Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Predictive Factors for Residual Stones after Endoscopic Surgery for Upper Urinary Tract Calculi in Children: A Single-Center Retrospective Study

Jian Zhao
Children's Hospital Affiliated of Zhengzhou University, Zhengzhou Children's Hospital
Liangbin Li
Children's Hospital Affiliated of Zhengzhou University, Zhengzhou Children's Hospital
Jianpeng Bi
bjp9527@126.com

Children's Hospital Affiliated of Zhengzhou University, Zhengzhou Children's Hospital

Research Article

Keywords: Pediatric urolithiasis, Endoscopic surgery, Residual stones, Stone-free rate

Posted Date: November 25th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11208020/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Purpose

Endoscopic surgery is an important minimally invasive treatment for pediatric upper urinary tract stones; however, predicting incomplete stone clearance remains challenging. This study aimed to evaluate surgical outcomes and identify predictors of residual stones in children.

Methods:

We retrospectively analyzed 92 pediatric patients with upper urinary tract stones involving 108 renal units who underwent endoscopic surgery from January 2019 to December 2024. Clinical characteristics, stone-related parameters, operative variables, and postoperative outcomes were collected. Predictors of residual stones were assessed using univariate analysis and multivariate logistic regression.

Results:

Complete stone clearance was achieved in 93 renal units, with a stone-free rate of 86.1%. Residual stones (>4 mm) occurred in 15 renal units (13.9%). Younger age, lower body mass index, higher stone density, longer operative time, preoperative ureteral stenting, greater stone complexity, and increased stone number were associated with residual stones in univariate analysis. Multivariate analysis identified stone complexity as the only independent predictor (OR=4.908, 95% CI: 1.068–22.544, P=0.041).

Conclusion:

Endoscopic surgery achieved favorable outcomes in pediatric upper urinary tract stones. Stone complexity was independently associated with residual stones and may assist in preoperative risk stratification and postoperative surveillance planning.

Introduction

Pediatric urolithiasis is a relatively uncommon condition; however, recent epidemiological studies indicate an increasing incidence in children[1–3]. Upper urinary tract stones can be managed surgically via extracorporeal shock wave lithotripsy (ESWL), retrograde intrarenal surgery (RIRS), or percutaneous nephrolithotomy (PCNL). Although RIRS was first described in 1983,[4] widespread adoption only occurred with the development of fiber-optic flexible ureteroscopes and the integration of nickel-titanium devices with Ho:YAG and Thulium laser lithotripsy.

Endoscopic surgery provides several advantages, including minimal invasiveness, direct visualization, and the ability to treat stones in multiple renal locations and ureteral segments. Due to its favorable safety profile, low complication rate, and reproducibility, flexible ureteroscopic lithotripsy has gradually gained popularity in pediatric urology.[5]

Nevertheless, pediatric endoscopic management is more challenging than in adults due to smaller calyceal systems, narrow ureters, and fragile renal parenchyma. [6, 7]Achieving optimal outcomes requires minimally invasive approaches, shorter operative times, and experienced surgeons. The primary

objectives of surgical intervention in pediatric upper urinary tract stones are to achieve a stone-free state while minimizing renal damage and reducing the risk of recurrence. Existing nephrolithometric scoring systems were primarily developed in adults, and their applicability in pediatric endoscopic surgery remains uncertain.

This study aimed to evaluate the efficacy and safety of endoscopic surgery for pediatric upper urinary tract stones and to identify key factors affecting postoperative stone clearance. We hypothesized that increased stone complexity and anatomical factors would be associated with a higher risk of residual stones after pediatric endoscopic surgery.

Methods

Study Design and Patient Selection

This retrospective study included pediatric patients diagnosed with upper urinary tract stones who underwent endoscopic surgery at our institution from January 2019 to December 2024. Pediatric patients aged < 18 years were included. A total of 92 patients, encompassing 108 renal units, were included. Patients were excluded if they had bladder stones, ureteropelvic junction obstruction, ureterovesical junction obstruction, duplicated kidneys, other congenital urinary anomalies, or a history of previous stone surgery. Institutional Review Board approval was obtained prior to study initiation.

