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Stone-free rate of laser lithotripsy for large pediatric stones: 15-year experience from a tertiary endourology pediatric center

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Abstract

Background: Pediatric urolithiasis, while less common than in adults, is increasing in incidence. However, current guidelines on the optimal management of this condition vary. Technological advances have led to improvements in the quality and size of ureteroscopes, thus enabling their use in children. Despite this, there remains some hesitancy about using ureteroscopic lithotripsy in the pediatric population, particularly in cases of large stones ⩾10 mm.

Objectives: In this study, our aim was to evaluate the efficacy and safety of ureteroscopy and laser stone fragmentation (URSL) for managing pediatric patients with a cumulative stone burden of ⩾10 mm in our tertiary referral center.

Methods: A dataset was collected of pediatric renal tract stone patients treated at a single tertiary urological center between June 2010 and May 2024 (15 years). Pediatric patients undergoing URSL procedures for a minimum cumulative stone burden ⩾10 mm were included. A retrospective analysis of the dataset was conducted. The primary outcomes measured were stone-free rates (SFR), complications classified according to the Clavien-Dindo classification, and hospital length of stay.

Results: A total of 61 pediatric patients with a mean age of 10 years (range: 2.3–16) underwent 83 URSL procedures in a tertiary endourology pediatric center over a 15-year period (2010–2024). The median initial stone burden was 17 mm (IQR: 12.5–24 mm), acquired from preoperative ultrasonography (USS). Results showed a first-pass SFR of 63.9% and a cumulative SFR of 93.4% (on USS) following one or multiple URSL procedures (1.4 procedures/patient). Immediate postoperative complications were minimal, with 6% experiencing complications classified as Clavien-Dindo I or II. The average hospital length of stay was 1.4 days.

Conclusion: The findings in this study support that URSL is effective in treating pediatric urolithiasis, even for larger stone burdens. Further research is needed to standardize guidelines and optimize management strategies in this population.

Plain language summary

Safety and outcomes of large paediatric stones treated by ureteroscopy

Large paediatric renal stones are often treated by percutaneous stone surgery procedure. In this paper we look at Ureteroscopy as a treatment for these large paediatric stones. Our data shows a good stone free rate with low risk of complications. Perhaps, ureteroscopy will offer an alternate treatment for these vulnerable age group especially for large renal stones.

Keywords: kidney calculi, large stone, pediatrics, RIRS, ureteroscopy

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Introduction

Despite being less common in children than it is in adults, the global incidence of pediatric urolithiasis has been rising.[1] Ward et al.[2] described a gradual increase in pediatric kidney stone disease (KSD) from 2005, with a peak at 65.2/100,000 person-years in 2011 in the USA. This trend has also been demonstrated in data from the Global Burden of Disease Collaborative Network,[3] and in observational studies across the world.[4–6] Within the pediatric population, sex distribution varies according to age, with boys representing the majority of stone-formers in children under 10, and girls being most at risk from the second decade of life.[7]

Metabolic disorders are one of the most common etiologies of pediatric kidney stones, with one review reporting this in one-third of patients.[8] Another study found that 50% of nephrolithiasis patients under 10 years of age had a metabolic disorder.[9] Of pediatric patients with metabolic abnormalities, over 50% were found to have hypercalciuria in an observational study of over 500 patients, with hyperoxaluria and cystinuria being the next most frequent abnormalities.[10] In line with this finding, when analyzing stone composition in the pediatric population, 70% of stones contain calcium oxalate.[11] In older children, increasing incidence is thought, in part, to reflect the rise in rates of obesity and lifestyle risk factors also found in adults.[8]

