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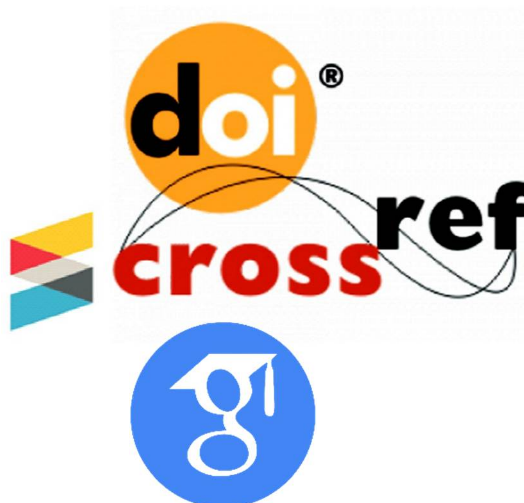

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THE IMPACT OF MINERAL AND ACID–BASE METABOLIC CORRECTION ON POSTOPERATIVE REHABILITATION IN CHILDREN WITH UROLITHIASIS

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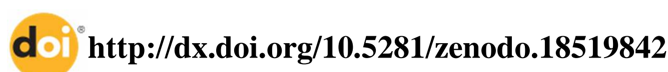
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Abstract

Urolithiasis in children is strongly associated with metabolic disturbances that persist even after successful surgical removal of urinary calculi. Disorders of mineral metabolism and acid–base balance play a crucial role in stone recurrence and long-term renal damage. Modern minimally invasive surgical techniques effectively eliminate calculi; however, they do not address the underlying metabolic causes of stone formation. This study analyzes the significance of correcting mineral and acid–base metabolism disorders as a key component of post-operative rehabilitation in pediatric patients with urolithiasis. The findings emphasize that targeted metabolic correction significantly reduces recurrence risk and improves long-term clinical outcomes.

Keywords: Pediatric urolithiasis; mineral metabolism; acid–base balance; metabolic disorders; postoperative rehabilitation; stone recurrence; urinary pH

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UROLITIAZ BILAN KASALLANGAN BOLALARDA OPERATSIYADAN KEYINGI REABILITATSIYAGA MINERAL VA KISLOTA-ASOSLI METABOLIK KORREKSIYANING TA’SIRI

ABSTRAKT

Bolalarda siydik-tosh kasalligi metabolik buzilishlar bilan kuchli bog‘liq bo‘lib, ular siydik toshlari jarrohlik yo‘li bilan muvaffaqiyatli olib tashlangandan keyin ham saqlanib qoladi. Tosh qaytalanishida va buyrakning uzoq muddat zararlanishida mineral moddalar almashinuvi va kislota-ishqor muvozanatining buzilishi muhim rol o‘ynaydi. Zamonaviy kam invaziv jarrohlik usullari toshlarni samarali yo‘q qiladi, ammo ular tosh hosil bo‘lishining asosiy metabolik sabablarini hal

qilmaydi. Ushbu tadqiqotda urolitiaz bilan ogʻrigan pediatrik bemorlarda operatsiyadan keyingi reabilitatsiyaning asosiy tarkibiy qismi sifatida mineral va kislota-ishqor almashinuvi buzilishlarini tuzatishning ahamiyati tahlil qilingan. Tadqiqot natijalari shuni koʻrsatadiki, maqsadli metabolik tuzatish kasallikning qaytalanish xavfini sezilarli darajada kamaytiradi va uzoq muddatli klinik natijalarni yaxshilaydi.

