JOURNAL OF ENDOUROLOGY
Volume 00, Number 00, Month 2026
Mary Ann Liebert, A Part of Sage

Pp. 000–000
DOI: 10.1177/08927790261431003

Mini-Percutaneous Nephrolithotomy *vs* Extracorporeal Shock Wave Lithotripsy for Management of Renal Stones in Pediatric Age Group Less Than 6 Years with Renal Stones Less Than 20 mm. A Prospective, Randomized Trial

Mohamed Abdelrahman Alhefnawy, MD,[1] Gamal Ibrahim Selmy, MD,[2,3] Emadeldeen Salah, MD,[4] Hazem Abdelsabour Deif, MD,[4] Ahmed Farag wahsh, MD,[4] Mahmoud Nader Abdel-razik Ahmad, MSc,[4] and Helmy Ahmed Eldib, MD, MRCS[1]

Abstract

Background: Pediatric nephrolithiasis continues to pose a substantial clinical challenge in pediatric urology because of its elevated recurrence rate and elevated morbidity with risk of end-stage renal failure. The management of pediatric nephrolithiasis involves dietary modification, pharmacological therapy, and urological intervention, with the choice of treatment guided by stone size, location, and composition.
Objective: To evaluate the efficacy and safety of mini-percutaneous nephrolithotomy (mini-PCNL) and extracorporeal shock wave lithotripsy (SWL) for the management of renal stones measuring 1–2 cm in pediatrics.
Cases and Methods: This prospective, randomized comparative research was conducted at the Department of Urology, Al-Azhar University Hospital, Assiut, Egypt, between December 2022 and November 2024. Sixty children with single renal stones were enrolled, with 30 undergoing SWL and 30 receiving mini-PCNL.
Results: Mini-PCNL achieved a significantly elevated stone-free rate (SFR, 93.33%) in contrast with SWL (33.33%) ($p < 0.001$). The SWL group also showed a higher rate of auxiliary approaches and retreatment. Overall complication rates were comparable.
Conclusion: Mini-PCNL is more effective than SWL for managing renal stones measuring 10–20 mm in children aged 6 months to 6 years. It provides an elevated SFR and lowers the likelihood of retreatment and hospital readmission, with a comparable safety profile.

Keywords: urinary calculi, kidney, lithotripsy, percutaneous, child

Introduction

Pediatric urolithiasis (PU) constitutes a growing global health challenge, particularly concerning the selection of optimal treatment strategies by health care providers. Several risk factors contribute to stone formation in the pediatric population, including geographic and climatic influences, as well as dietary practices. Epidemiological data indicate a morbidity rate, namely chronic kidney disease, as a result of increased PU recurrence rate and multiple interventions, ranging from 1% to 5% in developed countries and 5% to 15% in developing nations, with a notable upward trend in incidence noticed in industrialized regions.[1]

The most favorable stone-free outcomes following extracorporeal shock wave lithotripsy (SWL) have been exhibited in children aged 0–5 years, while the lowest rates are noticed in those aged 11–14 years.[2] With ongoing advancements in surgical technology and the continued miniaturization of endourological instruments, the management of PU has increasingly adopted minimally invasive treatment strategies. At present, percutaneous nephrolithotomy (PCNL), extracorporeal shock wave lithotripsy (SWL), and retrograde intrarenal surgery (RIRS) are recognized as standard treatment options for urinary stone disease in both adult and pediatric populations. Among these modalities, SWL remains the preferred first-line treatment for pediatric renal calculi, primarily

[1] Department of Urology, Benha University, Benha, Egypt.
[2] Department of Urology, Faculty of Medicine, Al-Azhar University (Assuit Branch), Cairo, Egypt.
[3] Department of Urology, Al-Azhar University, Cairo, Egypt.
[4] Department of Urology, Al-Azhar University, Asyut, Egypt.

due to its noninvasive nature. According to the European Association of Urology (EAU) guidelines, the indications for SWL in children are largely consistent with those in adults, with pediatric cases generally demonstrating more effective passage of stone fragments.[3] Similarly, the American Urological Association (AUA) guidelines support the use of either SWL or RIRS as first-line treatment options for pediatric cases presenting with a total renal stone burden measuring <20 mm.[4]

However, despite its widespread use, the clinical application of SWL in children remains somewhat limited due to certain drawbacks. Notably, the procedure is associated with relatively high retreatment rates, which may necessitate multiple sessions to achieve complete stone clearance. In addition, there are ongoing concerns regarding the potential biological effects of SWL on developing renal parenchyma and adjacent soft tissues, which may impact long-term renal function and overall safety in the pediatric population.[5,6]

In pediatrics, PCNL is advised for renal calculi >20 mm, particularly in cases involving multiple stones.[3,4] While effective, PCNL carries specific perioperative risks, including fever and hemorrhage, with some cases requiring blood transfusion. Additionally, concerns persist regarding the use of ionizing radiation during the procedure and its potential impact on renal function in the pediatric population.[7] Accordingly, the present research evaluated which treatment modality yields superior outcomes with a more favorable safety profile.

