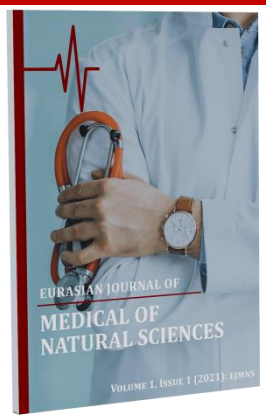

UROLITHIASIS IN CHILDREN

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ABSTRACT

Urolithiasis, the formation of stones in the urinary tract, is increasingly affecting children, with rising cases even in newborns. It commonly affects boys aged 3 to 12, with stones often found in the kidneys and ureters. This multifactorial disease results from metabolic imbalances, environmental factors, infections, and disrupted urinary outflow. Metabolic disorders like hyperuricemia, hyperoxaluria, and hypercalciuria are major contributors, along with external factors such as poor nutrition, vitamin deficiencies, and climate influences. The condition often presents with pain, dysuria, hematuria, and fever. Diagnosis relies on clinical evaluation, ultrasound, and advanced imaging like CT scans, with magnetic resonance urography emerging as a non-invasive alternative. Treatment includes dietary adjustments, hydration, medication, and modern minimally invasive procedures such as extracorporeal shock wave lithotripsy (ESWL) and percutaneous nephrolithotomy. Surgical interventions are reserved for severe cases or when other methods fail. Despite technological advances, recurrence rates remain significant due to unresolved underlying causes. Comprehensive care emphasizes preventive strategies, including tailored metabolic therapies and long-term follow-up. Future research is essential to enhance early diagnosis, understand stone formation mechanisms, and improve outcomes for pediatric patients.

Urolithiasis ranks second only to inflammatory diseases of the kidneys and urinary tract in terms of prevalence. Particularly concerning is the increasing incidence of urolithiasis among children, not only in traditionally endemic regions but also in areas previously considered unaffected. This phenomenon can be attributed to population migration and environmental degradation, which disrupt homeostasis and interfere with complex physicochemical processes in the body. Additional potential causes of this rise in pediatric

cases include elevated mineral content in drinking water, vitamin deficiencies in food, and other factors contributing to metabolic imbalances. Recently, urolithiasis has been increasingly diagnosed even in newborns and infants [1, 11].

Urolithiasis is most commonly observed in children aged 3 to 12 years, with boys being 2-3 times more likely to be affected. In 92% of cases, stones are found in the kidneys and ureters, 7% in the bladder, and only 1% in the urethra. Bilateral stone formation is observed in approximately 20% of children, while in 70% of cases, stones are localized in the renal pelvis [5].

The etiology and pathogenesis of the disease are highly complex, as urolithiasis is a multifactorial condition. Despite significant advances in understanding its pathogenesis, diagnosis is often made only after complications arise – typically when stones are detected through ultrasound or radiographic studies, or when they pass spontaneously.

The process of stone formation may be triggered by one or multiple factors, but usually, certain predisposing conditions are required.

The primary cause of nephrolithiasis is metabolic disturbances, primarily those related to the metabolism of lithogenic substances, as well as substances that either promote or inhibit stone formation [9].

The mechanism of stone formation involves several stages, ranging from the supersaturation of urine with salts to their crystallization and the subsequent growth of stones to clinically significant sizes. This occurs when the body's protective mechanisms against these processes are either absent or insufficiently active.

The most common metabolic disorders associated with urolithiasis include hyperuricemia, hyperoxaluria, hypercalciuria, hyperphosphaturia, and impaired urine acidification processes. Different researchers prioritize either external or internal factors as primary contributors; however, a combination of both is frequently observed. Interestingly, the presence of lithogenic factors does not always lead to the development of the disease.

In recent years, there has been an increasing distinction between general and local factors contributing to stone formation. The most significant factors are considered to be problems with urine outflow caused by incomplete obstruction or alterations in urodynamics resulting from neurogenic disorders [3]. Urine retention promotes the concentration of salts and the accumulation of mucus and bacteria. Infections caused by bacteria of the Proteus genus, particularly Proteus mirabilis and Proteus rettgeri, involve the enzyme urease breaking down urea into ammonia. This leads to urine alkalization, creating conditions favorable for the formation of stones composed of calcium phosphates. Furthermore, bacteria of the Enterobacteriaceae family, whose structure contains polysaccharides, play a dominant role in urinary tract infections.

