Super-Mini Percutaneous Nephrolithotomy in the Treatment of Pediatric Nephrolithiasis: Evaluation of the Initial Results

Yongda Liu, MD,^{1,*} Wenqi Wu, MD, PhD,^{1,*} Aierken Tuerxun, MD,^{2,*} Yang Liu, MD,^{1,*} Abulizi Simayi, MD,³
Jinxing Huang, MD,⁴ Abudukahaer Batuer, MD,² Yizhou Zhou, MD,¹ Jiawei Luo, MD,¹ Wen Zhong, MD,¹
Zhijian Zhao, MD,¹ Wei Zhu, MD,¹ and Guohua Zeng, MD, PhD¹

Abstract

Objective: To evaluate the efficacy and safety of super-mini percutaneous nephrolithotomy (SMP) in the treatment of pediatric kidney stones.

Patients and Methods: We reviewed the records of 111 children with renal stones treated with SMP technique in four different centers between September 2014 and September 2015. The indications for SMP treatment in all these kids were either previously failed shock wave lithotripsy or retrograde intrarenal surgery approaches, according to their parents' preferences. Nephrostomy tracts used in the SMP system ranged from 10F to 14F in size. Lithotripsy was performed using either a Holmium laser or pneumatic lithotripter. Perioperative and postoperative parameters along with operative data were recorded in detail and stone components were analyzed by infrared spectroscopy.

Results: This study included 71 boys and 40 girls with a mean age of 3.90 ± 3.53 years (range 0.5–15). The mean stone burden was 1.4 ± 0.6 cm (range 0.8–4.8). Mean operative time was 39.4 ± 26.2 minutes (range 7–105). The mean hemoglobin drop was 10.2 ± 7.1 g/L (range 0–25) and no transfusion was needed. Significant complications were observed in 17 (15.3%) children with 10 and 7 cases in Clavien grade I and grade II, respectively. Complete stone clearance on postoperative day 1 and on 3-month follow-up was 84.7% (94/111) and 90.1% (100/111), respectively. Ninety-five (85.6%) children did not require any type of catheters (total tubeless). The mean hospital stay was 2.7 ± 1.5 days (range 1–7).

Conclusions: Our preliminary data demonstrated that SMP was safe and effective. SMP could be a feasible treatment option for pediatric stone disease. Further randomized controlled trials are still needed to prove the efficacy of using the SMP system in children, particularly in those with larger stones.

Keywords: kidney stones, pediatric, super-mini percutaneous nephrolithotomy

Introduction

PEDIATRIC STONE DISEASE poses a challenge to urologists. Due to the common underlying metabolic and anatomic abnormalities, children with urolithiasis are part of the high-risk group for stone recurrence.^{1,2} Thus, the management of calculi in children requires a complete stone clearance to minimize the number of procedures and the detrimental effects on the growing kidneys.

Although shock wave lithotripsy (SWL) remains the first-line treatment option for most pediatric upper tract urinary calculi,³ the unpredictable results and higher retreatment rates are the main drawbacks of this approach.⁴ As was the concern with SWL, retrograde intrarenal surgery (RIRS) might cause vesicoureteral reflux and strictures in children, as a result of dilatation of small-caliber ureteral orifices by ureteral access sheath.⁵ Moreover, additional general anesthesia is required for subsequent stent removal.

¹Department of Urology, Minimally Invasive Surgery Center, The First Affiliated Hospital of Guangzhou Medical University, Guangdong Key Laboratory of Urology, Guangzhou, China.

²Department of Urology, The First People's Hospital of Kashi, Xinjiang, China.

³Department of Urology, The Xinjiang Uyghur Autonomous Region People's Hospital, Xinjiang, China.

⁴Department of Urology, Shache County People's Hospital, Xinjiang, China.

*These authors contributed equally to this work.

Impacted collecting system and delicate parenchyma of the children's kidney necessitate the use of the least invasive treatment approaches to limit the extent of damaging function.^{6,7} Percutaneous nephrolithotomy (PCNL) is advocated as a safe and effective treatment for children with larger and more complex calculi. However, there is continued concern that it will cause long-term renal damage and scarring.⁸ Recently, the miniaturization of PCNL equipment has revolutionized stone management.^{9–11} Accumulated evidences so far have proven that when performed in children, miniaturized PCNL techniques, including miniperc, microperc, and ultra-mini perc (UMP), were all associated with decreased morbidity and acceptable stone-free rates.^{12–14}

The super-mini PCNL (SMP) system was first defined and introduced as an alternative treatment of urinary stones less than 2.5 cm by Zeng et al.¹⁵ In this present study, by reporting our initial data, we evaluated the efficiency and safety of SMP technique in children with moderate-sized renal calculi.

