Totally Ultrasound-Guided Minimally Invasive Percutaneous Nephrolithotomy in Children: Is It Safe?

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Abstract

Objective: The objective of the study was to assess the outcome and feasibility of ultrasonography (US)-guided minimally invasive percutaneous nephrolithotomy (mini-PCNL) in children. **Materials and Methods:** Twenty-five children with upper urinary tract stones who had undergone US-guided mini-PCNL from June 2017 to June 2020 were enrolled in this study. Patients' demographic information and post-treatment results were retrospectively gathered and analysed. Pyelocaliceal system was punctured in prone position using US guidance, and the tract was dilated using single-shot dilation technique. All steps of renal access were done using only US. Mini-PCNL in all cases was done by using 15 Fr rigid nephroscope. Stones were fragmented with a pneumatic lithotripter and evacuated. **Results:** The patients' mean age was 6.30 ± 3.25 years (range: 1.5–15). The mean stone size was 16.04 ± 3.93 mm (range: 10–30). The mean access time to the stone was 1.50 ± 0.62 min (range: 1–4). The mean operation time was 94.66 ± 3.05 min (range: 90–100 min). The final stone-free rate was 96%. Post-operation fever occurred in 4 (16%) patients who were treated successfully with an antibiotic. No major complications occurred. **Conclusions:** We recommend US-guided mini-PCNL as a harmless alternative treatment option, in children with renal calculi due to its excellent outcomes and little complications.

Keywords: Minimal invasive, nephrolithiasis, nephrolithotomy, paediatrics, percutaneous, ultrasonography

Introduction

Epidemiologic studies have confirmed the continual growing rate of paediatric urinary stone disease over the past years. Although stone formation is less common in children than adults, it is more difficult to manage because of their urinary tract size and higher recurrence rate.[1] For most upper tract urinary calculi in children, the first-line treatment option is still extracorporeal shock wave lithotripsy (ESWL). However, the unpredictable outcome and lower stone-free rates (SFRs) are the primary disadvantages of this approach.[2] The increasing risk of diabetes, hypertension, renal tubular injury and arteriosclerosis is the main side effect of ESWL.[3] As a well-established procedure in adults, percutaneous nephrolithotomy (PCNL) is safe and effective. PCNL has been gradually adopted in children and is considered an option in children with renal stones.[4] Several series have been described using the paediatric mini-PCNL technique with acceptable SFR.[5]

The advantages of the mini-PCNL procedure include decreased incidence of bleeding and short hospitalisation. However, there are some downsides including the need for smaller size instruments and prolonged operation time.[6] An ideal tract size in mini-PCNL should be large enough to remove the stone fragment and small enough not to increase the bleeding risk.[6,7] Performing mini-PCNL under the guide of ultrasonography (US) can be a feasible, harmless and effective alternative to fluoroscopy when used by experienced surgeons.[5] Using US also decreases the radiation exposure to

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the surgeon and patient.[5] We conducted this study to assess the safety and feasibility of US-guided mini-PCNL in children with upper tract urinary calculi.

Materials and Methods

This study was approved by the Ethics Committees of Shiraz University of Medical Sciences (Approval code# IR.SUMS.MED.REC.1400.137) and performed in accordance with the Declaration of Helsinki. Twenty-five paediatric patients who had undergone US-guided mini-PCNL between June 2017 and June 2020 in our referral centres (Namazi Hospital and Ali-Asghar) were considered for this study. Almost all patients were referred to our clinic by a paediatric nephrologist.

We gathered the patients' preoperative data including age and sex, US finding, previous history of ESWL failure and stone characteristics such as radiopacity, location and size. We also gathered perioperative clinical lab data including complete blood count, renal function test (blood urea nitrogen [BUN] and creatinine) and urine culture. Positive cultures were treated with proper antibiotics and admitted with sterile urine for operation. All patients were admitted 6 h before the operation and received parenteral hydration and a single prophylactic antibiotic dose.

Operation and post-operation data were also gathered including the length of operation, SFR and hospitalisation period. Using the Modified Clavien grading system,[8] we classified post-operation complications into fever as Grade I; blood transfusion need, urine leakage and urinary tract infection (UTI) as Grade II; double-J placement for urine leakage, ureteroscopy and redo PCNL as Grade III; urosepsis and neighbouring organ injury as Grade IV and death as Grade V.