Aim of the Work

We aimed to compare the safety and efficacy of mini-PCNL and SWL in the management of 10–20 mm renal stones in pediatric cases.

Cases and Methods

The present prospective, randomized comparative trial was conducted at the Department of Urology, Al-Azhar University Hospital, Assiut, Egypt, between December 2022 and November 2024. The research included 60 children diagnosed with renal calculi; 30 children underwent SWL, while the remaining 30 were treated using mini-PCNL.

Randomization

A closed envelope assessor-blinded method of randomization was used; both patients and surgeons were aware of the type of surgery after opening the envelope, and only external assessors were blinded to avoid bias while recording perioperative data.

Ethical approval and written informed consent

Formal approval was obtained from the academic and institutional ethical review board of Al-Azhar University. All investigation procedures adhered strictly to ethical guidelines concerning human research. Written informed consent was obtained from the parents or legal guardians of all pediatric cases enrolled in the investigation, following a thorough explanation of the treatment procedures, potential benefits, risks, and alternatives.

Inclusion criterion. Pediatric cases aged between 6 months and 6 years who presented with a single renal stone measuring between 10 and 20 mm were eligible for inclusion in the investigation.

Exclusion criterion. Cases were excluded from participation based on the presence of any contraindication to SWL, such as active urinary tract infection (UTI), uncorrectable coagulopathy, the presence of distal urinary tract obstruction, or the existence of a renal artery aneurysm. Similarly, contraindications to PCNL, including active UTI, impaired coagulation status, or severe orthopedic deformities that may interfere with positioning, also warrant exclusion. Additional exclusion criterion included congenital anomalies of the kidney, significant comorbid conditions precluding general anesthesia or prone positioning, and the presence of concurrent urological pathologies requiring intervention during the same session, such as pelvi-ureteral junction obstruction or stones located within caliceal diverticula.

Data collection

Preoperative data. A comprehensive preoperative evaluation was performed for all enrolled cases. This included documentation of key demographic parameters such as age and gender, as well as clinical presentation, relevant medical history, and any history of prior urological interventions. Laboratory investigations comprised a full panel of tests, including serum creatinine, liver function tests, complete blood count (CBC), coagulation profile, routine urinalysis, and urine culture when clinically indicated.

Radiological evaluation was also performed systematically. Imaging included a plain abdominal radiograph of the kidney, ureter, and bladder (KUB), ultrasonography (US) of the abdomen and pelvis, noncontrast computed tomography (NCCT) of the urinary tract, and intravenous urography for cases requiring detailed anatomical assessment of the pelvicaliceal system. Stone characteristics were carefully recorded in each case, including stone size (maximum diameter), number, location (pelvic or caliceal), and radiodensity (when available).

Technique of shock wave lithotripsy

All SWL procedures were performed under either general anesthesia or sedo-analgesia, with the patient positioned in the supine posture. A PiezoLith 3000Plus lithotripter (Richard Wolf, Germany) was employed for all cases. Stone localization was achieved using real-time US, minimizing patient exposure to ionizing radiation. Shock waves were initiated at an energy level of 14 kV and incrementally increased to a maximum of 20 kV based on clinical judgment. The number of shock waves delivered during each session ranged from 1000 to 2500, adjusted according to patient age: 1000 shocks for children younger than 5 years and up to 2500 for older children. The shock delivery rate was modulated between 60 and 90 impulses per minute. Each session was concluded either when complete fragmentation of the stone was confirmed radiologically or when the preestablished limit for shock waves was reached.

Technique of Mini-PCNL

Mini-PCNL was performed under general anesthesia. All procedural steps were executed under fluoroscopic guidance using equipment supplied by KARL STORZ (Germany), including dilators, sheaths, a trocar, graspers, and a mini nephroscope.

The procedure commenced with the patient in the lithotomy position to allow insertion of a 5F retrograde ureteral catheter into the pelvicaliceal system. The catheter's tip was confirmed fluoroscopically following injection of a small volume of contrast medium. A Foley catheter, selected according to patient age and urethral diameter, was inserted and secured to the ureteral catheter to prevent dislodgment during repositioning. In cases with preoperative stenting, the initial stent was removed and replaced with a retrograde ureteral catheter prior to performing mini-PNL.