There has been a rise in the use of ureteroscopy and laser lithotripsy (URSL) for KSD in the pediatric population since Ritchey et al.[12] first described it in the late 1980s. Despite this technique being available for over 30 years, European Association of Urology (EAU) pediatric guidelines currently only recommend ureteroscopy (URS) as first-line management for lower ureteric stones, with shockwave lithotripsy (SWL) being favored in small pelvis stones (<10 mm), small lower pole calyx stones, and upper ureter stones, and percutaneous nephrolithotomy (PCNL) in large pelvic stones (>20 mm) or large lower pole calyx stones.[13] Specifically, the authors highlight the risk of complications when using URS in proximal ureteral stones in the pediatric population.[14] The American Urological Association guidelines from 2016 recommend using either SWL or URS as first-line therapy in renal stones if the total stone burden is less than 20 mm or for pediatric patients with ureteral stones that are unlikely to respond to conservative management.[15] This guideline recommends PCNL or SWL if the renal stone burden is >20 mm. In contrast, the United Kingdom's National Institute for Health and Care Excellence (NICE) guideline advocates the use of either URS, SWL, or PCNL for renal stones ⩾10 mm and recommends URS and SWL for ureteric stones ⩾10 mm in pediatric patients.[16] The discrepancy between different national and international guidelines highlights the paucity of research in this area of pediatric stone management.

URSL is routinely used in the management of adult KSD. There has been an increase in the development of endourological equipment and the use of different lithotripsy techniques making this a viable option in pediatric populations.[13] However, compared to adults, children undergoing URSL appear to have slightly higher complication rates which may be related to the fact that this procedure has not been used as extensively in this population and that the pediatric endourological equipment is still evolving.[17]

This case series describes the perioperative outcomes of URSL procedures undertaken in a pediatric population with renal and/or ureteric stone burden ⩾10 mm. Through this, it aims to highlight URSL's potential to push the boundaries of current minimally invasive surgical techniques in managing pediatric stones.

Methods

A dataset of pediatric renal tract stone patients treated at a single tertiary urological center between June 2010 and May 2024 was collected (15 years). The study was registered with our "Clinical Effectiveness and Audit department" (audit number 6901). Pediatric patients undergoing URSL procedures for a minimum cumulative stone burden ⩾10 mm were included. Exclusion criteria were age over 16 years, minimum cumulative stone burden less than 10 mm and patients with pelviureteric junction (PUJ) obstruction who needed a subsequent definitive procedure for PUJO or the PUJ was inaccessible. A retrospective analysis of the dataset was conducted. The data extracted included patient demographics, comorbidities, preoperative urine samples, anatomical variations, stone location, stone characteristics, total stone burden, pre- and postoperative stents, use of ureteric access sheath, type of scope, type of energy, length of stay in the hospital, stone-free rates (SFR), and intraoperative and postoperative complications. The complications were classified according to the Clavien-Dindo classification.

Patients underwent diagnostic imaging pre-operatively, primarily using ultrasound with additional X-ray or CT imaging in selected cases. A urine culture and a biochemical work-up were undertaken prior to the procedure taking place. Patients whose preoperative urine culture was positive were treated with antibiotics according to microbiological sensitivities.

All URSL procedures were performed with X-ray guidance by the specialist pediatric and adult stone team under general anesthesia. All patients received intraoperative antibiotics at induction in accordance with the local protocol. The surgical approach was tailored to each patient, with equipment selection based on patient age, anatomical considerations, and stone characteristics. Either a 6/7.5 Fr semirigid ureteroscope, a 7.5 Fr flexible ureteroscope (Karl Storz, Tuttlingen, Germany), or a 7.5 Pusen single-use flexible ureteroscope (CJ Medical, Truro, UK) was utilized. In select cases of renal stones, particularly where multiple ureteroscope passes were anticipated or enhanced irrigation flow was needed, and the ureter was compliant, a ureteral access sheath was used. Stone fragmentation was performed using a holmium:YAG laser (Lumenis, Israel). Laser settings were carefully adapted based on stone location, with a total power threshold of 10 Watts for ureteral stones and 25 Watts for stones in the pelvicalyceal system. A combination of fragmenting, dusting, and pop-dusting techniques was employed, with energy and frequency settings between 0.4–1 J and 5–50 Hz respectively. Stone extraction was carried out using Nitinol baskets (Cook Medical, Bloomington, IN, USA; or Boston Scientific Ltd., Hemel Hempstead, UK).

Following stone fragmentation and extraction, the decision to place a ureteral stent was made individually based on intraoperative findings, including the degree of ureteral edema, volume of residual small fragments or dust, and overall procedure complexity. When stents were placed, they were routinely removed in an outpatient setting 2–4 weeks after the procedure(s). Stone fragments were sent for stone composition analysis. Most patients were admitted overnight for observation following the procedure.