Exogenous factors, such as climate, ecology, and dietary composition (nitrates, sulfates, and other chemical compounds present in fertilizers and pesticides), can also have a toxic effect on the body and disrupt metabolism. Both internal and external factors contribute to the disruption of colloidal balance: hot climates, poor nutrition, vitamin A and D deficiencies, bone injuries, and endocrine disorders such as hyperparathyroidism [9]. All these factors may lead to dysfunction of the renal tubules (tubulopathies), which are accompanied by an increase in the concentration of lithogenic substances in the blood.

The elevated levels of these substances in the blood result in their supersaturation in urine, promoting the formation of crystals and microliths, which are precursors to stones. However, for the full development of the disease, other conditions are also required. It is well known that certain substances, which maintain the solubility of salts in urine, inhibit their crystallization. These include hippuric acid, xanthine, sodium chloride, citrates, magnesium, and other compounds. In low concentrations, these substances slow down the crystallization process, but in most patients with urolithiasis, they are either deficient or entirely absent [2, 10].

Clinical Presentation. The main symptoms of urolithiasis in children are pain, dysuria, hematuria, pyuria, and the passage of salt crystals or stones in the urine. The intensity and manifestation of these symptoms depend on the child's age: the younger the child, the less specific the symptoms. Pain often does not present as typical renal colic but is perceived as vague abdominal pain without clear localization. In older children, a more specific description of the nature and location of pain, including renal colic, is possible [6, 13]. Dysuria occurs when stones are located in or pass through the ureter, bladder, or urethra. Frequent urination is characteristic of stones in the distal ureter or bladder. Stones in the bladder may also result in an intermittent urinary stream.

Hematuria occurs in children in 25-47% of cases, with renal colic often preceding macroscopic hematuria [8].

Hyperthermia (elevated body temperature) is the body's response to inflammation caused by urolithiasis and is most commonly observed in younger children (78%), compared to 39% in older children.

Arterial hypertension in pediatric nephrolithiasis is rare, but when it does develop, it may indicate chronic kidney failure (CKF) and an unfavorable disease prognosis. In cases of unilateral kidney involvement, hypertension develops due to secondary kidney shrinkage, which may result from renal tissue dysplasia or congenital vascular anomalies. These, in turn, can be complicated by urolithiasis.

Diagnosis of Urolithiasis in Children. The diagnosis is based on medical history, an analysis of clinical symptoms, physical examination findings, and results from laboratory and instrumental studies. It is crucial not only to determine the presence, location, size, and shape of the stones but also to identify the causes of stone formation and factors contributing to recurrence.

The first step in the examination includes *palpation* of the abdomen and lumbar region. In younger children, this step can be challenging due to the child's anxiety and fear, which may interfere with obtaining objective data during palpation.

If urolithiasis is suspected, *ultrasound examination* of the urinary tract is one of the initial diagnostic methods. This is a safe and informative technique that allows the detection of stones throughout the urinary system. The ultrasound diagnosis of kidney stones is based on identifying hyperechoic areas with an acoustic shadow behind them, particularly when there is dilation of the calyceal system [7]. The advantage of ultrasound lies in its applicability even in cases of renal failure, radiolucent stones, or during episodes of renal colic. However, despite the high resolution of modern ultrasound devices, it is still not possible to completely rule out the presence of small stones in the calyceal system.

Radiological methods play a crucial role in diagnosing urolithiasis (urinary stone disease) in children. Plain radiography enables the detection of radiopaque stones, determining their location and characteristics. However, shadows of stones can only be identified on plain radiographs in 85-90% of patients. Occasionally, ureteral stone shadows may be obscured by pelvic bones, complicating diagnosis. Furthermore, some stones may be radiolucent or have low contrast due to their chemical composition. Stones in the lower ureter need to be differentiated from phleboliths, which are characterized by their specific shape with lucencies and areas of calcification within the pelvic organs.

