International Journal of Medical Sciences And Clinical Research

VOLUME Vol.06 Issue02 2026
PAGE NO. 44-52
DOI 10.37547/ijmscr/Volume06Issue02-11

Surgical Management Of Pediatric Nephrolithiasis: A Comparative Review Of Current Modalities

Otamuradov F.A.
Termez branch of Tashkent State Medical University, Termez, Uzbekistan

Kodirov A.B.
Kashkadarya Regional Children's Multidisciplinary Medical Center, Karshi, Uzbekistan

Nurmamatov D.S.
Kashkadarya Regional Children's Multidisciplinary Medical Center, Karshi, Uzbekistan

Xurramov F.M.
Tashkent State Medical University, Tashkent, Uzbekistan

Received: 20 December 2025; **Accepted:** 11 January 2026; **Published:** 15 February 2026

Abstract: The management of pediatric nephrolithiasis has undergone a fundamental paradigm shift from traumatic open surgery to minimally invasive endourological techniques. This review provides a comparative analysis of current surgical modalities, including Extracorporeal Shock Wave Lithotripsy (ESWL), Percutaneous Nephrolithotomy (PCNL), and Retrograde Intrarenal Surgery (RIRS). While open surgery is largely obsolete due to high morbidity, ESWL remains a viable non-invasive option for smaller calculi (<15 mm). However, for large (>20 mm) and complex stone burdens, PCNL and its miniaturized variants (mini-, ultra-mini-, and micro-PCNL) are established as the gold standard, offering superior stone-free rates. RIRS has emerged as a safe, effective alternative for intermediate-sized stones, utilizing advanced flexible ureteroscopy. The review concludes that contemporary treatment necessitates an individualized approach, balancing stone characteristics with anatomical and metabolic factors. Ultimately, the integration of miniaturized technologies optimizes stone clearance while prioritizing renal preservation in the pediatric population.

Keywords: Pediatric nephrolithiasis; minimally invasive surgery; percutaneous nephrolithotomy (PCNL); retrograde intrarenal surgery (RIRS); extracorporeal shock wave lithotripsy (ESWL); endourology.

Introduction: Nephrolithiasis in the pediatric population is a multifactorial condition with an increasing incidence over recent decades; notably, its etiology differs significantly from that observed in adult patients [1]. The pathogenesis of pediatric urolithiasis is characterized predominantly by metabolic abnormalities, which are identified in 35-50% of children with nephrolithiasis. Among these, hypercalciuria, hyperoxaluria, and hypocitraturia are the most prevalent anomalies [2]. Beyond metabolic factors, anatomical abnormalities of the urinary tract play a critical role in lithogenesis, occurring in approximately 30% of patients. Furthermore, a genetic predisposition can be detected in 11-32% of children through modern genetic testing methods [2].

Over the past three decades, the surgical management of pediatric nephrolithiasis has undergone a fundamental transformation, driven by the establishment of minimally invasive surgery as a priority in pediatric urology [3]. Traumatic open surgical interventions, which previously constituted the standard of care, have been almost entirely superseded by minimally invasive endourological techniques, owing to advancements in instrument miniaturization

and optical system refinement [4]. The contemporary paradigm for the surgical treatment of pediatric nephrolithiasis necessitates an individualized approach that considers the stone's size, location, and composition, the anatomical characteristics of the urinary tract, and the presence of concomitant metabolic disorders [5]. The drive to achieve complete stone clearance while minimizing complications and reducing recurrence risks underscores the relevance of examining the evolution of surgical technologies in the management of pediatric nephrolithiasis.

The Historical Phase: The Era of Open Surgery. Prior to the turn of the 21st century, open surgical intervention stood as the sole therapeutic modality available for the management of urolithiasis in children. During this period, pediatric patients were frequently conceptualized merely as "miniature adults," often without adequate consideration for the distinct physiological and anatomical nuances of the developing pediatric organism [6]. Classical operative techniques – specifically pyelolithotomy, nephrolithotomy, and ureterolithotomy – were predominantly performed via a lumbotomy incision. These procedures were inherently characterized by significant surgical trauma inflicted upon the growing child [7]. Although open surgery demonstrated relatively high efficacy rates, achieving complete stone clearance in 91-100% of cases, these invasive interventions were invariably associated with substantial perioperative risks and necessitated a prolonged, challenging rehabilitation period [8].