Patients were classified as stone-free when they had endoscopically and radiologically confirmed clearance of the treated stone, or residual fragments ⩽2 mm in size. This involved a follow-up ultrasound approximately 2–3 months after the patient's last procedure, which was carried out at the operating center or at the referring hospital. New stone development following confirmation of stone clearance were classified as new stone episodes. The SFR was defined as the percentage of patients achieving stone-free status.

Data analysis and presentation were performed in accordance with the adapted CARE guidelines for surgical case reports (SCARE).[18] The completed checklist is available in Supplemental Table 1.

Results

Between June 2010 to May 2024, 61 patients underwent URSL for a minimum stone size of 10 mm. Of those, 26 were male and 35 were female. The average age of affected patients was 10 years (SD: 4.3). Metabolic abnormalities were found in 17 patients (27.9%), 13 with hypercalciuria and 4 with cystinuria. Preoperative urine culture was positive prior to 11 of the procedures, with patients receiving antibiotics according to microbial sensitivities and local guidelines.

As some patients required multiple procedures for a single stone episode, 83 URSL procedures were carried out in total, for an average of 1.4 procedures per patient. There were 45 procedures carried out on the left side, 33 on the right side, and 5 bilaterally. Baseline characteristics of the patient cohort and periprocedural features are outlined in Table 1. Individual patient characteristics are included in Supplemental Table 2.

Preoperative work-up demonstrated stones in multiple locations in 29 patients. The most frequent stone location was renal lower pole ($n=29$), followed by renal pelvis ($n=19$), renal middle pole ($n=8$), and distal ureter ($n=8$). The median initial stone burden was 17 mm (interquartile range: 12.5–24 mm).

A preoperative stent was present in 36 cases (43.4%) with a nephrostomy in 5 (6%) cases. The stent was placed for infection, obstruction, or urosepsis. In some cases, it was done in a peripheral hospital that did not offer primary ureteroscopy. A percutaneous nephrostomy was

Table 1. Patient cohort characteristics (per patient) and perioperative characteristics (per procedure).

Patient and stone characteristics (*n* = 61) Number of procedures (*n* = 83)	
Gender—*n* (%)	
Male	26 (42.6%)
Female	35 (57.4%)
Age—mean ± SD (years)	10.0 ± 4.3
Metabolic abnormalities—*n* (%)	
Hypercalciuria	13 (21.3%)
Cystinuria	4 (6.6%)
Anatomical abnormalities—*n* (%)	
Horseshoe kidney	3 (4.9%)
Antenatal hydronephrosis	2 (3.3%)
Duplex system	2 (3.3%)
Transplanted kidney	1 (1.6%)
Tortuous ureter	1 (1.6%)
Solitary kidney	1 (1.6%)
Preoperative stent—*n* (%)	
No	42 (50.6%)
Yes	36 (43.4%)
Indwelling nephrostomy	5 (6.0%)
Stones in multiple locations—*n* (%)	29 (47.5%)
Stone location*—*n* (%)	
Renal	
Upper pole	6 (9.8%)
Middle pole	8 (13.1%)
Lower pole	29 (47.5%)
Pelvis	19 (31.1%)
Pelviureteric junction (PUJ)	4 (6.6%)
Ureteric	
Proximal ureter	2 (3.3%)
Mid-ureter	2 (3.3%)
Distal ureter	8 (13.1%)
Ureteral access sheath use—*n* (%)	32 (38.6%)
Postoperative stent or catheter**	
No	29 (34.9%)
JJ stent	37 (44.6%)
Open-ended ureteral catheter	14 (16.9%)
Indwelling nephrostomy	3 (3.6%)
Stone composition**—*n* (%)	
Calcium oxalate	22 (36.1%)
Calcium phosphate	21(34.4%)
Cystine	2 (3.3%)
Magnesium ammonium phosphate	15 (24.6%)
Not available	15 (24.6%)

*Some patients had stones in more than one location.
**Some patients had more than one stone type.

inserted for urosepsis. A ureteral access sheath (9.5/11.5F) was used in 32 cases (38.6%). A JJ stent was left in situ following 37 URSL procedures (44.6%), and an open-ended ureteral catheter was left in situ after 14 procedures (16.9%), with one bilateral procedure involving both stent and open-ended ureteral catheter insertion.