Preoperative Assessment

All patients underwent routine urinalysis, blood biochemistry, and complete blood count. Stone characteristics were evaluated using ultrasonography and non-contrast computed tomography (CT). Preoperative variables recorded included age, sex, laterality of the stone, body mass index (BMI), stone complexity, stone number, stone burden, operative time, preoperative ureteral stenting, postoperative residual stones, stone density, and perioperative complications. Stone burden (mm^2) = Maximum length of the stone(Lmax) × Maximum width of the stone(Wmax) × 0.785. Stone density was expressed as mean Hounsfield units (HU) on CT. This study classified the complexity of calculi based on the number of affected sites: Grade l 1, calculi only affect one site in the upper urinary tract (kidney pelvis, renal calyx or ureter); Grade 2, calculi affect two sites in the upper urinary tract (renal calyx and/or kidney pelvis and/or ureter); Grade 3, calculi affect three sites in the upper urinary tract (kidney pelvis, renal calyx and ureter).

Surgical Technique

All surgeries were performed under general anesthesia by pediatric urologists with over 10 years of experience. Endoscopic surgery was considered for patients with renal stones unsuitable for conservative management, particularly those with stones < 2 cm or selected cases requiring endoscopic

intervention. Patients with urinary system anatomical abnormalities were excluded. For patients with narrow ureters, preoperative passive dilation using a ureteral stent was performed 2–4 weeks prior to surgery.

For stones located in the ureter or stones accessible with rigid ureteroscopes, rigid ureteroscopy was used preferentially. Stones located in the mid- or lower calyces, inaccessible with rigid instruments, were treated with flexible ureteroscopes. Laser lithotripsy was performed using Holmium laser or Thulium lasers.

Postoperatively, ureteral stents were routinely placed and removed after 4–6 weeks. Stone clearance was assessed four weeks after stent removal using ultrasonography. Residual fragments > 4 mm were considered clinically significant.

Statistical Analysis

Data analysis was performed using SPSS version 27.0. Continuous variables not conforming to normal distribution were reported as median (interquartile range, P25–P75) and compared using the Mann–Whitney U test. Categorical variables were compared using the chi-square test. Variables with statistical significance in univariate analysis were included in multivariate logistic regression models to identify independent predictors of residual stones. Statistical significance was defined as $P < 0.05$.

Results

A total of 92 pediatric patients, comprising 108 renal units, underwent endoscopic surgery and were included in the analysis. Overall, postoperative ultrasonography demonstrated complete stone clearance in 93 renal units (86.1%), while 15 units (13.9%) had residual stones > 4 mm.

The median age of the cohort was 42.5 months (interquartile range [IQR], 25.0–83.5 months), with 71 male patients (76.9%) and 21 female patients (23.1%). Stone laterality was approximately balanced, with 53 left-sided (49.1%) and 55 right-sided (50.9%) renal units. Preoperative ureteral stenting was performed in 36 renal units (33.3%). Complexity of calculi was predominantly grade 1 (78 units, 72.2%), followed by grade 2 (25 units, 23.2%) and grade 3 (5 units, 4.6%). The median BMI was 16.4 kg/m² (IQR, 14.5–18.1), median stone density was 663 HU (IQR, 132.3–1123.5), median stone burden was 41.8 mm² (IQR, 23.6–80.1), and median operative time was 65 minutes (IQR, 50–90).

Among the 108 renal units, 93 achieved complete stone clearance and 15 had residual stones. Patients in the residual stone group were younger, with a median age of 28.0 months (IQR 14.0–47.0) compared with 49.5 months (IQR 28.0–84.0) in the stone-free group ($P = 0.021$). Similarly, BMI was lower in the residual stone group, with a median of 13.6 kg/m² (IQR 12.9–17.1) versus 16.8 kg/m² (IQR 15.1–18.2) in the stone-free group ($P = 0.001$).