Patients and Methods

Patients

A total of 111 children treated in four different centers between September 2014 and September 2015 were included in this study program. Institutional review board and ethics committee approval documents were obtained from each of the participating centers. Parents and children (if possible) were well informed about the technique, and informed consent was obtained from all patients (or their parents) before the procedure. The inclusion criteria for our study were (1) children with stones resistant to and/or requiring multiple sessions for SWL and RIRS treatment, (2) stone diameter larger than 2.0 cm, or (3) those parents who preferred SMP regardless of stone size.

Methods

The detailed information regarding the patients' demographics and stone-related factors (size, location, and composition) has been evaluated and recorded. The preoperative tests included complete blood count, routine urine test, urine culture, and serum biochemistry. In patients older than 3 years, 24-hour urine sample was collected for stone risk analysis. Radiologic evaluation of the stone included kidneys, ureters, and bladder (KUB), low-dose CT, and abdominal ultrasonography (US). In patients with a positive culture, antibiotics were selected according to the bacterial sensitivity results. Patients who had negative urine cultures received a single dose of broad-spectrum antibiotic prophylaxis just before the procedure.

SMP technique

The patient was placed in the lithotomy position under general anesthesia. A 4F or 5F open-end ureteral catheter (Boston Scientific Corporation, Miami, FL) was retrogradely inserted into the collecting system. The patient was then turned prone with appropriate padding placed under the chest and the ipsilateral flank. The selected calix was punctured under ultrasound guidance and a 0.032-inch guidewire was inserted into the collecting system. Nephrostomy tract was established using metal dilators (12–14F depending on patient's size and the stone burden) in one step. The corre-

sponding size of suction-evacuation sheath was then placed. The sheath was connected to the specimen collection bottle via the oblique branch of a metal connector. A rubber cap, with a center aperture, was placed at the end of the straight branch of the connector. A negative pressure aspirator was attached to the collection bottle. The negative pressure was adjusted to a setting of 150–200 mmHg. The miniature endoscope was inserted into the sheath through the metal connector. The main irrigation was delivered into the working channel of the endoscope sheath using a pump. When the flow of the main irrigation system was insufficient, the auxiliary irrigation system could be used. Holmium:YAG laser with a laser fiber up to 365 μ m and/or pneumatic lithotripter with a 0.8 mm probe were used for stone fragmentation. Under continuous suction, tiny stone fragments passed through the space between the scope and the sheath and then exited through the oblique sluice. For larger fragments, the scope was slowly withdrawn to the end of the connector to form an unimpeded channel, and then, the large fragments could pass through the oblique side-port. The negative pressure could be adjusted by either partially or completely occluding the pressure vent. A basket was used for difficult aspirated fragments. The procedure for the SMP technique has been described in detail previously.¹⁵

A visual and fluoroscopic examination was performed to estimate stone-free status at the end of the procedure. "Totally tubeless PCNL" (no ureteral stent and nephrostomy tube) was performed in cases without residual stone fragment and significant bleeding. A Double-J or nephrostomy tube was only used in the presence of residual stone fragments, significant bleeding, extravasation, or upper urinary tract obstruction.

The stone-free status was evaluated by KUB and/or US or low-dose CT, if necessary, on postoperative day 1 and at 3 months. Any residual fragments less than 2 mm were considered to be clinically insignificant residual fragments (CIRF). A patient was considered to be stone free if there were no residual fragments or with clinically "insignificant" residual stones on radiologic evaluation after the procedure.

The chemical compositions of the stones were analyzed using infrared spectroscopy. Intraoperative and postoperative procedure-related parameters were recorded, including operational duration; number and position of accesses; need for nephrostomy tube and/or Double-J stent; complications and hemoglobin decrease. In addition, stone clearance rates and hospital stay were also analyzed in each patient.