Intra-operatively, both flexible and rigid ureteroscopes were used in 50 cases (60.2%), compared with 23 cases (27.7%) and 10 cases (12.0%) in which flexible and rigid ureteroscopes were used, respectively. Laser lithotripsy was used in 79 procedures (95.2%) and was combined with basket retrieval in 35 instances. Stone composition analysis revealed that calcium oxalate and calcium phosphate stones were the most common, followed by magnesium ammonium phosphate stones. In 15 patients, this data was not available, although it is worth noting that, of those, six had hypercalciuria, two had cystinuria, and one had an established diagnosis of Dent's disease.

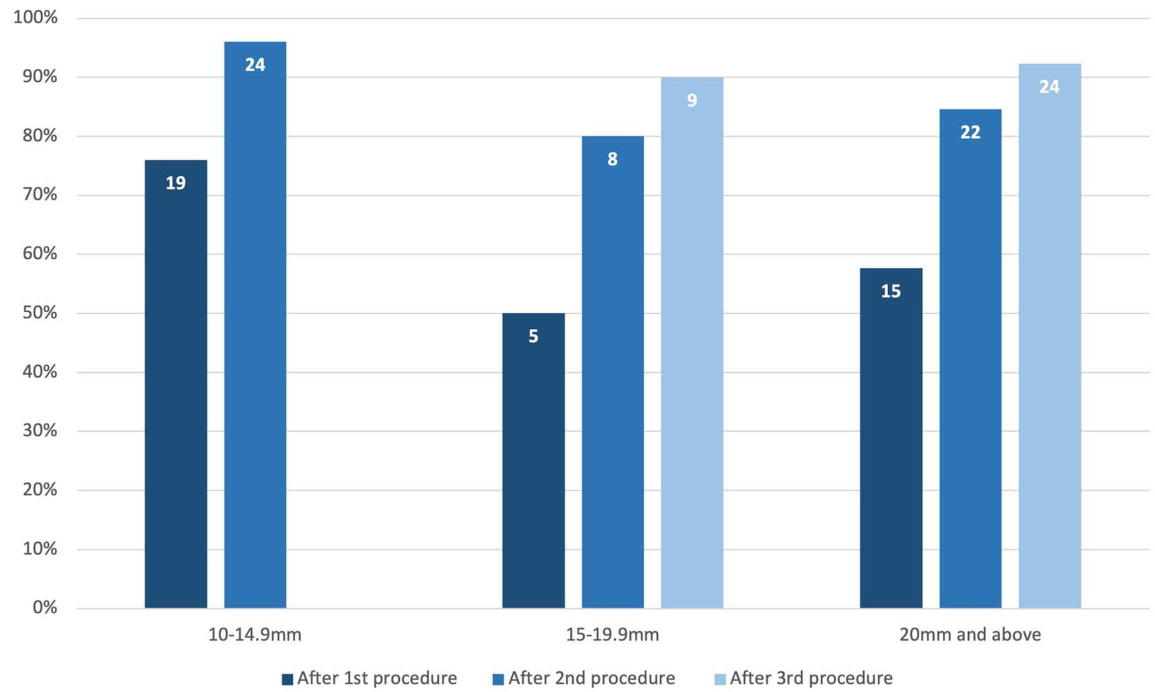

Figure 1. Cumulative stone-free rate per patient, according to stone burden and number of procedures undertaken.
Absolute numbers are shown within each bar.

The first URSL procedure was successful in 39 patients, achieving an SFR of 63.9%. In 19 cases, patients underwent a second procedure, with a further 15 becoming stone-free (88.5% cumulative SFR). In an additional three cases, a third procedure was carried out, achieving a cumulative stone-free rate of 93.4%. Figure 1 outlines the cumulative stone-free rate per patient, according to stone burden and number of procedures undertaken. Four patients did not achieve stone-free status. They all initially presented with at least one stone in the renal lower pole.