Sex distribution and stone laterality did not differ significantly between groups. The residual stone group included 9 males (60.0%) and 6 females (40.0%), whereas the stone-free group included 74 males (79.6%) and 19 females (20.4%; P = 0.095). Left-sided stones were present in 6 units (40.0%) of the residual group versus 47 units (50.5%) in the stone-free group, and right-sided stones in 10 units (60.0%) versus 46 units (49.5%; P = 0.449).

Preoperative ureteral stenting was more common in the residual stone group, performed in 10 of 15 renal units (66.7%) compared with 26 of 93 units (28.0%) in the stone-free group (P = 0.003). The median stone burden was slightly higher in the residual group at 49.8 mm^2 (IQR 36.4–86.4) versus 41.6 mm^2 (IQR 23.0–78.8) in the stone-free group, although this difference did not reach statistical significance (P = 0.141). Stone density, however, was significantly higher in the residual stone group, with a median of 968 HU (IQR 488–1246) compared with 530 HU (IQR 127.3–1121.8) in the stone-free group (P = 0.018). Operative time was also longer in the residual group, with a median of 80 minutes (IQR 60–115) versus 65 minutes (IQR 46.3–90.0) in the stone-free group (P = 0.043).

Complexity of calculi differed significantly between groups. In the residual stone group, 4 renal units (26.7%) were grade 1, 7 units (46.7%) were grade 2, and 4 units (26.7%) were grade 3. In contrast, in the stone-free group, the majority were grade 1 (74 units, 79.6%), followed by grade 2 (18 units, 19.4%) and grade 3 (1 unit, 1.1%; P < 0.001). The number of stones was higher in the residual group as well: 1 stone in 4 units (26.7%), 2 stones in 5 units (33.3%), 3 stones in 4 units (26.7%), and 4 stones in 2 units (13.3%), compared with 68 units (73.1%) with 1 stone, 21 units (22.6%) with 2 stones, 2 units (2.2%) with 3 stones, and 2 units (2.2%) with 4 stones in the stone-free group (P < 0.001).

In univariate analysis, younger age, lower BMI, higher stone density, longer operative time, preoperative ureteral stenting, greater complexity of calculi, and higher stone number were significantly associated with postoperative residual stones(Table 1). Multivariate logistic regression analysis identified complexity of calculi as the only independent predictor of residual stones after endoscopic surgery (OR = 4.908, 95% CI 1.068–22.544, P = 0.041). Age, BMI, stone density, operative time, and stone number did not remain significant in the multivariate model (all P > 0.05). (Table 2)

Table 1
Univariate analysis of factors influencing residual stones after ureteroscopic treatment of upper urinary tract stones

Parameters n, (%)	**Cleared n = 93**	**Not cleared n = 15**	**P**
Gender (n, %)			0.095
Male	74(79.6%)	9(60.0%)	
Female	19(20.4%)	6(40.0%)	
Side (n, %)			0.449
Left	47(50.5%)	6(40.0%)	
Right	46(49.5%)	9(60.0%)	
Pre-operative stenting (n, %)			0.003
Yes	26(28.0%)	10(66.7%)	
No	67(72.0%)	5(33.3%)	
Age (months)	49.5(28.0,84.0)	28.0(14.0,47.0)	0.021
BMI(kg/m^2)	16.8(15.1,18.2)	13.6(12.9, 17.1)	0.001
Stone burden(mm^2)	41.6(23.0,78.8)	49.8(36.4, 86.4)	0.141
Stone density (Hounsfield unit, Hu)	530.0(127.3, 1121.8)	968.0(488.0, 1246.0)	0.018
Operation duration (min)	65.0(46.3, 90.0)	80.0(60.0,115.0)	0.043
Complexity of calculi			< 0.001
1	74(79.6%)	4(26.7%)	
2	18(19.4%)	7(46.7%)	
3	1(1.1%)	4(26.7%)	
No. stones			< 0.001
1	68(73.1%)	4(26.7%)	
2	21(22.6%)	5(33.3%)	
3	2(2.2%)	4(26.7%)	
4	2(2.2%)	2(13.3%)	