Results

A total of 111 procedures were performed in 71 boys and 40 girls (male/female = 1.81). The mean age of the children was 3.9 ± 3.5 years (range 0.5–15) and 65 (58.6%) of them were younger than 3 years. The mean stone size was 1.4 ± 0.6 cm (range 0.8–4.8) with a mean stone density value of 735.2 ± 329.1 HU (range 288–1378). Mean body mass index value was 17.0 ± 3.4 kg/m² (range 11.2–31.9). The characteristics of the patients are summarized in Table 1.

Of the 111 patients, 25 patients (22.5%) had bilateral stones. All patients with bilateral urinary stones only needed unilateral SMP. The contralateral stones were small and treated by other means. A single nephrostomy tract was used in all patients. Of all the cases, 2 (1.8%) tracts were 10F in size, 94 (84.7%) tracts were 12F, and 15 (13.5%) tracts were 14F.

TABLE 1. DEMOGRAPHICS AND STONE CHARACTERISTICS OF THE PATIENTS WHO UNDERWENT SUPER-MINI PERCUTANEOUS NEPHROLITHOTOMY

Characteristics	Number
Patients, <i>n</i>	111
Male:Female (ratio)	71:40 (1.8)
Mean age $\pm$ SD, years	3.9 $\pm$ 3.5
Range	0.5–15
Younger than 3 years, <i>n</i> (%)	65 (58.6%)
Mean (SD, range) BMI, kg/m ²	17.0 $\pm$ 3.4 (11.2–31.9)
Mean (SD, range) stone size, cm	1.4 $\pm$ 0.6 (0.8–4.8)
Positive preoperative urine culture, <i>n</i> (%)	16 (14.4%)
Patient stone in kidney position, <i>n</i> (%)	
Left	43 (38.7%)
Right	43 (38.7%)
Bilateral	25 (22.5%)
Mean (SD, range) Hounsfield units	735.2 $\pm$ 329.1 (288–1378)
Stone location, <i>n</i> (%)	111
Upper ureter	33 (29.7%)
Pelvis	26 (23.4%)
Upper calix	14 (12.6%)
Middle calix	9 (8.1%)
Lower calix	21 (18.9%)
Multiple	8 (7.2%)
Access sheath size, <i>n</i> (%)	111
F10	2 (1.8%)
F12	94 (84.7%)
F14	15 (13.5%)

Intraoperative parameters are summarized in Table 2. The renal punctures were done via supracostal and infracostal approaches in 76 (68.5%) and 35 (31.5%) patients, respectively. Mean operative time, which was defined as the interval, from puncturing the needle to the removal of drapes was 39.4 $\pm$ 26.2 minutes (range 7–105). The mean hemoglobin loss was 10.2 $\pm$ 7.1 g/L (range 0–25). None of the children required blood transfusion. The complete stone clearance on postoperative day 1 was 84.7% (94/111), with 6.3% (7/111) considered as CIRF. Another 10 (9.0%) cases had residual calculi of >2 mm. Of those children, four required an RIRS and the other six required an SWL to disintegrate the residual fragments. During a 3-month follow-up, the SFR increased to 90.1% (100/111) with 6 (5.4%) children having CIRF. Five (4.5%) had asymptomatic residual fragments of 3–6 mm. For these cases, a close follow-up program was applied.

Total tubeless SMP was applied in 95 (85.6%) cases. Thirteen (11.7%) children had a Double-J stent placed for 2–6 weeks due to the following reasons: endopyelotomy for PUJ obstruction in 2 cases, ipsilateral distal ureteral stone with semirigid ureteroscope in 3, significant pyelocaliceal blood clots in 1, significant residual stones in 4, and 3 cases for minor pelvis perforation. Nephrostomy tube was placed in 3 (2.7%) children due to urinary extravasation.

A total of 17 (15.3%) children had significant complications and were classified using the Clavien grading system.¹⁶ Postoperative fever was the most common complication observed in 7 (6.3%) children. No significant difference of complications was found between children with supracostal and infracostal puncture (Supplementary Table S1; Supple-