There were no intraoperative complications but there were five postoperative complications. In three cases, patients required only simple analgesia for pain management (Clavien-Dindo I). In further two cases, there was a suspicion of postoperative urinary tract infection (UTI), requiring antibiotics (Clavien-Dindo II), although none had confirmed growth on urine culture. Following each procedure, the average length of stay in the hospital was 1.4 days, with a median stay of 1 day.

Discussion

In this case series of pediatric patients with a minimum urinary stone burden ⩾10 mm, the first-pass stone-free rate achieved through URSL was 63.9%, with a cumulative stone-free rate of 93.4%. This is in line with previously reported rates, ranging from 75% to 100% in small studies.[17] However, it is worth noting that most of the previous analyses were conducted in patients with lower average stone burden, which suggests that URSL is as effective in patients with large stone burden as it is in patients with stone burden <10 mm. A previous analysis of pediatric patients with a stone burden ⩾10 mm reported a stone-free rate of 89% with a mean of 1.8 procedures per patient, which is in line with our findings.[19] Our analysis showed that 19 patients (31%) required subsequent procedures to achieve stone clearance. This is higher than the findings by Suliman et al.,[20] who found that over 14% of stone episodes required a second procedure, to achieve an overall clearance of 89%. The discrepancy in the number of patients requiring more than one procedure may arise from the high stone burden in our studies, which was not reported in work by Suliman et al.[20] The hypothesis that stone burden may be contributing to the higher number of second procedures in this patient cohort is supported by the fact that patients with lower stone burden achieved more favorable outcomes. This is demonstrated by the fact that patients with a total stone burden of 10–14.9 mm achieved an SFR of 76% after a single procedure and 96% after two procedures, compared with 58% and 85% respectively for patients with a total stone burden of 20 mm or more.

Postoperative complications were experienced following 6% of procedures, and these were relatively mild (Clavien-Dindo classification I–II). There have been various reported rates of complications in children, ranging from 0% to 31%, with a mean complication rate reported to be 12.6% in a review.[17] In adults, the Clinical Research Office of Endourological Society URS Global study[21] reported a complication rate of 7.4%. In this case series, the most common complications were pain and possible UTI, a finding that is in line with published literature in adults and children.[17,21,22]

A recent review by Peng et al.[23] described that, for large stones, standard PCNL achieved an SFR of 56%–100% in the pediatric population. However, modern PCNL techniques performed better, and mini-PCNL, ultra-mini-PCNL, super-mini-PCNL, or microperc had SFR between 76% and 100%.[23] This appears to be comparable to the data obtained in this case series and in a previous review,[17] suggesting that URSL may be a suitable alternative to PCNL. One significant advantage of URSL over PCNL is a reduced risk of bleeding requiring transfusion, which, in PCNL, ranges from 0.4% to 24% in children.[24] In contrast, only one patient in this case series experienced minor bleeding, which led to the procedure being terminated due to obscured views. This patient did not require any transfusions, nor a prolonged period of observation, and subsequently had a successful URSL. In adults undergoing URSL, intraoperative bleeding is reported in 1.41% of cases.[21] Another advantage of URSL over PCNL is the reported shorter length of stay (LOS). While mini-PCNL has been highlighted as reducing the LOS in children compared to traditional PCNL, case series report an average LOS of 2.24–3.54 days.[25,26] This appears to be significantly more than the average LOS in this study (1.4 days), or in a review of 11 studies (mean LOS: 1.3 days).[17]