Table 2
Univariate and multivariate analysis of factors influencing residual stones after endoscopic surgery in children

Variables	Univariate analysis				Multivariable analysis			
	OR	95% CI		P	OR	95% CI		P
		Lower	Upper			Lower	Upper	
Gender	0.385	0.122	1.216	0.104				
Side	0.652	0.215	1.980	0.451				
Age (months)	0.977	0.957	0.988	0.033	0.977	0.953	1.002	0.075
BMI(kg/m^2)	0.708	0.537	0.933	0.014	0.889	0.611	1.292	0.536
Stone burden(mm^2)	1.009	0.997	1.021	0.125	-	-	-	-
Stone density (Hounsfield unit)	1.001	1.000	1.003	0.042	1.000	0.998	1.002	0.830
Operation duration (min)	1.016	1.002	1.031	0.026	1.012	0.992	1.033	0.237
Complexity of calculi	7.996	2.909	21.976	< 0.001	4.908	1.068	22.544	0.041
No. stones	3.447	1.775	6.695	< 0.001	1.390	0.496	3.899	0.531
Pre-operative stenting (n, %)	5.154	1.607	16.525	0.006	2.068	0.373	11.479	0.406
Variables not included in the multivariable model are indicated by —.								

In summary, residual stones occurred in 13.9% of renal units. Although several clinical and stone-related factors were associated with residual stones in univariate analysis, only complexity of calculi remained an independent predictor after multivariate adjustment.

Discussion

The present study evaluated factors associated with residual stones after endoscopic treatment of upper urinary tract calculi in children and demonstrated an overall stone-free rate (SFR) of 86.1%. Although younger age, lower body mass index (BMI), higher stone density, longer operative time, preoperative ureteral stenting, greater stone complexity, and a higher stone number were associated with residual stones in univariate analyses, only the complexity of calculi remained independently associated with residual stones after multivariable adjustment. These findings are clinically relevant because contemporary pediatric stone surgery has increasingly shifted toward minimally invasive endourological approaches[7], while incomplete clearance remains an important concern even when overall procedural

success is favorable[8]. Rather than identifying a single conventional stone characteristic as the dominant determinant of outcome, our results suggest that the anatomical extent of stone involvement may better capture the overall difficulty of endoscopic clearance in children.

The SFR observed in our cohort is consistent with previously reported outcomes of pediatric ureteroscopic treatment. In a systematic review of flexible ureteroscopy and laser lithotripsy for pediatric renal calculi, Ishii et al. reported a mean initial SFR of 85.5%, although substantial variation existed among individual studies[8]. Li et al. reported a single-session SFR of 94.6% in infants undergoing flexible ureteroscopic lithotripsy [5], whereas Erkurt et al. reported initial and second-session SFRs of 83.1% and 92.3%, respectively, in preschool-aged children [9]. Similarly, a series including both rigid ureteroscopy and retrograde intrarenal surgery reported a first-procedure success rate of 76.6%, increasing to 93.3% after a second intervention [10]. These data place our SFR of 86.1% within the range reported for contemporary pediatric endoscopic stone management. Importantly, however, comparison of SFRs across studies should be interpreted cautiously because definitions of stone-free status, imaging modalities, timing of postoperative assessment, stone burden, and the proportion of rigid versus flexible ureteroscopic procedures differ substantially. Our cohort included both rigid and flexible ureteroscopic procedures, and therefore our findings are best interpreted as outcomes of pediatric endoscopic management rather than of flexible ureteroscopy alone.