One of the most critical challenges defining the era of open surgery was the high incidence of stone recurrence, a phenomenon largely attributable to the insufficient correction of underlying metabolic abnormalities. Long-term follow-up data indicated that the five-year recurrence rate following surgical treatment reached as high as 55%, with renal calculi exhibiting a significantly higher propensity for recurrence compared to ureteral stones [9]. A particularly unfavorable prognosis was observed in patients presenting with calculi exceeding 5 mm in diameter and concurrent anatomical anomalies of the urinary tract; such clinical scenarios frequently necessitated repeated operative interventions throughout the patient's lifetime [10]. The cumulative effect of multiple open surgeries resulted in the development of irreversible cicatricial changes in the renal parenchyma – a condition termed "scarred kidney." This pathological state was strongly associated with a progressive decline in renal function and an elevated risk of progression to chronic renal failure [6].

The deleterious sequelae of repeated open interventions extended beyond functional impairment to include the formation of extensive adhesive processes within the retroperitoneal space. This fibrosis significantly complicated the technical execution of any subsequent surgical procedures. Clinical studies have demonstrated that a history of prior open renal surgery is associated with increased operative duration for subsequent endourological interventions and a heightened risk of intraoperative complications, including inadvertent bowel injury [11]. Furthermore, the economic burden imposed by open surgery was substantial, particularly in developing nations. In these regions, delays in seeking medical attention often led to severe complications – such as pyonephrosis, obstructive renal atrophy, and sepsis – requiring increasingly invasive interventions, up to and including nephrectomy [12]. Ultimately, the accumulation of evidence regarding the long-term adverse outcomes of open surgery served as a powerful catalyst, stimulating the search for less traumatic, alternative modalities for the treatment of pediatric nephrolithiasis.

Extracorporeal Shock Wave Lithotripsy (ESWL). The clinical introduction of ESWL into pediatric practice in 1986 represented a watershed moment, marking a revolutionary paradigm shift from invasive surgical approaches toward minimally invasive management strategies for nephrolithiasis [12]. Fundamentally, ESWL is defined as a non-invasive therapeutic procedure predicated on the application of focused shock waves generated by an external source. These waves penetrate soft tissues with minimal attenuation to fragment the calculus into minute particles, which are subsequently capable of spontaneous elimination via the urinary tract. The pediatric population presents a unique set of anatomical and physiological advantages that facilitate the efficacy of ESWL. Specifically, children possess a shorter skin-to-stone distance, a smaller body habitus, and shorter, more compliant ureters. These characteristics collectively contribute to significantly superior fragment clearance

rates compared to those observed in the adult cohort [12].

Nevertheless, the clinical efficacy of ESWL in children is multifactorial. Data from large-scale multicenter studies indicate that the overall stone-free rate (SFR) three months post-procedure is approximately 66.7% [13]. Stone burden remains the most significant predictor of success: for calculi measuring less than 10 mm, stone-free rates reach an impressive 90-92%, whereas efficacy notably declines to 81% for stones ranging from 10 to 20 mm in diameter [13]. Stone localization also plays a critical role in outcomes; calculi situated in the proximal ureter and renal pelvis demonstrate optimal treatment response. Conversely, lower pole calculi are associated with reduced fragmentation efficiency and impeded fragment evacuation due to dependent anatomy [15]. Interestingly, contemporary research has established that preoperative determination of stone density via Hounsfield units (HU) on computed tomography is not a clinically significant predictor of ESWL success in children. This finding is pivotal, as it supports the reduction of unnecessary radiation exposure in this vulnerable population [14].