TABLE 2. INTRAOPERATIVE AND POSTOPERATIVE VARIABLES

Variable	Value
Mean operative time ($\pm$ SD), minute	39.4 $\pm$ 26.2 (7–105)
Mean hemoglobin drop ($\pm$ SD), g/L	10.2 $\pm$ 7.1 (0–25)
No. of puncture locations (<i>n</i> = 111)	
Upper pole/Interpolar/	65 (58.6%)/
Lower pole calix, <i>n</i> (%)	33 (29.7%)/
Supracostal/Infracostal, <i>n</i> (%)	13 (11.7%)
Supracostal/Infracostal, <i>n</i> (%)	76 (68.5%)/
Supracostal/Infracostal, <i>n</i> (%)	35 (31.5%)
Initial SFR, <i>n</i> (%)	
Completely stone free	94 (84.7%)
Residual fragments	10 (9.0%)
Insignificant residual stone fragments (<2 mm)	7 (6.3%)
Final SFR at 3 months, <i>n</i> (%)	
Completely stone free	100 (90.1%)
Residual fragments	5 (4.5%)
Insignificant residual stone fragments (<2 mm)	6 (5.4%)
Significant complication, <i>n</i> (%)	17 (15.3%)
Fever (>38.5°C)	7 (6.3%)
Grade I	6
Grade II	1
Hematuria (Grade I)	4 (8.1%)
Extravasation (Grade II)	3 (2.7%)
Perforation (Grade II)	3 (2.7%)
Blood transfusion rate	0
Total tubeless, <i>n</i> (%)	95 (85.6%)
Double-J stent, <i>n</i> (%)	13 (11.7%)
Nephrostomy tube, <i>n</i> (%)	3 (2.7%)
Mean postoperative hospital stay, days	2.7 $\pm$ 1.5 (1–7)

mentary Data are available online at www.liebertpub.com/end). Of the seven cases, two were cured by keeping the urethral catheter for 24–48 hours, one case required additional oral antibiotics, the remaining four had a spontaneous recovery without special management. Four (3.6%) children had hematuria (Grade I), which resolved spontaneously without further intervention. Three (2.7%) children had minor pelvis perforation (Grade II), which was managed by leaving a Double-J stent for 2 weeks. Another 3 (2.7%) children with urinary extravasation (Grade II) were treated with diuretic and keeping a nephrostomy tube for 24–48 hours. No other complications beyond grade III were noted. The mean length of stay (LOS) was 2.7 $\pm$ 1.5 days (range 1–7).

TABLE 3. THE MAJOR STONE COMPOSITIONS OF CHILDREN TREATED WITH SUPER-MINI PERCUTANEOUS NEPHROLITHOTOMY

Stone composition	Number, <i>n</i>
Calcium phosphate	4
Magnesium ammonium phosphate	6
Carbonate apatite	1
Uric acid	10
Calcium oxalate	25
Ammonium urate	37
Cystine	1
Total	84

Stone composition analyses were available in 84 patients. Ammonium urate was the most common stone composition (Table 3).

Discussion

Improvements in technology and growing experience have dramatically changed the concepts of pediatric urolithiasis management in the last two decades.^{17,18} Historically, large renal stones in children were treated by open surgical removal with prolonged hospital admission. This approach has largely been replaced by minimally invasive techniques, including SWL, PCNL, and RIRS methods.¹⁷ Although SWL is associated with minimal morbidity, its clearance in certain stone components such as cysteine and lower pole stones is marginal.¹⁹ Additional general anesthesia sessions and further radiation exposure may be required for multiple SWL sessions in children. In recent years, with significant improvements in the miniaturization and durability of endoscopic equipment, RIRS has become a common alternative treatment modality in young children. Nevertheless, the stone clearance of RIRS can be significantly affected by the stone burden and renal anatomy.⁵ Also, long-term complications of pediatric RIRS such as vesicoureteral reflux and UVJ stricture remain undefined.

The ultimate objective of stone therapy is to render the patient stone free. This is particularly crucial in the pediatric population as urolithiasis in children is often associated with anatomical and metabolic abnormalities, and the risk of complications and recurrences is high.¹ In this study, the initial SFR of SMP on postoperative day 1 was 84.7%, and this rate was increased to 90.1% at postoperative 3 months. Our findings are in line with other published series of miniaturized PCNL in children.^{12–14}

The adoption of PCNL for the treatment of stone disease in children has lagged behind in adults due to concerns regarding the use of large size nephrostomy tract in a small collecting system. Accumulating evidences have suggested that the size of the tract is significantly correlated with the morbidity of PCNL in children.^{20,21} Bilén et al²¹ compared the safety of three different sizes of tract (26F, 20F, and 14F) in children and found an obvious lower rate of complications and transfusions in the 14F tract group. In our trial, most of the cases (84.7%) were achieved with a 12F sheath. The mean hemoglobin deficit was 10.2 g/L, and none of the patients required a blood transfusion.