The principal finding of the present study was the independent association between stone complexity and postoperative residual stones. This observation is consistent with the broader concept that surgical outcome is determined not simply by the size of a stone but by the interaction between stone burden, distribution, anatomical accessibility, and the geometry of the collecting system. Importantly, a pediatric study externally validating several RIRS scoring systems found significant differences between stone-free and non-stone-free groups in stone complexity and cumulative stone size, and demonstrated that models incorporating multiple anatomical and stone-related parameters provided meaningful discrimination of postoperative SFR [11]. More recently, Özgür et al. reported an overall SFR of 86.2% after pediatric semi-rigid ureteroscopy and found stone volume, dimensions, and localization to be independently associated with stone-free outcome, whereas patient age and stone density were not independent predictors [12]. Although that population primarily involved ureteral stones and therefore is not directly equivalent to the present cohort, the findings reinforce the concept that the spatial characteristics of stone disease may be more informative than isolated patient characteristics when estimating the likelihood of complete clearance.

The complexity classification used in the present study was specifically designed to reflect the number of upper urinary tract anatomical regions involved by calculi. This approach differs from established nephrolithometric systems developed predominantly for adult patients. The Resorlu–Unsal Stone Score, for example, incorporates stone size, stone number, lower-pole anatomy, and abnormal renal anatomy to estimate SFR after RIRS [13]. The R.I.R.S. scoring system similarly combines stone density, inferior-pole location, stone burden, and renal infundibular length [14]. These systems illustrate that anatomical accessibility and stone distribution contribute substantially to the probability of complete clearance. In

addition, a systematic review examining pelvicalyceal anatomy demonstrated that an unfavorable infundibulopelvic angle can impair clearance after RIRS for lower-pole stones [15]. Collectively, these observations provide a mechanistic explanation for our finding: when calculi involve multiple anatomical regions, successful treatment may require repeated repositioning of the ureteroscope, access to different calyces or ureteral segments, repeated fragmentation and retrieval, and management of fragments displaced into less accessible portions of the collecting system. Each additional anatomical site may therefore increase the opportunity for residual fragments to remain despite technically successful lithotripsy.

Several findings from the univariate analysis warrant careful interpretation. Younger children and those with lower BMI had higher rates of residual stones; however, neither variable remained significant in the multivariable model. Younger age and lower BMI may partly reflect smaller body and ureteral dimensions, which can increase technical difficulty, but these characteristics may also be correlated with one another and with procedural selection. Similarly, higher stone density was associated with residual stones in univariate analysis but lost significance after adjustment. Stone density may influence fragmentation efficiency, but it does not directly describe whether all involved sites can be reached and cleared. Notably, recent pediatric ureteroscopy data similarly found no independent association between HU and SFR after adjustment for other stone characteristics [12].

The association between preoperative ureteral stenting and residual stones should likewise not be interpreted as evidence that stenting reduces surgical success. In our practice, preoperative stenting was selectively performed when the ureter was narrow and passive dilation was considered necessary. Therefore, stenting is likely to represent a marker of more technically challenging anatomy or anticipated difficult access rather than a causal determinant of residual stones. The same caution applies to operative time. Longer procedures were associated with residual stones in univariate analysis, but operative duration is partly an intraoperative consequence of stone complexity, difficult access, fragmentation requirements, and repeated endoscopic manipulation. It should therefore be considered more appropriately as a marker of procedural difficulty than as a true preoperative predictor. This distinction is important if the ultimate goal of the proposed complexity classification is preoperative risk stratification.

The lack of an independent association between stone number and residual stones after adjustment is also informative. Stone number was strongly associated with outcome in univariate analysis, yet it did not retain independent significance. Number alone does not indicate where stones are located. Two or more stones clustered within an easily accessible renal pelvis may be technically less challenging than a similar number distributed among separate calyces and the ureter. In this context, our anatomical complexity grade may integrate information that stone count alone cannot capture. Nevertheless, this interpretation should be considered hypothesis-generating rather than definitive because the proposed grading system has not yet undergone independent validation. Its principal potential advantage is simplicity: the grade can be determined according to the anatomical extent of stone involvement without complex measurements. Conversely, this simplicity necessarily sacrifices anatomical detail, including

specific calyceal location, infundibular anatomy, and the distinction between favorable and unfavorable lower-pole access. Accordingly, the current system should be described as a preliminary risk-stratification framework rather than a validated nephrolithometric score.