Despite its established safety profile and high efficacy, ESWL is not without limitations in pediatric practice. A primary challenge is the frequent necessity for multiple treatment sessions to achieve complete clearance, particularly for stones exceeding 15 mm. This often necessitates repeated administration of general anesthesia, thereby increasing the cumulative physiological burden and potential radiation exposure [13]. The most frequently encountered complication is the formation of a "steinstrasse" (stone street) – an accumulation of stone fragments in the distal ureter – which occurs with a frequency of 6-10% and may mandate adjunctive endourological interventions [12]. Furthermore, for stone burdens exceeding 20 mm, ESWL demonstrates a substantial reduction in efficacy, often necessitating a combined modality approach or the selection of alternative surgical strategies [15]. Current clinical guidelines from the European Association of Urology (EAU) recommend ESWL as the first-line therapy for renal calculi up to 20 mm in size. However, for larger stone burdens, percutaneous nephrolithotomy (PCNL) or retrograde intrarenal surgery (RIRS) are considered the preferred therapeutic options [16].

The Evolution of Endourology: PCNL and Mini-PCNL. PCNL has emerged as a revolutionary alternative to open surgery for the management of large and complex renal calculi in the pediatric population. The technique has undergone a significant evolutionary trajectory, advancing from standard PCNL – utilizing 24-30 French (F) instruments – to a spectrum of minimally invasive variants. These include mini-PCNL (14-20 F), ultra-mini PCNL (11-14 F), and micro-PCNL (<10 F). This progressive miniaturization of the armamentarium was driven by a imperative to minimize traumatic injury to the developing renal parenchyma, substantially reduce intraoperative blood loss, and mitigate the incidence of postoperative complications [17].

Current data substantiate the high efficacy of PCNL in the pediatric cohort, maintaining SFR exceeding 85% with an overall complication rate of less than 7%, irrespective of patient age [18]. Standard PCNL remains the gold standard for calculi exceeding 20 mm in diameter, as well as for lower pole stones larger than 10 mm. Its primary advantage lies in the capability to achieve complete stone clearance within a single hospitalization, offering the versatility to utilize multiple access tracts for complex staghorn calculi. However, the utilization of large-caliber instruments is intrinsically associated with an elevated risk of hemorrhage necessitating blood transfusion and potential damage to the renal parenchyma – complications that are particularly critical to avoid in the growing pediatric kidney.

The advent of mini-PCNL marked a critical milestone in pediatric endourology, offering a strategic compromise between surgical efficacy and safety. Evidence from randomized controlled trials has demonstrated that mini-PCNL yields stone clearance rates comparable to standard PCNL (88% vs. 92%, p=0.64), while substantially mitigating blood loss (hemoglobin drop 1.1±0.31 g/dL vs. 1.7±0.23 g/dL, p<0.0001) [19]. These findings were corroborated by a study involving 77 children in Iraq, which confirmed the safety profile and efficacy of mini-PCNL, reporting an SFR of 87% with minimal transfusion requirements and a negligible incidence of visceral injury [20].

For the management of large and complex burdens, including staghorn calculi, the integration of mini-PCNL

with high-power holmium laser lithotripsy has yielded impressive clinical outcomes. In a case series of 41 pediatric patients with a mean stone size of 16.28±3.43 mm, the initial stone-free rate was 73.2%; this figure improved to 100% at the 3-month follow-up after adjunctive endoscopic procedures [21]. This underscores the pivotal importance of a multimodal approach and the utility of staged minimally invasive interventions to ensure complete stone eradication.

The drive toward further miniaturization facilitated the development of micro-PCNL and ultra-mini PCNL. A systematic review comprising 14 studies and 456 patients indicated that micro-PCNL (<10 F) achieves an SFR ranging from 80% to 100%, with an overall complication rate of 11.2% [17]. However, comparative analyses have elucidated certain limitations inherent to ultra-mini technologies. When juxtaposed with mini-PCNL and RIRS, micro-PCNL demonstrated the lowest efficacy (62.5% vs. 80.8% for mini-PCNL and 93.3% for RIRS). This disparity is largely attributed to compromised visualization and the technical challenges of fragmenting stones through a highly restricted working channel [23].