Tayanch iboralar: Bolalar siydik tosh kasalligi; minerallar almashinuvi; kislota-ishqor muvozanati; metabolik buzilishlar; operatsiyadan keyingi reabilitatsiya; toshlarning qaytalanishi; siydik pH

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ВЛИЯНИЕ МИНЕРАЛЬНОЙ И КИСЛОТО-ОСНОВНОЙ МЕТАБОЛИЧЕСКОЙ КОРРЕКЦИИ НА ПОСЛЕОПЕРАЦИОННУЮ РЕАБИЛИТАЦИЮ У ДЕТЕЙ С УРОЛИТИАЗОМ

АБСТРАКТ

Уролитиаз у детей тесно связан с нарушениями обмена веществ, которые сохраняются даже после успешного хирургического удаления мочевых камней. Нарушения минерального обмена и кислотно-щелочного баланса играют решающую роль в рецидиве камней и длительном повреждении почек. Современные малоинвазивные хирургические методы эффективно устраняют калькулы; однако они не устраняют метаболические причины образования камней. В данном исследовании проанализировано значение коррекции нарушений минерального и кислотно-щелочного обмена как ключевого компонента послеоперационной реабилитации у детей с уролитиазом. Результаты подчеркивают, что целенаправленная метаболическая коррекция значительно снижает риск рецидива и улучшает отдаленные клинические результаты.

Ключевые слова: Детский уролитиаз; минеральный обмен; кислотно-щелочной баланс; нарушения обмена веществ; послеоперационная реабилитация; рецидив камней; pH мочи

Introduction

Pediatric urolithiasis is increasingly recognized as a chronic metabolic disease rather than an isolated surgical condition [1,2]. Unlike adult stone disease, pediatric urolithiasis is frequently associated with persistent metabolic abnormalities, including hypercalciuria, hypocitraturia, hyperoxaluria, and disturbances in urinary pH regulation [2–4]. These disorders create a favorable environment for crystal nucleation and growth, leading to high recurrence rates after stone removal [3,4].

Although minimally invasive surgical techniques—such as ureterorenoscopy, percutaneous nephrolithotomy, and extracorporeal shock wave lithotripsy—have significantly improved immediate treatment outcomes, recurrence prevention remains a major challenge [6,7]. Consequently, postoperative rehabilitation must focus on correcting metabolic and acid–base disorders to achieve sustainable disease control [2,5].

Materials and Methods

Post-operative rehabilitation strategies were analyzed with emphasis on metabolic evaluation and correction. Assessment included biochemical analysis of blood and urine, evaluation of urinary pH, and identification of mineral metabolism abnormalities following surgical intervention [2,4].

Table 1. Major Metabolic and Acid–Base Disorders in Pediatric Urolithiasis After Surgical Stone Removal

Metabolic disorder	Diagnostic criterion	Pathophysiological significance	Clinical implication
Hypercalciuria	Urinary Ca > 4 mg/kg/day	Increased calcium supersaturation	High risk of calcium stone recurrence
Hypocitraturia	Urinary citrate < 320 mg/day	Reduced inhibition of crystal aggregation	Enhanced crystallization tendency
Hyperoxaluria	Urinary oxalate > age-adjusted norm	Promotion of calcium oxalate nucleation	Aggressive stone growth
Acidic urine	Urinary pH < 5.5	Uric acid crystallization	Risk of uric acid stones
Alkaline urine	Urinary pH > 7.0	Phosphate and struvite precipitation	Infection-related stones
Mixed disorders	≥2 abnormalities	Synergistic lithogenic effect	High recurrence probability

Correction strategies were individualized and based on detected metabolic profiles, incorporating dietary modification, hydration optimization, and pharmacological therapy when indicated. The timing of metabolic assessment was standardized to ensure reliable results under stable dietary and physiological conditions.

Results

Clinical observations indicate that a significant proportion of pediatric patients demonstrate persistent metabolic abnormalities after stone removal. Disorders of calcium metabolism and impaired acid–base balance were among the most prevalent findings [2,4].