The patient was then carefully turned into the prone position with appropriate padding at all pressure points to ensure safety and comfort. The collecting system was opacified by contrast injection through the ureteral catheter. The target calix was identified under fluoroscopy, and an access needle was inserted antegradely. A guidewire was advanced through the needle, ideally reaching the ureter. The needle was withdrawn, and a small skin incision was made using an 11F scalpel.

Tract dilation was carried out sequentially using metal dilators up to 18F, followed by placement of a 20F Amplatz sheath. A 16F mini-nephroscope was then introduced to visualize the collecting system directly. Continuous irrigation with isotonic saline was maintained to ensure adequate endoscopic visibility.

Stones were identified and fragmented using a pneumatic lithotripter, and the fragments were removed using 5F pediatric nephroscope forceps. Direct visualization and fluoroscopic imaging confirmed complete clearance. A Double-J (DJ) ureteral stent was placed in cases requiring postoperative drainage, and nephrostomy tubes were inserted when indicated to maintain access and ensure adequate postoperative urinary diversion.

Postoperative data

Postoperative variables assessed included hospital length of stay, achievement of stone-free status, the need for ancillary procedures, retreatment rate, and the incidence of postoperative complications. Cases were followed for a period of up to 1 year to evaluate both immediate and long-term outcomes.

- **SWL group:** We performed follow-up assessments at 2 weeks, and at 3, 6, and 12 months following the final treatment session. These assessments included urinalysis, serum creatinine levels, plain abdominal KUB, and pelvic-abdominal ultrasonography.
- **Mini-PCNL group:** CBC was performed within the first 24 hours postoperatively. Follow-up evaluations, including urinalysis, serum creatinine, plain abdominal KUB, and pelvic-abdominal ultrasonography, were conducted at 24 hours and at 1, 3, 6, and 12 months postprocedure.
- NCCT is more sensitive in detecting stone-free rate (SFR) but our rationale is that in children we try as much as possible to avoid exposure to high dose of radiation with its hazards specially in this age group and with the technical difficulties to perform high-quality images in this group without the need of sedation, which poses an added more risk with more exposure to hazards of general anesthesia or sedative medications and we really did not encounter cases in our study in which ultrasound or KUB were not sufficient to assess stone-free status.

Data analysis

We conducted data analysis using the Statistical Package for the Social Sciences (SPSS), version 24 (IBM Corp., Armonk, NY, USA). Categorical variables were expressed as absolute frequencies and percentages (*n*, %), whereas continuous variables were exhibited as mean ± standard deviation or as median values with corresponding ranges, depending on the distribution of the data.

Primary outcomes included the SFR and overall complication rate. Univariate and multivariate statistical models were employed to assess factors influencing clinical outcomes. All statistical tests were two-sided, and a p-value ≤ 0.05 was considered to indicate statistical significance.

Results

This investigation was designed as a prospective, randomized, and comparative clinical trial, conducted at the Department of Urology, Al-Azhar University Hospital, Assiut, Egypt, between December 2022 and November 2024. A total of 60 pediatric cases with a single renal stone measuring between 10 and 20 mm were enrolled. Participants were randomly assigned to two equal groups: 30 cases received SWL and 30 underwent mini-PCNL.

The study cohort included 36 males (60%) and 24 females (40%), with a mean age of 3.25 ± 1.375 years. Regarding stone laterality, 24 cases (40%) had right-sided stones, and 36 cases (60%) had left-sided stones. Anatomically, 39 cases (65%) presented with renal pelvic stones, whereas 21 cases (35%) had caliceal stones, 13 cases with middle caliceal stones (21.66%), 6 cases with upper caliceal stones (10%), and 2 cases with lower caliceal stones (3.3%).

SWL and mini-PCNL groups were comparable in terms of stone laterality or location. Table 1 summarizes the preoperative demographic and stone characteristics for both groups. Table 2 presents the perioperative data for cases in each treatment arm. All cases had normal baseline laboratory values prior to intervention.