A significant technical innovation has been the implementation of "tubeless" PCNL – a modification wherein the procedure is concluded without the placement of a nephrostomy tube. A meta-analysis of 13 studies involving 661 pediatric patients demonstrated that tubeless PCNL is associated with a statistically significant reduction in hospital stay (weighted mean difference -1.60 days, 95% CI: -2.27 to -0.92), shorter operative times, and reduced postoperative analgesic requirements, all while maintaining comparable efficacy and safety profiles [18]. This approach is particularly advantageous in pediatric practice as it eliminates the discomfort associated with external nephrostomy tubes and prevents potential complications related to urinary leakage.

Concurrently, the debate regarding operative positioning continues to be a subject of active research. Comparative analyses have indicated that performing mini-PCNL in the supine position offers efficacy comparable to the traditional prone position, with the added benefits of improved anesthesiologic access and the facilitation of simultaneous combined retrograde procedures [22]. Contemporary surgical practice emphasizes adapting patient positioning to the specific clinical scenario, patient anatomy, and stone localization.

When compared with alternative modalities such as ESWL and RIRS, percutaneous access demonstrates distinct advantages for larger stone burdens. A randomized prospective study revealed that mini-PCNL outperforms ESWL in efficacy for borderline stone sizes (15-20 mm), ensuring a higher rate of complete clearance in a single session [26]. Conversely, for stones measuring 10-20 mm in children under 3 years of age, micro-PCNL and RIRS exhibit comparable outcomes; in these scenarios, the choice of modality is often dictated by stone location, anatomical considerations, and surgeon expertise [25].

Nevertheless, mini-PCNL is not devoid of limitations. The procedure is associated with prolonged operative times compared to standard PCNL, a consequence of the smaller diameter of the working channel which necessitates more meticulous and time-consuming fragmentation and evacuation of stone burden [19]. Furthermore, patients with a history of prior open renal surgery present with a heightened risk of complications, such as colonic injury. This necessitates mandatory preoperative evaluation with computed tomography to delineate anatomy and rule out retrorenal colon positioning.

In summary, PCNL and its miniaturized iterations represent a safe and effective armamentarium for treating large and complex renal stones in children, allowing for instrument sizing to be tailored to the specific characteristics of the patient and the calculus. The continued evolution of surgical technique, including tubeless approaches and the optimization of access, aims to further reduce morbidity while preserving the high therapeutic efficacy of the procedure.

Retrograde Intrarenal Surgery (RIRS). RIRS constitutes a premier minimally invasive endourological modality, predicated on the utilization of flexible ureteroscopy to access and treat renal calculi via the natural urinary tract pathways, thereby obviating the need for percutaneous access. Over the past decade, RIRS has evolved from a niche experimental technique into a cornerstone therapeutic option for pediatric renal stones measuring up to 20 mm. This paradigm shift is

formally recognized and reflected in the contemporary clinical guidelines of the European Association of Urology (EAU) [29].

The technological refinement of modern flexible ureteroscopes – now available with diameters as small as 7.5 French – permits the safe execution of RIRS even in toddlers and infants with a body mass of less than 20 kg. A notable Italian study validated the safety and efficacy of RIRS utilizing a ureteral access sheath (UAS) in a cohort of 13 preschool-aged children, reporting a SFR of 81.3% with a negligible complication rate during both short- and long-term follow-up [35]. In children younger than 5 years of age, the mean stone-free rate is approximately 76.3% following a single procedure, with the potential for further optimization of outcomes through staged secondary sessions [33].

A critical technical consideration in RIRS is the deployment of a UAS. The UAS serves multiple functions: it facilitates the repeated effortless passage of the ureteroscope, enhances optical visualization, and crucially, mitigates elevated intrarenal pressure by allowing continuous fluid egress. A multicenter study involving 389 pediatric patients demonstrated that RIRS can be performed safely either with or without a UAS. However, in children under 5 years of age, the restricted use of UAS was often correlated with smaller stone burdens and shorter operative durations [27]. Conversely, for calculi exceeding 1 cm in diameter, the application of a UAS offers significant operational advantages, irrespective of the patient's age.