Intravenous urography is used as an indirect method to confirm the presence of a ureteral stone causing obstruction. On a radiograph taken 1-2 minutes after the administration of a contrast agent, increased density of the kidney shadow on the obstructed side can often be observed. This effect is associated with renal papillary spasm during renal colic. Urograms may also reveal a filling defect in the renal pelvis or ureter caused by the presence of a stone. However, performing excretory urography during renal colic or immediately after its resolution is not recommended, as the obstructed kidney during this period does not excrete contrast medium, making visualization of the affected urinary tract impossible. Renal arteriography is rarely used in children and is typically employed for surgical planning in cases of significant renal function impairment [10].

Renal tomography is one of the modern methods for detecting radiolucent stones. Computed tomography (CT) allows the detection of small stones in the anterior and posterior segments of the kidneys, as well as their relationship with larger stones, aiding in the selection of optimal treatment strategies.

Multislice computed tomography (MSCT) with three-dimensional image reconstruction is a more informative diagnostic method compared to traditional radiological techniques (ultrasound, excretory urography). Modern CT methods provide detailed data for prognosis and the selection of the most effective treatment. These methods are distinguished by high objectivity, superior resolution, and the ability to create three-dimensional organ images, enabling virtual endoscopy. The success of urolithiasis treatment is enhanced through the evaluation of prognostic factors such as stone localization, size, and density, as well as the condition of the upper urinary tract.

Radioisotope Diagnostic Methods. To assess the functional condition of the affected kidney in nephrolithiasis, preference is given to dynamic nephroscintigraphy. This method provides an objective basis for developing treatment strategies and plays a crucial role in choosing between organ-preserving and organ-removing surgical procedures. Scanning with radionuclides also aids in detecting parathyroid adenoma, which may be one of the causes of nephrolithiasis.

In recent years, the method of magnetic resonance urography has been actively developed. First introduced into clinical practice in 1990, this technique is based on the ability to capture the magnetic resonance signal from stationary fluid in the urinary tract and convert it into a graphical image. The main advantages of magnetic resonance urography over excretory urography lie in its non-invasiveness and the absence of a need for contrast agents [7].

Therapeutic and Preventive Measures for Urolithiasis in Children. Significant progress has been made in the treatment of children with urolithiasis due to high diagnostic standards and modern physiotherapy methods. The introduction of extracorporeal shock wave lithotripsy and percutaneous nephrolithotomy has substantially changed treatment approaches. It is essential that the treatment of urolithiasis be comprehensive, addressing the root causes early on (etiotropic therapy) as well as the mechanisms contributing to stone formation (pathogenetic therapy). However, the polyetiological nature of urolithiasis complicates identifying the causes, which are often diagnosed late or remain unclear.

The comprehensive therapeutic approach includes dietary management, ensuring adequate hydration, phytotherapy, pharmacological treatments, physiotherapy, balneological procedures, therapeutic physical exercises, and spa-based treatments.

Pharmacotherapy aimed at correcting metabolic disturbances is prescribed based on diagnostic evaluations. Universal medications for treating all forms of urolithiasis include angioprotectors, antiplatelet agents, anti-inflammatory and antibacterial drugs, diuretics, lithokinetic agents, herbal remedies, analgesics, and antispasmodics.

Conservative treatment is indicated for children with stones measuring up to 5 mm, characterized by smooth and rounded shapes, infrequent episodes of renal colic, and the absence of signs of calyceal-pelvic system dilation on ultrasound imaging.

The primary goal of conservative treatment is the prevention of urolithiasis recurrence. Litholytic therapy involves the use of medications selected based on the chemical composition of the stone. The number of treatment courses is determined individually under the supervision of a physician and laboratory testing.

Surgical intervention is primarily indicated in cases of primary hyperparathyroidism as an etiological factor of urolithiasis.

Surgical treatment of urolithiasis is categorized into several types:

1. Open surgeries. These procedures can be divided into those aimed directly at stone removal and those addressing etiological and pathogenetic issues, as well as surgeries performed in cases of urolithiasis complications.