Recent series encourage the adoption of UMP and microperc for the treatment of small renal stones in pediatric patients.²² Silay et al¹² performed the microperc in 19 children with a mean stone size of 14.8 mm, the overall SFR at 1 month was 89.5%, and the mean hemoglobin decrease was 0.1 ± 0.3 mg/dL. Dede et al¹³ reported their experience of UMP treatment in 39 children with a mean stone burden of 20.4 mm. A similar SFR (87.1%) to that of microperc was achieved with UMP. Those miniaturized PCNL techniques have been shown with minimal injury to children's kidney without reducing the effectiveness. However, due to the usage of fine tracts, drawbacks of these techniques included raised intrapelvic pressures, insufficient irrigation, and inability to retrieve larger fragments.^{9–11}

New technique may face the question whether operative complexity, fragmentation requiring time, and the difficulty

of calculi removal are increased. In the SMP procedure, however, stone fragments were actively removed by a 12F or 14F modified suction sheath with continuous negative pressure aspiration. Another advantage of SMP is it does not require forceps to extract fragments. Therefore, SMP is not only able to shorten the operating time but most importantly it also decreases the renal pelvic pressure. In our study, the mean operative time was 39.4 ± 26.2 minutes, and only seven (6.3%) children developed a minor postoperative fever.

An optimal treatment for renal stone should ensure high stone clearance with low complications rate. SMP has been shown to be safe with a total of 15.3% complication rate in this trial, which was similar to those of UMP (15.3%)¹³ and 16F miniperc (15.8%).¹⁴ All the complications were in Clavien grade I to II, and postoperative fever was the most common complication. No other serious complications (grade III to IV) were observed.

One of the important drawbacks of the URS is the necessity of placing a post-URS stent in all children. Stents result in symptoms, healthcare cost, decreased quality of life, and repeated anesthesia to facilitate removal. In our study, only 13 (11.7%) children had a Double-J stent placement and 95 children (85.6%) were totally tubeless. Three children had a nephrostomy tube (2.7%). Tubeless PCNL has been shown to decrease hospital stay and postoperative pain.²³ The mean LOS of our patients was 2.7 ± 1.5 days, this was comparable with those recent UMP procedures performed in children (2.8 ± 0.42 days).¹³

All fragments remaining in the urinary tract 3 months after the last intervention were considered as residual fragments. At present, the term “clinically insignificant residual fragments” or “CIRF” was referring to residual fragments after SWL, RIRS, or PCNL, which are smaller than 4 mm (or sometime 5 mm), asymptomatic, nonobstructive, noninfectious, and associated with sterile urine.^{24–26} Evidence showed that residual stones >6 mm and symptomatic stones <4–5 mm are indications for active stone removal. The indication for follow-up is asymptomatic stones <4–5 mm.²⁷ In our study, a close follow-up program was applied for children with asymptomatic residual fragments of 3–6 mm.

We believe that each technique has its indications. SMP will not replace the URS or SWL but simply complement them for children with moderate stone size. Based on our experience, SMP could minimize the invasiveness with high efficiency compared with standard PCNL. The careful selection of patients is one of the key factors for avoiding complications and increasing the success rates.

Conclusions

Our current findings demonstrated that the SMP technique could be a safe and effective alternative for the management of pediatric kidney stones. With its tubeless feature, SMP is suitable for renal calculi that are not amenable to RIRS or SWL in pediatric cases. We imply that for pediatric stones of 10–20 mm, SMP could be an ideal choice with a high stone-free rate and minimal invasiveness.

Author Disclosure Statement

No competing financial interests exist.

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Address correspondence to:

Guohua Zeng, MD, PhD

Department of Urology

Minimally Invasive Surgery Center

the First Affiliated Hospital of Guangzhou

Medical University

Guangdong Key Laboratory of Urology

Kangda Road 1[#], Haizhu District

Guangzhou 510230

China

E-mail: gzgyzgh@vip.tom.com

Abbreviations Used

CIRF = clinically insignificant residual fragments

CT = computed tomography

KUB = kidneys, ureters, and bladder

LOS = length of stay

PCNL = percutaneous nephrolithotomy

RIRS = retrograde intrarenal surgery

SFR = stone-free rate

SMP = super-mini percutaneous nephrolithotomy

SWL = shock wave lithotripsy

UMP = ultra-miniperc

US = ultrasonography