Comparative analyses assessing the efficacy of RIRS in pediatric versus adult populations have revealed comparable clinical outcomes when identical instrumentation is employed. In a study of 55 pediatric patients with a mean stone size of 13.9±6.6 mm, both stone-free rates and complication profiles were statistically indistinguishable from those observed in the adult cohort, thereby reinforcing the safety of this methodology in pediatric practice [32]. Overall, RIRS consistently achieves stone-free rates ranging from 93.3% to 100% following primary or secondary procedures in children under 12 years of age [31].

A significant technological breakthrough in this domain is represented by the widespread adoption of single-use (disposable) flexible ureteroscopes. These devices effectively eliminate the logistical challenges associated with sterilization, instrument durability, and the limited availability of reusable scopes. A compelling clinical case describing the successful laser lithotripsy of multiple large intrarenal stones in a 2-year-old child using a 7.5 Fr single-use ureteroscope and high-power laser settings demonstrated the feasibility of this technology even in the youngest patients with minimal morbidity [29]. Furthermore, comparative research indicates that single-use ureteroscopes provide efficacy and complication rates (4.6% vs. 5%) comparable to reusable counterparts, while offering a potentially superior cost-effectiveness ratio in the pediatric setting [30].

When comparing RIRS with micro-PCNL for stones smaller than 2 cm, stone-free rates were found to be comparable (80% vs. 82.2%). However, RIRS was characterized by significantly shorter operative and fluoroscopy times, albeit with a higher rate of deviation from the planned procedure and increased need for re-intervention [34]. It is important to note that for lower pole calculi of mixed composition, RIRS is associated with a heightened risk of postoperative complications, necessitating rigorous patient selection.

In conclusion, RIRS represents a safe, effective, and less invasive alternative to percutaneous techniques for the management of pediatric renal stones up to 20 mm. It is particularly advantageous for calculi located in the renal pelvis and upper calyces, ensuring high clearance rates while adhering to the principles of minimal invasiveness.

Comparative Analysis and Contemporary Trends. A comparative evaluation of the efficacy of various surgical modalities for the management of pediatric nephrolithiasis reveals a distinct clinical paradigm shift toward endourological technologies. A systematic review and meta-analysis comprising 474 pediatric patients elucidates that RIRS, when juxtaposed with PCNL, offers distinct perioperative advantages. Specifically, RIRS is associated with a significantly reduced duration of hospitalization (mean difference of -1.44 days) and decreased fluoroscopy time (mean difference of -72.72 seconds), while maintaining comparable SFR and a lower overall complication rate [36]. These findings underscore the clinical utility of RIRS for carefully selected cases, particularly those involving smaller stone burdens where minimizing invasiveness is paramount.

A comprehensive Cochrane systematic review of 31 randomized controlled trials highlights the inherent trade-offs between non-invasive and invasive approaches. The analysis demonstrated that ESWL exhibits a lower 3-month success rate compared to PCNL (Risk Ratio 0.67) and RIRS (Risk Ratio 0.85). However, ESWL retains a superior safety profile, being associated with a statistically significantly lower frequency of complications compared to PCNL [37]. These data emphasize the critical necessity of a nuanced, individualized approach to treatment selection, balancing the probability of stone clearance against the potential risks of procedural morbidity based on stone size and location.

Further granular insight is provided by a Bayesian network meta-analysis of minimally invasive procedures for stones measuring 10-20 mm. The study revealed that ESWL is inferior to RIRS, mini-PCNL, and standard PCNL in terms of efficacy. Notably, Super-Mini PCNL (SMP) emerged as the optimal modality, demonstrating the highest probability of achieving complete stone clearance while maintaining a minimal risk of complications [38]. Corroborating this, a recent meta-analysis of 13 studies involving 1,019 patients confirmed that micro-PCNL outperforms RIRS regarding stone-free rates and is associated with a lower incidence of postoperative fever, a finding that is particularly relevant in the management of younger children [39].