Shock wave lithotripsy group

In the SWL group, preoperative insertion of a DJ stent was required in six cases (20%) during a separate session due to significant pelvicaliceal back pressure. Of the 30 renal units treated, 7 cases (23.33%) had grade A SFR, 2 cases (6.66%) had grade B SFR, and 1 case (3.33%) achieved grade C SFR (Fig. 1). The remaining 20 units (66.6%) showed inadequate response: 18 cases (60%) subsequently underwent successful mini-PCNL, whereas 2 cases (6.6%)

Table 1. Preoperative Characteristics

	Overall (n = *60*)	*Mini-PNL* (n = *30*)	*SWL* (n = *30*)	p-*Value*
Stone size, mm				0.637
Mean ± SD	17.13 ± 2.45	17.29 ± 2.41	16.97 ± 2.52	
Median	18	18	17	
Minimum to maximum	13:20	13:20	13:20	
IQR	5	3	5	
Stone radiodensity, HU				0.857
Mean ± SD	1308.04 ± 245.5	1288.76 ± 264.4	1328.42 ± 226.6	
Median	1500	1500	1500	
Minimum to maximum	900:1650	920:1650	900:1515	
IQR	452	515	400	
Hemoglobin, g/dL				
Mean ± SD	13.37 ± 0.78	13.31 ± 0.75	13.44 ± 0.89	0.208
Median	13.70	13.50	13.70	
Minimum to maximum	11.0 to 15.0	11.0 to 14.1	11.0 to 15.0	
IQR	0.90	1.30		
Serum creatinine, mg/dL				0.210
Mean ± SD	1.04 ± 0.34	1.02 ± 0.31	1.05 ± 0.37	
Median	0.93	0.87	1.00	
Minimum to maximum	0.60 to 1.30	0.85 to 1.30	0.60 to 1.20	
IQR	0.25	0.20	0.23	

IQR = interquartile range; mini-PCNL = mini-percutaneous nephrolithotomy; SD = standard deviation; SFR = stone-free rate; SWL = extracorporeal shock wave lithotripsy.

required ureteroscopy—one due to steinstrasse and the other due to distal migration of an unfragmented stone into the mid ureter.

No intraoperative complications were observed in this group. Postoperatively, complications occurred in 6 cases (20%), including persistent renal pain in 2 (6.6%), pyelonephritis in 2 (6.6%), steinstrasse in 1 (3.3%), and stone migration in 1 (3.3%).

Percutaneous nephrolithotomy group

In the mini-PCNL group, 23 (76.66%) achieved grade A stone-free status, 4 cases (13.3%), while only 1 case (3.33%) achieved grade C SFR. This group showed a significantly elevated grade A SFR when compared to the SWL group (76.66% *vs* 23.33%, $p < 0.001$) (Fig. 1). Complications were documented in 8 cases (26.6%). Intraoperative complications included renal pelvic perforation in 2 cases and hemorrhage necessitating blood transfusion in 1 patient (10% overall). Postoperatively, 5 cases (16.6%) developed complications—4 experienced fever and 1 had transient urinary leakage.

Although the total complication rate was elevated in the mini-PCNL group in contrast with SWL (26.6% *vs* 20%), this difference was not statistically significant ($p = 0.386$). The mean operative time was significantly shorter in the mini-PCNL group (51 ± 14.02 minutes) in contrast with the SWL one (64 ± 16.90 minutes; $p = 0.001$).

Hospitalization was required only in the mini-PCNL group, with a mean stay of 4.09 ± 0.90 days. In contrast, SWL was performed on an outpatient basis.

The mean fluoroscopy time recorded in the mini-PCNL group was 199.41 ± 98.78 seconds. Fluoroscopy was not used during SWL, as stone localization was performed exclusively using ultrasonography, thereby reducing radiation exposure.

The retreatment rate was significantly lower in the mini-PCNL group (6.6%) in contrast with the SWL one (66.6%) ($p < 0.001$), indicating superior treatment durability.

There was also a significant difference in hemoglobin reduction between the groups. In the mini-PCNL group, the mean hemoglobin drop was 1.24 ± 1.46 g/dL, whereas no significant change was recorded in the SWL group ($p = 0.003$). Despite this, only one patient (3.3%) in the mini-PCNL group required blood transfusion. All cases in the SWL group maintained stable hemoglobin levels throughout follow-up.

Table 2. Perioperative Data of Mini-Percutaneous Nephrolithotomy Group and Extracorporeal Shock Wave Lithotripsy Group

	Mini-PCNL group	*SWL group*
Operative time (mean ± SD) (minutes)	51.38 ± 14.02	63.70 ± 16.90
Track formation time (minutes)	6.65 ± 3.41	
Total number of shock waves (mean ± SD)		6251.52 ± 1387.47
Fluoroscopy time (mean ± SD) (minutes)	199.41 ± 98.78	All cases were done ultrasound guided
Stone-free rate	28/30 (93.33%)	10/30 (33.33%)
Hemoglobin reduction (mean ± SD)	1.24 ± 1.46	
Hospitalization time (days) (mean ± SD)	4.09 ± 0.90	All sessions were performed as a day-case procedure