The definition and detection of residual stones deserve particular attention. In the present study, residual fragments > 4 mm were considered clinically significant. This threshold is supported by previous pediatric endourological experience; Erkurt et al. used residual calculi > 4 mm as an indication for second-stage RIRS [9], and Ferretti et al. similarly distinguished residual fragments greater than 4 mm in pediatric URS/RIRS outcomes [10]. More importantly, residual fragments in children should not necessarily be regarded as clinically irrelevant. Dincel et al. followed children with residual fragments < 4 mm after SWL, PNL, or RIRS and found that a substantial proportion developed symptoms, fragment regrowth, or ultimately required secondary intervention [16]. Thus, although our > 4-mm threshold provides a clinically pragmatic outcome definition, smaller fragments cannot be assumed to be biologically or clinically insignificant, particularly in a population with a long remaining lifetime at risk for recurrent stone disease.

Postoperative stone clearance in our cohort was assessed by ultrasonography. This approach reflects an important pediatric trade-off between diagnostic sensitivity and radiation exposure. Ultrasound avoids ionizing radiation and is therefore particularly suitable for repeated surveillance in children. However, its limitations must be acknowledged. Roberson et al. found that ultrasound had high specificity but only moderate sensitivity for detecting pediatric nephrolithiasis when CT was used as the reference standard, with most missed stones being small [17]. Consequently, our ultrasound-based follow-up may have underestimated the frequency of small residual fragments and may partly contribute to differences in SFR when compared with studies using CT-based endpoints. Nevertheless, routine CT for postoperative surveillance in every child would introduce an additional radiation burden. A recent review of CT use in pediatric urolithiasis emphasized both variability in radiation exposure and the need to use low- or ultra-low-dose protocols selectively when CT is clinically required [18]. Thus, the use of ultrasonography in the present study is clinically defensible, but the reported SFR should specifically be interpreted as an ultrasound-defined outcome.

The clinical implications of these findings extend beyond prediction of a single postoperative imaging result. Children with higher stone complexity may benefit from more detailed preoperative counseling regarding the possibility of incomplete clearance or staged treatment, more careful procedural planning, and closer postoperative surveillance. This is particularly relevant because pediatric stone disease has a substantial long-term recurrence burden. Tasian et al. reported that approximately half of children with an incident symptomatic stone experienced symptomatic recurrence within three years [19]. In addition, metabolic abnormalities are frequent enough to justify systematic evaluation in pediatric stone formers; contemporary metabolic studies have identified low urine volume and hypocitraturia among common abnormalities in children presenting with nephrolithiasis [20]. Therefore, achieving surgical clearance should not be considered the endpoint of management. Children with complex stone disease, and

especially those with residual fragments, may require a combined strategy incorporating imaging surveillance, metabolic evaluation, and individualized recurrence-prevention measures.

Several limitations of the present study should be acknowledged. First, this was a retrospective, single-center study with a relatively small sample size. Only 15 renal units developed clinically significant residual stones, while several variables were entered into multivariable analysis. The limited number of outcome events is reflected by the wide confidence interval around the association between complexity and residual stones and increases the risk of model instability and overfitting. Accordingly, the magnitude of the odds ratio should be interpreted cautiously, and the principal conclusion should be the presence of an independent association rather than the precise effect size. Second, the analysis was performed at the renal-unit level, and some children contributed bilateral renal units; observations from the same patient may therefore not be completely independent. Future multicenter studies should account for within-patient clustering where applicable. Third, detailed information on individual calyceal stone location and collecting-system anatomy was unavailable. These features may influence endoscopic access and clearance and may improve the predictive ability of future versions of the classification. Fourth, stone composition was not available. Because stone composition can influence fragmentation characteristics and was incorporated into previous RIRS outcome models [13], this represents a potentially relevant unmeasured factor. Fifth, postoperative assessment relied on ultrasound rather than CT, which may have resulted in underdetection of small residual fragments. Finally, the complexity grading system was developed and evaluated within the same cohort. Prospective external validation, evaluation of interobserver reproducibility, and comparison with established RIRS scoring systems are required before it can be recommended as a formal clinical prediction tool.