A tangible global trend is currently observable, characterized by the increasing utilization of RIRS and PCNL, concurrent with a proportional decline in the application of ESWL for pediatric nephrolithiasis. Contemporary guidelines from the European Association of Urology (EAU) strongly advocate for a holistic, multidisciplinary strategy. This approach dictates that treatment decisions should not be based solely on stone size and location but must also integrate the patient's metabolic profile, specific anatomical variations, and the imperative of long-term renal preservation [40]. The future trajectory of pediatric endourology is defined by the integration of single-use instrumentation, the refinement of laser technologies, and a concerted effort to minimize cumulative radiation exposure.

CONCLUSION

The evolution of surgical management for pediatric nephrolithiasis over the past three decades represents a remarkable paradigm shift, transitioning from the era of traumatic open surgery to the dominance of minimally invasive endourological modalities. This technological renaissance has been driven by the progressive miniaturization of the surgical armamentarium, significant refinements in optical systems, and the exponential accumulation of specialized clinical expertise within the field of pediatric urology. Consequently, the contemporary therapeutic paradigm is predicated on a highly individualized strategy. This approach meticulously integrates variables such as stone burden, precise localization, anatomical nuances, and underlying metabolic abnormalities, while prioritizing the mitigation of long-term sequelae for the developing renal unit.

(ESWL retains its established utility as the primary non-invasive modality for calculi measuring up to 10-15 mm, offering a favorable balance of efficacy and minimal invasiveness. Conversely, Mini-PCNL and its miniaturized variants have solidified their status as the gold standard for the management of large and complex stone burdens. These techniques consistently achieve stone-free rates exceeding 85% while maintaining a controlled and acceptable morbidity profile. RIRS occupies a pivotal intermediate position in the treatment algorithm, offering an optimal equilibrium between safety and efficacy for stones of intermediate size.

The relentless trajectory of technological innovation – encompassing the widespread adoption of single-use ureteroscopes, the advent of high-power laser systems, and protocols for radiation minimization – holds the promise of further enhancing clinical outcomes. Ultimately, the cornerstone of sustainable long-term success remains the prevention of recurrence through the rigorous correction of metabolic derangements. This objective necessitates a cohesive, multidisciplinary collaboration involving pediatricians, nephrologists, and urologists to ensure optimal health outcomes for the pediatric patient.

REFERENCES

1. Pecoraro L, Zuccato A, Vitella R, et al. Pediatric Nephrolithiasis: A Changing Landscape Through

Time and Space. Medicina (Kaunas). 2024 Dec 2;60(12):1993.