Discussion

PU is frequently associated with metabolic disturbances, anatomical anomalies, or infectious etiologies. Consequently, the risk of recurrence is elevated, highlighting the need for treatment approaches that are both minimally invasive and capable of achieving high SFR and low retreatment rates.[8]

Current treatment strategies for pediatric nephrolithiasis include medical management, SWL, RIRS, PCNL, and, in selected cases, open, laparoscopic, or robotic-assisted surgery. Achieving complete stone clearance in a single session is of particular importance in pediatric cases to minimize repeated exposure to general anesthesia.[9]

Although SWL is widely employed as a first-line treatment, residual fragments following the procedure may lead to recurrence, thereby undermining the goal of definitive management. Moreover, concerns remain regarding the long-term biological effects of SWL on developing renal tissues.[8]

Initial reluctance to adopt PCNL in pediatric cases was due to concerns related to smaller renal anatomy, the size of instruments, radiation exposure, and the potential for significant complications. However, the development of mini-PCNL has mitigated many of these issues by offering reduced postoperative pain, minimized bleeding, shorter hospitalization, and enhanced overall safety, establishing it as a favorable treatment alternative.[10]

In the present research, we assessed the efficacy and safety of SWL and mini-PCNL in the treatment of single renal stones (10–20 mm) in pediatric cases. Mini-PCNL was significantly more effective, yielding an SFR of 93.33% in contrast with 33.3% in the SWL group. All cases treated with mini-PCNL became stone free after a single procedure and did not require secondary intervention. In contrast, the SWL group showed a considerably elevated retreatment rate, with most cases requiring more than two treatment sessions.

Our findings are consistent with prior studies comparing mini-PCNL and SWL for pediatric renal stones within this size range, further supporting the superiority of mini-PCNL in terms of efficacy and reduced need for retreatment.

Tarek et al.[11] conducted a comparative investigation involving 90 children with single renal stones. The cohort included three groups: 30 underwent flexible URS, 30 received SWL, and 30 were treated with mini-PCNL. In the SWL group, cases had a mean stone size of 1.3 ± 0.4 mm and were treated using the Piezolith 3000Plus lithotripter (the same device employed in our investigation). The exhibited operative time was 78 ± 21 minutes, and the SFR was 83.3%—notably elevated compared to our findings. This discrepancy may be attributed to the larger mean stone size in our investigation (16.97 ± 2.52 mm). The complication rate in the SWL group was 20%, which is identical to that noticed in our cohort.

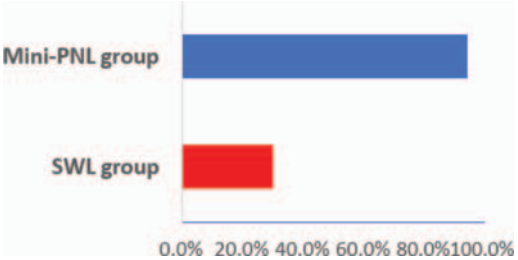

FIG. 1. Total SFR in both groups. Mini-PCNL group showed significant total SFR "93.33% *vs* 33.33% in the SWL group". Mini-PCNL = mini-percutaneous nephrolithotomy; SFR = stone-free rate; SWL = extracorporeal shock wave lithotripsy.

In the mini-PCNL group of the same investigation, the mean stone size was 1.4 ± 0.2 mm. The mean operative time was 99 ± 13 minutes, and the fluoroscopy time was 103 ± 11 seconds. In contrast, the fluoroscopy time in our investigation was longer (199.41 ± 98.78 seconds), likely due to the elevated complexity associated with larger stones. The SFR was 90%, slightly lower than 93.3% achieved in our research. However, the complication rate reported by Tarek et al. was higher (40%) in contrast with our mini-PCNL group (26.6%).[11]

These findings are in partial concordance with those reported by Farouk et al.,[12] who conducted a randomized trial involving 108 pediatric cases under 12 years of age with single renal stones measuring 10–20 mm. Cases were allocated into two equal groups ($n = 54$) to undergo either mini-PCNL using a 16.5F sheath or SWL with a Dornier Compact Sigma lithotripter. The reported SFRs were 92.59% in the mini-PCNL group and 88.89% in the SWL group ($p = 0.639$). However, the mean hospital stay and fluoroscopy time were both significantly higher in the mini-PCNL group (63.70 ± 11.09 hours and 268.89 ± 66.35 seconds, respectively) compared to the SWL group (4.89 ± 0.97 hours and 79.07 ± 19.37 seconds). The overall complication rate was higher in the mini-PCNL group (22.2%) *vs* the SWL group (14.8%), though the difference did not reach statistical significance ($p = 0.484$), a trend that mirrors our own findings.