The inclusion criteria were renal stones more than 10 mm and/or history of previous ESWL failure. The exclusion criteria were all cases with active UTI, congenital abnormalities, uncorrected coagulopathy and those who underwent transplantation or urinary diversion.

Surgical procedure

Under general anaesthesia, with the thigh abducted in the supine position, ureteral catheter 3–4 Fr was inserted into the kidney and then taped to urethral Foley catheter (6–12 Fr, depending on age) after insertion. The patient's position changed to a prone position. After padding the chest, abdomen, knee and ankle, we draped the patient with sterile coverage. Then, under the Colour-Doppler US guide with a 3.5-MHz probe (BK Medical), the pelvicalyceal system (PCS) was visualised. Using a one-shot dilatation technique, an 18G access needle was passed into the appropriate calyx by attaching the needle to the curved US probe. Afterwards, its stylet was removed and 0.035-inch J-tipped guidewire was introduced into the targeted calyx. The skin was incised and an 8 Fr polyurethane dilator first dilated the nephrostomy tract. Then, the Alken guide was replaced, and a single 18 Fr Amplatz dilator was passed on the Alken guide, on which an Amplatz sheath was introduced into the PCS.

Using the measured tract length and Amplatz shadow during the insertion, we confirmed the correct position; then, the complex of Amplatz dilator and Alken guide was removed, and the Amplatz sheath and working guidewire were left in place. After that, 15 Fr rigid nephroscopy was performed. During renal access, all the processes were monitored under the guidance of US without using fluoroscopy. Lithotripsy was done with pneumatic lithoclast, and its particles were removed by forceps. Warm saline solution was used as irrigation for the prevention of possible hyponatraemia and hypothermia.

Stone-free status was checked at the end of the operation by the US. Finally, if no significant perforation occurred, no stone residue was seen, bleeding was minimal and access was done with a single tract, we choose tubeless mini-PCNL. After 12–24 h, both ureteral stent and urethral Foley catheter were removed. The patients were followed by KUB X-ray and US 1 day after the operation. If residual 5 mm stone or below were detected, the patient was followed for spontaneous stone passage.

Only in the cases of any inflammatory ureteric polyp due to stone obstruction, pelvic ureteric junction obstruction, significant residual stone and concurrent lithotripsy of ipsilateral ureteric stone, a 3 Fr Double-J stent was inserted.

Statistical analysis

Using mean and standard deviation, we assessed the continuous variables. Variables were presented using numbers and percentages in different categories. All statistical analyses were done using SPSS software (IBM SPSS, version 13, Armonk, New York: IBM Corp).

Results

Demographic data of the patients are as shown in Table 1. The patient's a mean age was 6.30 ± 3.25 years (range: 1.5 and 15 years). About 10 (40%) stones were located in the renal pelvis and 6 (24%) in the lower pole. The mean stone size was 16.04 ± 3.93 mm (range: 10–30 mm). The mean time to renal stone access was 1.50 ± 0.62 min (range: 1–4 min). The length of the tract was varied between 2.5 cm and 4 cm. The mean procedure time was 94.66 ± 3.05 minutes (range: 90–100 min). Moreover, the patients were discharged after 36–48 h, with a mean hospital stay of 46.08 ± 4.49 h. Almost all cases required a single surgical session (24 cases, 96%), except for one case (4%), which required another session (ESWL). The haemoglobin concentration decreased by 0.3–1.5 g/L after the operation, with a mean haemoglobin drop 0.77 ± 0.30 g/L. The final SFR was 96% 1 month after the operation. Post-operative complications occurred in 4 (16%) patients including >38.5 _C fever, which was treated successfully with antibiotics. Double J stent insertion was required in two patients due to constant urinary leakage from nephrostomy tract. Our study did not show any case of adjacent organ injury or need for blood

Table 1: Demographic characteristics of the patients who underwent minimally invasive - percutaneous nephrolithotomy

Characteristics	*n* (%)
Male: female (ratio)	18/7 (72:28)
Mean age±SD (years), range	6.30±3.25 (1.5-15)
History of failed ESWL	11 (44)
History of previous PCNL	2 (8)
History of UTI	5 (20)
Size of stone (mm), range	16.04±3.93 (10-30)
Location of stone in kidney	
Upper pole	1 (4)
Mid pole	1 (4)
Lower pole	6 (24)
Renal pelvis	10 (40)
Stag horn stone	7 (28)
Stone opacity	
Opaque	16 (64)
Nonopaque	9 (36)
Hydronephrosis	
Mild	16 (64)
Moderate	7 (28)
Severe	2 (8)
Mean pre-operation HB±SD (g/dl), range	10.14±1.08 (7.5-11.5)
Mean pre-operation BUN±SD (mg/dl), range	18.00±2.10 (14-22)
Mean pre-operation Cr±SD (mg/dl), range	0.76±0.11 (0.6-1.0)