In conclusion, endoscopic treatment using rigid and/or flexible ureteroscopy achieved a favorable SFR in children with upper urinary tract calculi. Although several patient-, stone-, and procedure-related variables were associated with residual stones on univariate analysis, stone complexity was the only factor that remained independently associated with incomplete clearance after adjustment. A simple classification based on the anatomical extent of stone involvement may therefore provide useful information beyond stone number or density alone. At present, this classification should be considered a preliminary risk-stratification approach. If validated in larger multicenter pediatric cohorts, assessment of stone complexity may assist with preoperative counseling, operative planning, identification of children who may require staged treatment, and selection of patients who warrant closer postoperative surveillance.

Conclusion

Endoscopic surgery provides satisfactory stone clearance with acceptable safety in pediatric patients with upper urinary tract stones. In this cohort, the overall stone-free rate reached 86.1%, confirming the effectiveness of flexible ureteroscopic management in children. Among the evaluated clinical and stone-related parameters, complexity of calculi was identified as the independent predictor of postoperative residual stones. Preoperative assessment of stone complexity using standardized scoring systems may

help identify patients at higher risk of incomplete clearance, facilitate individualized surgical decision-making, and optimize postoperative surveillance strategies.

Declarations

Funding:

No funding was received for conducting this study.

Competing interests

The authors have no relevant financial or non-financial interests to disclose.

Data Availability:

The data supporting the findings of this retrospective study are not publicly available because they contain sensitive clinical information from pediatric patients and are subject to ethical and institutional privacy restrictions. The study was approved by the ethics board of Children's Hospital Affiliated of Zhengzhou University, Henan Children's Hospital, Zhengzhou Children's Hospital, and individual consent for this retrospective analysis was waived. De-identified data may be available from the corresponding author, Jianpeng Bi (bjp9527@126.com), upon reasonable request and with approval from the institutional ethics board. No public repository was used.

Authors' contributions:

Jian Zhao contributed to the analysis and interpretation of the data, the study design, as well as writing of the manuscript under the instructions of Jianpeng Bi. Liangbin Li provided and collected the clinical data. All authors read and approved the final manuscript.

Ethics approval:

The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics board of Children's Hospital Affiliated of Zhengzhou University, Henan Children's Hospital, Zhengzhou Children's Hospital.

Consent to participate:

The requirement for informed consent was waived by the Ethics Committee of [institution] because of the retrospective nature of the study.