2. Ramya K, Krishnamurthy S, Manikandan R, et al. Metabolic and Genetic Evaluation in Children with Nephrolithiasis. Indian J Pediatr. 2022 Dec;89(12):1226-1232.
3. Destro F, Selvaggio GGO, Lima M, et al. Minimally Invasive Approaches in Pediatric Urolithiasis. The Experience of Two Italian Centers of Pediatric Surgery. Front Pediatr. 2020 Jul 29;8:377.
4. Paraboschi I, Gnech M, De Marco EA, et al. Pediatric Urolithiasis: Current Surgical Strategies and Future Perspectives. Front Pediatr. 2022 Jun 9;10:886425.
5. Peng T, Zhong H, Hu B, et al. Minimally invasive surgery for pediatric renal and ureteric stones: A therapeutic update. Front Pediatr. 2022 Aug 18;10:902573.
6. Marra G, Taroni F, Berrettini A, et al. Pediatric nephrolithiasis: a systematic approach from diagnosis to treatment. J Nephrol. 2019 Apr;32(2):199-210.
7. Önal B. Pediatric stone disease: Current management and future concepts. Turk Arch Pediatr. 2021 Mar;56(2):99-107.
8. Rizvi SA, Sultan S, Ijaz H, et al. Open surgical management of pediatric urolithiasis: A developing country perspective. Indian J Urol. 2010 Oct;26(4):573-576.
9. Lao M, Kogan BA, White MD, et al. High recurrence rate at 5-year followup in children after upper urinary tract stone surgery. J Urol. 2014 Feb;191(2):440-444.
10. Demirtas F, Çakar N, Özçakar ZB, et al. Risk factors for recurrence in pediatric urinary stone disease. Pediatr Nephrol. 2024 Jul;39(7):2105-2113.
11. Sakly A, Khaldi S, Touati A, et al. Outcomes and complications of percutaneous nephrolithotomy as primary versus secondary procedure for kidney stones: a prospective cohort study. Ann Med Surg (Lond). 2024 Aug 30;86(10):5711-5715.
12. Cao B, Daniel R, McGregor R, Tasian GE. Pediatric Nephrolithiasis. Healthcare (Basel). 2023 Feb 13;11(4):552.
13. Satjakoesoemah AI, Alfarissi F, Wahyudi I, et al. Factors related to the success rate of pediatric extracorporeal shock wave lithotripsy (ESWL) in Cipto Mangunkusumo Hospital: an 8-year single-center experience. Afr J Urol. 2021 Jul 3;27:92.
14. Akinci A, Akpinar C, Babayigit M, et al. Predicting ESWL success by determination of Hounsfield unit on non-contrast CT is clinically irrelevant in children. Urolithiasis. 2022 Apr;50(2):223-228.
15. Mohamed ER, Elmogazy HM, Zanaty AK, et al. Extracorporeal shock wave lithotripsy for treatment of large pediatric renal pelvic stone burden more than 2 cm. J Pediatr Urol. 2023 Oct;19(5):561.e1-561.e11.
16. Garcia-Roig M, Delenbach N, Kirsch J, et al. Extracorporeal shock wave lithotripsy versus ureteroscopy for management of pediatric nephrolithiasis in upper urinary tract stones: multi-institutional outcomes of efficacy and morbidity. J Urol. 2019 Aug;202(2):371-378.
17. Jones P, Bennett G, Aboumarzouk OM, et al. Role of minimally invasive percutaneous nephrolithotomy techniques-micro and ultra-mini PCNL (<15F) in the pediatric population: A systematic review. J Endourol. 2021 Sep;35(9):816-824.
18. Fang H, Wang Z, Wei K, et al. Safety and efficacy of standard vs. tubeless percutaneous nephrolithotomy in pediatric populations: an updated systematic review and meta-analysis. BMC Urol. 2025 May 2;25(1):110.
19. Kumar N, Yadav P, Kaushik VN, et al. Mini-versus standard percutaneous nephrolithotomy in pediatric population: a randomized controlled trial. J Pediatr Urol. 2023 Dec;19(6):688-695.
20. Jaffal WN, Hasan Al-Timimi HF, et al. The safety and efficacy of miniaturized percutaneous nephrolithotomy in children. Urolithiasis. 2024 Oct 14;52(1):142.
21. Al Mousawi S, Guzel R, Zaid M, et al. Minipercutaneous Nephrolithotomy in the Management of Large and Complex Renal Calculi in Children: How Effective Is It? J Endourol. 2023 Apr;37(4):387-393.
22. Bitkin A, Özlü DN, Ekşi M, et al. A comparative analysis of the efficacy and safety of mini-

percutaneous nephrolithotomy performed in the supine and prone positions for the treatment of pediatric kidney stones: a single-center experience. Urolithiasis. 2023 Oct 17;51(1):122.

23. Sorokin NI, Afanasievskaya EV, Kadysheva AM, et al. [Mini-PCNL, micro-PCNL or RIRS: comparative efficacy and safety in renal stones up to 2 cm]. Urologiia. 2023 Sep;(4):98-104.

24. Mahmoud MA, Shawki AS, Abdallah HM, et al. Use of retrograde intrarenal surgery (RIRS) compared with mini-percutaneous nephrolithotomy (mini-PCNL) in pediatric kidney stones. World J Urol. 2022 Dec;40(12):3083-3089.

25. Wang W, Ge Y, Wang Z, et al. Comparing micropercutaneous nephrolithotomy and retrograde intrarenal surgery in treating 1-2 cm solitary renal stones in pediatric patients younger than 3 years. J Pediatr Urol. 2019 Oct;15(5):517.e1-517.e6.