A total of 4 out of 61 patients were not stone-free after one or multiple procedures. Interestingly, all of them presented with renal lower pole stones. However, it is possible that this is due to the higher prevalence of lower pole stones in this population, compared to other stone locations. This is supported by the fact that the outcomes from procedures undertaken in patients with or without lower pole stones were similar. The management of lower pole stones has generated considerable debate. Historically, PCNL was the preferred treatment option, as it was thought to offer better SFR, albeit with higher complication rates.[27] However, technological advances have given ureteroscopes greater maneuverability around the lower pole angle, to access lower pole stones, and therefore improve SFR.[27,28] As such, Bozzini et al.[29] undertook a prospective randomized trial comparing different management methods to address lower pole stones. They found that PCNL seemed to have a higher complication rate, but outcomes between PCNL and endoscopic approaches were not significantly different.[29] Another study confirmed that SFR at 1-month and 3-months post-operatively were similar in patients who had undergone URS or ultra-mini-PCNL for lower pole stones.[30] In the pediatric population, similar results were observed in a study of 53 patients undergoing URS or micro-PCNL for lower pole stones.[31] The authors found that the SFR rate was similar in both groups (84.2% vs 86.7%, $p = 1.000$), but that the PCNL group had longer LOS and higher complication rates.[31] There have also been concerns that the lower pole angle forces greater deflection of ureteroscopes, thus putting stress on the instrument and limiting its lifespan.[28] However, this has been addressed by advances in ureteroscopes capable of secondary deflection and the proposed occasional use of disposable URS in situations where scopes are expected to be put under stress, to preserve the lifespan of non-disposable equipment.[28] These advances in technology and the proven outcomes of URS have established it as a viable management option for lower pole stones in adults. This has prompted Huang et al.[32] to develop a scoring system to help clinicians choose the best intervention for lower pole stones.

This case series presents some limitations. It analyses patients from a single tertiary center, with a relatively small patient sample size. Due to this, only four patients did not achieve stone-free status, which would not have provided the study with enough statistical power to perform a meaningful multivariate analysis. In view of this, there was a focus on descriptive statistics and univariate analysis. In addition, operative details, such as operative time, laser time, fluoroscopy time, and basketing time, were not recorded at the time of data collection. These can provide valuable information about subsequent outcomes. However, it is worth noting that all procedures were performed by an adult endourologist and a pediatric endourologist, most often operating together, which would provide a degree of standardization in the operative method. Due to the pediatric age group, following the principles of ALARA, the mode of pre- and post-procedural imaging was ultrasound scan in most patients, which did not allow us to look at the Hounsfield unit or stone volume measurements. Finally, many patients were referred from peripheral centers and therefore did not have long-term follow-up beyond initial follow-up. Therefore, while there were no major complications identified during the follow-up period, the available data does not enable conclusions to be drawn about the long-term safety of URSL in this population. Future studies should also include measurements such as fragmentation time, operation time, fluoroscopy time, and laser time.

This case series highlights that URSL is an effective method of achieving stone clearance in children with urinary stones ⩾10 mm. The cumulative SFR achieved in this population is comparable to the SFR reported for URSL and PCNL in the literature. However, URSL appears to carry a lower complication rate and a shorter hospital LOS. Overall, this case series contributes to the growing body of evidence supporting URSL as an effective, minimally invasive option for managing pediatric urolithiasis.

Future prospective randomized trials comparing approaches would provide a strong foundation to standardize clinical guidelines.[33] While ureteroscopy is now common in non-index patients,[17,34] more work needs to be done regarding the cost of treatment and using some form of patient-reported outcome measures (PROMs) to compare different surgical options.[35,36]

Conclusion

Our single-center case series shows the efficacy of ureteroscopy in stone treatment for large pediatric stones with a good SFR, although staged procedures may be needed for these patients. There were a few minor and no major complications noted in the immediate postoperative period and during short-term follow-up, highlighting the suitability of URSL in this population. Further research is essential to help standardize treatment and update guidelines for large pediatric stones.

Declarations

Ethics approval and consent to participate

The study was registered with our "Clinical Effectiveness and Audit department" (audit number 6901, University Hospital Southampton). All parents signed a written consent form to the procedure and to take part in the study/audit.

Consent for publication

This is a retrospective audit of outcomes, and our study was registered with the hospital audit department to give us the authorization to share and publish the data.

Author contributions

Sohani N. Dassanayake: Data curation; Formal analysis; Project administration; Writing – original draft.

Victoria Jahrreiss: Data curation; Formal analysis; Methodology; Project administration; Writing – review & editing.

Stephen Griffin: Conceptualization; Writing – review & editing.

Bhaskar K. Somani: Conceptualization; Supervision; Writing – review & editing.

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Competing interests

The authors declare that there is no conflict of interest.

Availability of data and materials

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Supplemental material

Supplemental material for this article is available online.

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