2. Instrumental methods of stone removal, such as cystolithotripsy and ureterolithoextraction, as well as contact ureteroscopic stone fragmentation. Instrumental methods also include ureteral catheterization, ureteral orifice blockage, incision, mechanical ureterolithotripsy, and electrophysical techniques.

3. Percutaneous stone removal or destruction, including percutaneous nephrostomy combined with mechanical stone fragmentation.

4. Extracorporeal shock wave lithotripsy (ESWL). In recent years, this method and its variants have become increasingly common in the treatment of urolithiasis, along with percutaneous puncture nephro- and ureterolithotomy, as well as laparoscopic interventions.

For a long time, open surgery dominated treatment, characterized by high invasiveness and complex postoperative outcomes. Frequent recurrences often necessitated repeated interventions under challenging conditions [10].

With the introduction of extracorporeal shock wave lithotripsy (ESWL), this method has proven to be a reliable and effective approach for treating kidney and ureteral stones. The primary objective is the safe and minimally invasive fragmentation of stones. In modern

international and domestic clinical settings, open surgeries have decreased to 10% in favor of stone disintegration via lithotripsy.

Numerous clinical studies confirm the feasibility of extracorporeal lithotripsy for children with stones in the renal calyceal system measuring no more than 1.5-2 cm. However, this method is contraindicated in cases of developmental anomalies of the upper urinary tract, acute inflammatory processes, hematuria of unknown etiology, and during the intermittent stage of chronic renal failure.

Initially, it seemed that the number of cases of recurrent stone formation had decreased. This can be partially explained by the fact that for patients in cities and towns where equipment for extracorporeal shock wave lithotripsy is available, this procedure has become more accessible and is performed faster than surgical intervention. However, despite the positive outcomes, extracorporeal lithotripsy does not guarantee complete prevention of recurrent stone formation, which occurs quite frequently – affecting 5.4-18.9% of patients [3, 4]. This is due to the fact that lithotripsy, like traditional stone removal, does not address the root cause of stone formation, which remains an unresolved issue.

Moreover, with the growing experience in performing extracorporeal lithotripsy, many physicians report a high rate of complications and side effects associated with the use of lithotripters: injuries to internal organs (such as the intestines and lungs), the development of subcapsular and perirenal hematomas. Therefore, it is crucial to emphasize that this procedure should only be performed in specialized medical centers with extensive experience in treating urolithiasis in children [4].

Special attention should be given to the treatment of staghorn urolithiasis: the severe complications of this disease in children, its aggressive progression, and the rapid recurrence of stone formation have an extremely negative impact on the function of the developing kidney.

In the case of staghorn and multiple stones, medical opinions diverge. Some specialists prefer open surgeries (such as pyelolithotomy, nephrotomy of various extents, including sectional nephrotomy), while others favor combined treatment methods: extracorporeal lithotripsy, percutaneous nephrolithotripsy, nephro- and lithoextraction, and nephrolapaxy. Open surgeries are only undertaken when other methods prove ineffective. If urolithiasis is complicated by congenital kidney anomalies that impair urine outflow, the only option is surgical correction of the anomaly combined with simultaneous stone removal [7].

It is worth noting that the removal of a stone does not imply the complete elimination of urolithiasis. After surgery to remove stones in nephrolithiasis, it is critically important to conduct individually tailored metaphylaxis, taking into account all possible causes of the disease in a specific child.

Conclusion: Significant progress has been made in pediatric urology in the diagnosis and treatment of urolithiasis, particularly due to the development of minimally invasive and non-invasive treatment methods. Advances in metabolic diagnostics allow for better selection of individualized treatment and prevention programs.

Despite these advances, challenges remain in early diagnosis, especially in younger children, whose symptoms are often nonspecific. Additionally, the treatment of metabolic disorders requires long-term follow-up and may be complicated by recurrences. The lack of

knowledge about the mechanisms of stone formation in children also remains a pressing issue requiring further research.

Modern diagnostic and treatment methods for urolithiasis in children have significantly improved patient outcomes. However, further investigation of etiopathogenetic mechanisms and the development of preventive strategies are necessary to minimize the risks of recurrences and complications.

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