Similarly, Elsheemy et al.[13] evaluated 118 children aged ≤6 years with single renal pelvic or lower caliceal stones measuring 10–25 mm. A total of 64 cases underwent SWL, whereas 54 underwent mini-PCNL. The mini-PCNL group demonstrated a significantly elevated SFR (94.4%) compared to the SWL group (81.2%) ($p < 0.001$). Additionally, the retreatment rate was substantially lower in the mini-PCNL group (5.6%) than in the SWL group (54.5% needed a second session and 9.1% a third session) ($p < 0.001$). No statistically significant difference in overall complication rates was noticed between the two groups (mini-PCNL: 16.7% *vs* SWL: 12.5%; $p = 0.521$). Reported complications in the mini-PCNL group included bleeding requiring transfusion (1.9%), bleeding not requiring transfusion (1.9%), renal pelvis perforation (1.9%), urinary leakage (1.9%), fever (12.96%), and UTI (3.7%). In the SWL group, complications included four cases of steinstrasse (6.2%), with two managed conservatively and two requiring ureteroscopy due to associated fever, UTI, and obstruction, along with isolated cases of UTI (3.1%) and fever (3.1%).

Shokeir et al.[14] also provided relevant comparative data in their investigation of 166 children under 15 years of age who underwent either SWL or mini-PCNL. In the SWL group ($n = 91$), the mean stone size was 13.9 ± 4.2 mm, and the SFR was exhibited as 84.9%. Only one patient (1.1%) of steinstrasse was encountered, which was successfully managed with ureteroscopy. In the mini-PCNL group ($n = 75$), with a mean stone size of 14.4 ± 3.1 mm, the SFR after a single session was 86.6%. The 11 cases (13.4%) with residual

stones were subsequently treated with second-look mini-PCNL ($n = 7$; 8.5%) or SWL ($n = 4$; 4.9%). The mean operative time in the mini-PCNL group was 53 ± 25 minutes, and the average hospital stay was 3 ± 1.2 days.

Kumar et al.[15] conducted a randomized trial involving 212 also conducted a randomized investigation involving 212 pediatric cases under the age of 15 years, each with a single radio-opaque lower caliceal renal stone measuring between 1 and 2 cm. The cases were equally divided into two groups. In the SWL group ($n = 106$; mean stone size: 12.9 ± 1.3 mm), the overall SFR at 3 months was 83%, with a retreatment rate of 41.5% and a need for auxiliary procedures in 14.2% of cases. Treatments were performed using the Dornier Alpha Compact lithotripter, with up to four sessions allowed per patient. Notably, an infundibulopelvic angle less than 90° was significantly associated with reduced SFR.

In comparison, the mini-PCNL group ($n = 106$; mean stone size: 12.7 ± 1.2 mm) demonstrated an elevated SFR of 94.3%, with a significantly lower retreatment rate (2.8%) and auxiliary procedure requirement (5.6%). Although the mini-PCNL group experienced longer operative times, elevated fluoroscopy exposure, and prolonged hospital stays, these were offset by its superior effectiveness—particularly in anatomically challenging cases such as lower pole stones.

In the current investigation, no intraoperative complications were recorded in the SWL group. However, among cases undergoing mini-PCNL, intraoperative complications occurred in 3 cases (10%), and postoperative complications were noticed in 5 cases (16.6%). Despite this, the overall complication rate did not differ significantly between groups (20% in SWL *vs* 26.6% in mini-PCNL; $p = 0.386$), consistent with results from Farouk et al.,[12] who also showed no statistically significant difference in complication rates (22.2% for mini-PCNL *vs* 14.8% for SWL; $p = 0.484$).

A key limitation of SWL is its high retreatment rate. In our investigation, the mini-PCNL group demonstrated a significantly lower retreatment rate compared to the SWL group (6.6% *vs* 66.6%; $p < 0.001$). This observation aligns with the findings of Kumar et al.,[15] who similarly reported higher retreatment rates in the SWL group (41.5%) relative to mini-PCNL (2.8%).

Elsheemy et al.[13] further supported this pattern, reporting significantly elevated retreatment rates in the SWL group for both renal pelvic and lower caliceal stones. Specifically, for pelvic stones, the retreatment rate was 46.2% in SWL *vs* 7.7% in mini-PCNL, whereas for lower caliceal stones, it was 66.7% *vs* 6.7%, respectively. Overall, the retreatment rate across all locations was significantly elevated in the SWL group (66.7%) in contrast with mini-PCNL (6.7%; $p = 0.003$).