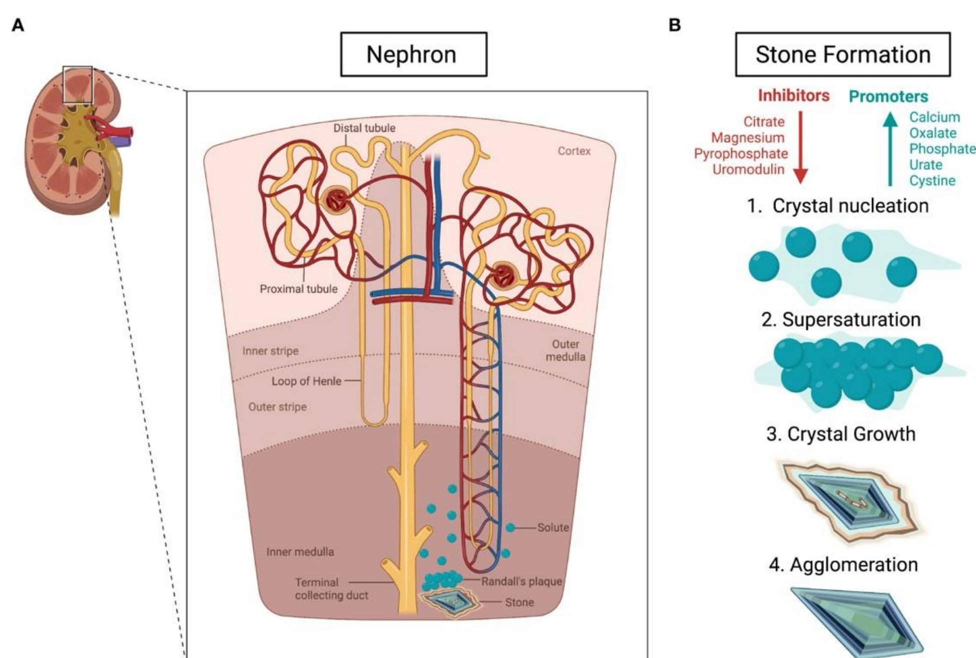

Figure 1. Pathophysiological mechanisms of nephrolithiasis [5,8].
(A) Formation of renal calculi associated with Randall's plaque development within the nephron.
(B) Sequential stages of kidney stone formation initiated by disruption of the balance between crystallization inhibitors (indicated in red) and promoters (indicated in blue). Arrows denote processes of enhancement (blue) and suppression (red).

Correction of hypocitraturia through alkalinizing therapy resulted in improved urinary inhibitory capacity against crystallization. Regulation of calcium excretion via dietary sodium restriction and pharmacologic intervention contributed to decreased lithogenic risk. Adjustment of urinary pH proved essential in preventing recurrence of uric acid and cystine stones.

Children receiving structured metabolic rehabilitation showed a marked reduction in stone recurrence rates and improved stabilization of renal function during follow-up.

Discussion

Mineral and acid–base metabolism disorders represent fundamental pathogenic mechanisms in pediatric urolithiasis [2,5,8]. Failure to correct these disturbances significantly increases the likelihood of recurrent stone formation, even after technically successful surgery [1,6].

Targeted metabolic correction transforms postoperative care from a reactive to a preventive strategy. Individualized rehabilitation programs not only reduce recurrence but also limit the cumulative impact of repeated interventions on renal parenchyma and overall child development.

Table 2. Individualized Correction Strategies for Metabolic Disorders in Pediatric Urolithiasis

Identified disorder	Correction strategy	Mechanism of action	Expected outcome
Hypocitraturia	Alkalinizing therapy (citrate salts)	Increases urinary citrate and pH	Reduced crystal aggregation
Hypercalciuria	Sodium restriction, thiazides	Decreased urinary calcium excretion	Lower calcium supersaturation
Acidic urine	Alkalization	Shift of urinary pH	Prevention of uric acid stones
Alkaline urine	Diet modification	Reduction of phosphate precipitation	Lower infection stone risk
Combined disorders	Multimodal approach	Synergistic metabolic correction	Long-term stabilization

The integration of metabolic correction into standard postoperative protocols aligns with modern principles of personalized medicine and long-term disease management in pediatric urology.

Conclusion

Correction of mineral and acid–base metabolism disorders is a cornerstone of effective post-operative rehabilitation in children with urolithiasis. Personalized metabolic management significantly reduces stone recurrence, supports renal function preservation, and improves long-term outcomes [2,5,7]. Post-operative care in pediatric urolithiasis should therefore extend beyond stone removal to include comprehensive metabolic evaluation and targeted correction strategies.

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