References

1. Bush NC, Xu L, Brown BJ, et al (2010) Hospitalizations for Pediatric Stone Disease in United States, 2002–2007. Journal of Urology 183:1151–1156. https://doi.org/10.1016/j.juro.2009.11.057
2. Novak TE, Lakshmanan Y, Trock BJ, et al (2009) Sex Prevalence of Pediatric Kidney Stone Disease in the United States: An Epidemiologic Investigation. Urology 74:104–107. https://doi.org/10.1016/j.urology.2008.12.079
3. Tasian GE, Ross ME, Song L, et al (2016) Annual Incidence of Nephrolithiasis among Children and Adults in South Carolina from 1997 to 2012. Clinical Journal of the American Society of Nephrology 11:488–496. https://doi.org/10.2215/CJN.07610715
4. Huffman JL, Bagley DH, Lyon ES (1983) Extending cystoscopic techniques into the ureter and renal pelvis. Experience with ureteroscopy and pyeloscopy. JAMA 250:2002–2005. https://doi.org/10.1001/jama.1983.03340150044024
5. Li J, Xiao J, Han T, et al (2017) Flexible ureteroscopic lithotripsy for the treatment of upper urinary tract calculi in infants. Exp Biol Med (Maywood) 242:153–159. https://doi.org/10.1177/1535370216669836
6. Fahlenkamp D, Noack B, Lebentrau S, Belz H (2008) Urolithiasis bei Kindern – rationelle Diagnostik, Therapie und Metaphylaxe. Urologe 47:545–555. https://doi.org/10.1007/s00120-008-1733-2
7. Onal B, Citgez S, Tansu N, et al (2013) What changed in the management of pediatric stones after the introduction of minimally invasive procedures? A single-center experience over 24 years. Journal of Pediatric Urology 9:910–914. https://doi.org/10.1016/j.jpurol.2012.12.015
8. Ishii H, Griffin S, Somani BK (2014) Flexible ureteroscopy and lasertripsy (FURSL) for paediatric renal calculi: Results from a systematic review. Journal of Pediatric Urology 10:1020–1025. https://doi.org/10.1016/j.jpurol.2014.08.003
9. Erkurt B, Caskurlu T, Atis G, et al (2014) Treatment of renal stones with flexible ureteroscopy in preschool age children. Urolithiasis 42:241–245. https://doi.org/10.1007/s00240-013-0636-x
10. Ferretti S, Cuschera M, Campobasso D, et al (2021) Rigid and flexible ureteroscopy (URS/RIRS) management of paediatric urolithiasis in a not endemic country. Arch Ital Urol Androl 93:26–30. https://doi.org/10.4081/aiua.2021.1.26
11. Zhao F-Z, Xia J-Z, Li J, et al (2022) External validation of efficacy and reliability of different retrograde intrarenal surgery (RIRS) scoring systems for pediatric nephrolithiasis. Journal of Pediatric Urology 18:313.e1-313.e6. https://doi.org/10.1016/j.jpurol.2022.03.023
12. Özgür MÖ, Halil Baloğlu İ, Karlı G, Horasanlı K (2026) Predictive factors for stone-free rates and evaluation of mucosal injury using PULS grading system in pediatric ureteroscopy: a single-center experience. Urolithiasis 54:78. https://doi.org/10.1007/s00240-026-01985-4
13. Resorlu B, Unsal A, Gulec H, Oztuna D (2012) A New Scoring System for Predicting Stone-free Rate After Retrograde Intrarenal Surgery: The “Resorlu-Unsal Stone Score.” Urology 80:512–518. https://doi.org/10.1016/j.urology.2012.02.072
14. Xiao Y, Li D, Chen L, et al (2017) The R.I.R.S. scoring system: An innovative scoring system for predicting stone-free rate following retrograde intrarenal surgery. BMC Urol 17:105.

https://doi.org/10.1186/s12894-017-0297-0

15. Karim SS, Hanna L, Geraghty R, Somani BK (2020) Role of pelvicalyceal anatomy in the outcomes of retrograde intrarenal surgery (RIRS) for lower pole stones: outcomes with a systematic review of literature. Urolithiasis 48:263–270. https://doi.org/10.1007/s00240-019-01150-0
16. Dincel N, Resorlu B, Unsal A, et al (2013) Are small residual stone fragments really insignificant in children? Journal of Pediatric Surgery 48:840–844. https://doi.org/10.1016/j.jpedsurg.2012.07.061
17. Roberson NP, Dillman JR, O'Hara SM, et al (2018) Comparison of ultrasound versus computed tomography for the detection of kidney stones in the pediatric population: a clinical effectiveness study. Pediatr Radiol 48:962–972. https://doi.org/10.1007/s00247-018-4099-7
18. MacNevin W, Chua M, Kraus MS, Keefe DT (2024) Radiation exposure associated with computed tomography for pediatric urolithiasis evaluation: A scoping review of the literature. Journal of Pediatric Urology 20:386–394. https://doi.org/10.1016/j.jpurol.2024.03.007
19. Tasian GE, Kabarriti AE, Kalmus A, Furth SL (2017) Kidney Stone Recurrence among Children and Adolescents. Journal of Urology 197:246–252. https://doi.org/10.1016/j.juro.2016.07.090
20. Bevill M, Kattula A, Cooper CS, Storm DW (2017) The Modern Metabolic Stone Evaluation in Children. Urology 101:15–20. https://doi.org/10.1016/j.urology.2016.09.058