In terms of fluoroscopic exposure, the mean fluoroscopy time in our mini-PCNL group was 199.41 ± 98.78 seconds. This was notably longer than the times reported in previous studies, such as Resorlu et al.[16] (113.7 ± 36.6 seconds) and Kumar et al.[15] (157.1 ± 1.3 seconds). In contrast, fluoroscopy was not utilized in our SWL group, as all procedures were guided by US, thereby eliminating intraoperative radiation exposure in that cohort.

In the SWL group, all procedures were performed on a day-patient basis, eliminating the need for hospital admission. Conversely, cases in the mini-PCNL group experienced significantly longer hospitalizations, with a mean duration of 4.09 ± 0.90 days ($p < 0.001$). These findings are consistent with previously published data. Resorlu et al.[16] and D'Souza et al. reported mean hospital stays of 3.1 ± 1.2 days and 3 days, respectively. Tze et al.[17] noted longer hospitalizations, and Onal et al.[18] reported mean durations of 4.78 days (range: 2–11 days) and 5.1 ± 3.3 days, respectively. Collectively, these data confirm that postoperative hospitalization is significantly prolonged in cases undergoing mini-PCNL in contrast with those managed with SWL ($p < 0.001$).

Additionally, the mean hemoglobin decline was significantly elevated in the mini-PCNL group (1.24 ± 1.46 g/dL) compared to the SWL group ($p = 0.003$). Despite this, blood transfusion was needed in only one patient (3.3%) in the mini-PCNL group. This observation is consistent with the findings of Karatag et al.,[19] who reported a higher mean hemoglobin drop of 1.85 ± 1.39 g/dL among 63 pediatric cases (mean age = 9.32 ± 4.98 years) undergoing mini-PCNL. In both studies, transfusion was needed exclusively among mini-PCNL cases, with no transfusion needs noticed in the SWL groups. Notably, the highest transfusion rate exhibited in the literature was 13.64%, as documented by Saad et al.[20]

Conclusion

Mini-PCNL group showed a significantly elevated grade A SFR when compared to the SWL group (76.66% *vs* 23.33%, $p < 0.001$). Although the total complication rate was elevated in the mini-PCNL group in contrast with the SWL group (26.6% *vs* 20%), this difference was not statistically significant ($p = 0.386$). The retreatment rate was significantly lower in the mini-PCNL group (6.6%) in contrast with the SWL group (66.6%) ($p < 0.001$). In view of the above, mini-PCNL is more effective than SWL for managing renal stones measuring 10–20 mm in children aged 6 months to 6 years, with better outcomes in terms of SFR and lower retreatment rates and a safer profile in terms of procedure-related complications.

Limitations

This investigation is subject to several limitations. The assessment of SFR relied on KUB radiography and US, imaging modalities that are less sensitive than NCCT for detecting residual fragments. The assessment of stone dimensions should be best done by volumetric measurement rather than by maximum length in cm. Despite small, non-significant number of lower caliceal stones involved in the study, they would be better excluded from the study or not assigned to the SWL group to avoid bias. The investigation did not include a metabolic evaluation, which could have helped identify underlying etiologies contributing to stone formation. The relatively short follow-up duration may have limited the ability to fully assess long-term outcomes, including recurrence. Additionally, information regarding stone composition was not available, which may have influenced treatment response and the likelihood of recurrence.

Authors' Contributions

All authors contributed to the surgical procedures, research conception, and design. Material preparation, data collection, and analysis were performed by M.A.A., G.I.S.,

E.S., H.A.D., A.F.w., M.N.A.-r.A., and H.A.E. G.I.S. supervised the material preparation, data collection, and analysis. H.A.E. wrote the first draft of the article, and all authors commented on previous versions of the article. All authors read and approved the final version of the article.

Ethical Approval

All procedures were performed in compliance with relevant laws and institutional guidelines and have been approved by the appropriate institutional ethical committee.

Data Availability

Sequence data that support the findings of this research are available upon request.

Author Disclosure Statement

The authors have no competing interests to declare that are relevant to the content of this article.