26. Farouk A, Tawfick A, Shoeb M, et al. Is mini-percutaneous nephrolithotomy a safe alternative to extracorporeal shockwave lithotripsy in pediatric age group in borderline stones? a randomized prospective study. World J Urol. 2018 Jul;36(7):1139-1147.

27. Tanidir Y, Sekerci CA, Bujons A, et al. The Utility and Safety of Ureteral Access Sheath During Retrograde Intrarenal Surgery in Children. Urology. 2024 May;187:71-77.

28. Gatti C, Cerchia E, Della Corte M, et al. Retrograde Intrarenal Surgery for Renal Stones: Is It a Safe and Effective Option in Preschool Children? J Pediatr Surg. 2024 Mar;59(3):407-411.

29. Tatanis V, Spinos T, Lamprinou Z, et al. Successful Treatment of Multiple Large Intrarenal Stones in a 2-Year-Old Boy Using a Single-Use Flexible Ureteroscope and High-Power Laser Settings. Pediatr Rep. 2024 Sep 11;16(3):806-815.

30. Mille E, El-Khoury E, Haddad M, et al. Comparison of single-use flexible ureteroscopes with a reusable ureteroscope for the management of paediatric urolithiasis. J Pediatr Urol. 2023 Jun;19(3):248.e1-248.e6.

31. Thangavelu M, Sawant A, Sayed AA, et al. Retrograde Intrarenal Surgery (RIRS) for upper urinary tract stones in children below 12 years of age: A single centre experience. Arch Ital Urol Androl. 2022 Jun 29;94(2):190-194.

32. Ozkent MS, Piskin MM, Balasar M, et al. Is Retrograde Intrarenal Surgery as Safe for Children as It Is for Adults? Urol Int. 2021;105(11-12):1039-1045.

33. Chandramohan V, Siddalingaswamy PM, Ramakrishna P, et al. Retrograde intrarenal surgery for renal stones in children <5 years of age. Indian J Urol. 2021 Jan-Mar;37(1):48-53.

34. Dogan HS, Asci A, Kahraman O, et al. Comparison of Efficiency and Safety of Retrograde Intrarenal Surgery and Micropercutaneous Nephrolithotomy in Pediatric Kidney Stones Smaller than 2 cm: A Prospective Cohort Study. J Endourol. 2021 Aug;35(8):1124-1129.

35. Berrettini A, Boeri L, Montanari E, et al. Retrograde intrarenal surgery using ureteral access sheaths is a safe and effective treatment for renal stones in children weighing <20 kg. J Pediatr Urol. 2018 Feb;14(1):59.e1-59.e6.

36. Chen Y, Deng T, Duan X, et al. Percutaneous nephrolithotomy versus retrograde intrarenal surgery for pediatric patients with upper urinary stones: a systematic review and meta-analysis. Urolithiasis. 2019 Apr;47(2):189-199.

37. Srisubat A, Potisat S, Lojanapiwat B, et al. Extracorporeal shock wave lithotripsy (ESWL) versus percutaneous nephrolithotomy (PCNL) or retrograde intrarenal surgery (RIRS) for kidney stones. Cochrane Database Syst Rev. 2023 Aug 1;8(8):CD007044.

38. Zhao FZ, Li J, Tang L, et al. Comparison of efficacy and safety of minimally invasive procedures for 10-20 mm pediatric renal Stones-A bayesian network meta-analysis. J Pediatr Urol. 2020 Dec;16(6):771-781.

39. Yuan Y, Liang YN, Li KF, et al. A meta-analysis: retrograde intrarenal surgery vs. percutaneous nephrolithotomy in children. Front Pediatr. 2023 May 2;11:1086345.

40. Tong CM, Ellison JS, Tasian GE. Pediatric stone disease: current trends and future directions. Urol Clin North Am. 2023 Aug;50(3):465-475.

41. Khurramov , F., Khamidov, B., & Nasimova , M. (2025). UROLITHIASIS IN CHILDREN. Евразийский журнал медицинских и естественных наук, 5(1), 121–128. извлечено от https://in-academy.uz/index.php/EJMNS/article/view/43214