Funding Information

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

1. Mahmud M, Zaidi ZL. Percutaneous nephrolithotomy in children before school age: Experience of a Pakistani Centre. BJU Int 2004;94(9):1352–1354.
2. Aksoy Y, Ozbey I, Atmaca AF, Polat O. Extracorporeal shock wave lithotripsy in children: Experience using a mpl-9000 lithotriptor. World J Urol 2004;22(2):115–119.
3. Turk C, Petřík A, Sarica K, et al. EAU guidelines on interventional treatment for urolithiasis. Eur Urol 2016;69(3):475–482.
4. Assimos D, Krambeck A, Miller NL, et al. Surgical management of stones: American Urological Association/Endourological Society Guideline, PART I. J Urol 2016; 196(4):1153–1160.
5. Guven S, Istanbulluoglu O, Ozturk A, et al. Percutaneous nephrolithotomy is highly efficient and safe in infants and children under 3 years of age. Urol Int 2010;85(4):455–460.
6. Dogan HS, Kilicarslan H, Kordan Y, Celen S, Oktay B. Percutaneous nephrolithotomy in children: Does age matter? World J Urol 2011;29(6):725–729.
7. Dogan HS, Tekgul S. Minimally invasive surgical approaches to kidney stones in children. Curr Urol Rep 2012;13(4):298–306.
8. Maldone MC, Docimo SG, Ost MC. Contemporary surgical management of pediatric urolithiasis. Urol Clin North Am 2010;37:253–267.
9. Sabnis RB, Chhabra JS, Ganpule AP, Abrol S, Desai MR. Current role of PNL in pediatric urolithiasis. Curr Urol Rep 2014;15(7):423.
10. D'Souza N, Paul S. Mini percutaneous nephrolithotomy for renal calculi in pediatric cases: A review of twenty cases. Urol Ann 2016;8:16–19.
11. Soliman Othman T, Shaher H, Abd Elzaher M, et al. Management of pediatric renal stones (10-20mm) by flexible ureteroscopy (F-URS), miniaturized percutaneous nephrolithotomy (Mini-PNL) or extracorporeal shock wave lithotripsy (EWL): Comparative research. Benha J Appl Sci 2023;8(6):119–124.
12. 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 research. World J Urol 2018; 36(7):1139–1147; doi: 10.1007/s00345-018-2231-9
13. ElSheemy MS, Daw K, Habib E, et al. Lower calyceal and renal pelvic stones in preschool children: A comparative research of mini-percutaneous nephrolithotomy versus extracorporeal shockwave lithotripsy. Int J of Urology 2016;23(7):564–570.
14. Shokeir AA, Sheir KZ, El-Nahas AR, et al. Treatment of renal stones in children: A comparison between percutaneous nephrolithotomy and shock wave lithotripsy. J Urol 2006;176(2):706–710.
15. Kumar A, Kumar N, Vasudeva P, et al. A single center experience comparing miniperc and shock wave lithotripsy (SWL) for treatment of radioopaque 1–2 cm lower calyceal renal calculi in children: A prospective randomized research. J Endourol 2015;29:805–809.
16. Resorlu B, Unsal A, Tepeler A, et al. Comparison of retrograde intrarenal surgery and mini-percutaneous nephrolithotomy in children with moderate-size kidney stones: Results of multi- institutional analysis. Urology 2012;80(3):519–523.
17. Wah TM, Kidger L, Kennish S, et al. Mini-PNL in a pediatric population. Cardiovasc Intervent Radiol 2013;36:249–254.
18. Onal B, Dogan HS, Satar N, et al. Factors affecting complication rates of percutaneous nephrolithotomy in children: Results of a multi- institutional retrospective analysis by the pediatric stone disease research group of the Turkish pediatric urology society. J Urol 2014;191(3):777–782.
19. Karatag T, Tepeler A, Silay MS, et al. A comparison of 2 percutaneous nephrolithotomy techniques for the treatment of pediatric kidney stones of sizes 10-20 mm: Micro-PNL vs Mini-PNL. Urology 2015;85(5):1015–1018.
20. Saad KSM, Youssif ME, Al Islam Nafis Hamdy S, Fahmy A, El Din Hanno AG, El-Nahas AR. Percutaneous nephrolithotomy vs retrograde intrarenal surgery for large renal stones in pediatric cases: A randomized controlled trial. J Urol 2015;194(6):1716–1720.

Address correspondence to:
Helmy Ahmed Eldib, MD, MRCS
Department of Urology
Benha University
Benha City
Qalyubia Governorate
Farid nada street
Benha 13511
Qalubia
Egypt

E-mail: drhelmyeldeep@gmail.com

Abbreviations Used

CBC = complete blood count
EAU = European Association of Urology
KUB = kidney, ureter, and bladder
NCCT = noncontrast computed tomography

Abbreviations Used (Cont.)

PCNL = percutaneous nephrolithotomy
PU = pediatric urolithiasis
RIRS = retrograde intrarenal surgery
SFR = stone-free rate
SWL = shock wave lithotripsy
US = ultrasonography
UTI = urinary tract infection