SD: Standard deviation, ESWL: Extracorporeal shock wave lithotripsy, PCNL: Percutaneous nephrolithotomy, UTI: Urinary tract infection, HB: Haemoglobin, BUN: Blood urea nitrogen, Cr: Serum creatinine

Table 2: Outcome and complications of minimally invasive - percutaneous nephrolithotomy in paediatric patients

Characteristics	*n* (%)
Mean tract length size±SD (cm), range	3.19±0.36 (2.5-4.0)
Mean access time (min), range	1.50±0.62 (1.0-4.0)
HB drop±SD (g/dl), range	0.77±0.30 (0.30-1.50)
SFR	24 (96)
Nephrostomy tube	5 (20)
Size of residual stone (mm)	7
Double j stent insertion	2 (12.5)
Hospital admission (h)	
36	4 (16.0)
48	21 (84.0)
Second access (ESWL)	1 (4.0)
Postoperative fever	4 (16)

SD: Standard deviation, HB: Haemoglobin, SFR: Stone-free rate, ESWL: Extracorporeal shock wave lithotripsy

transfusion [Table 2]. The outcome and complications of mini-PCNL was showed in Table 2

Discussion

Abnormalities in the urinary tract anatomy, metabolic disorders and infections are the most common causes of urinary tract stones formation, especially in paediatric populations.[9] In the case of upper urinary tract stones, ESWL, PCNL and retrograde intrarenal surgery (RIRS) are standard treatment options in children. In addition, we preferred to treat the stones with the least invasive options since stone recurrence is high. Thus, ESWL is the preferred option for stones <20 mm in diameter. However, in ESWL, lower SFR and the possible need for multiple treatment session are the main limitations of this procedure since complete stone removal is the target.[3,10] Another useful technique is RIRS, which may be limited to treating the large and complex stones. The vesicoureteral reflux, ureteral strictures and more general anaesthesia are the main limitation of this procedure.[11,12] As to the upper urinary tract stone, studies showed a higher SFR of PCNL.[13] The European Association of Urology 2015 guidelines suggest that for paediatric patients with kidney stones more than 2 cm and lower pole stones more than 1 cm, PCNL should be considered as the ideal management. The lithotripsy procedure can be monitored visually using US-guided PCNL while lowering the needs for auxiliary facilities over ESWL.[14] In the paediatric population, due to the smaller and fragile kidney, suitable size PCNL equipment is preferred over traditional adult size equipment. Previous studies showed that mini-PCNL had a significant edge over conventional PCNL when comparing bleeding-related complications.[15] US-guided mini-PCNL has many advantages such as an ongoing monitoring of the surrounding tissues and vessels during the procedure, better understanding for increasing accuracy in access to the stone, the staff 's less exposure to radiation, and also no need for contrast injection.[3,5] Since the skin to stone distance is shorter in paediatric population compared to adults, US makes it easier for both precise placement of the needle to PCS and dilation of the tract in children.[16]

Mini-PCNL under US-guidance can be a feasible, dependable, harmless and effective alternative to fluoroscopy in experienced hands and reduces the radiation exposure to the urologist and patient.[5] Most complications of PCNL are arising from the percutaneous access step, in which the size of PCNL access tracts plays the role of a significant contributing factor.[17] The technology of miniaturisation of the access sheath has progressed recently, and the miniaturised PCNL has been categorised into mini-PCNL (≤22 Fr), Chinese mini-PCNL (14–20 Fr), super-mini-PCNL (10–14 Fr), ultra-mini-PCNL (11–13 Fr), micro-PCNL (4.8 Fr) and mini-micro-PCNL (8 Fr).[6] Mini-PCNL is a new method used to improve the SFR and safety of this procedure. Zeng *et al*. reported mini-PCNL as a safe and effective method for managing the upper urinary tract stones smaller than 2.5 cm. It was also shown that, when performing mini-PCNL, the tubeless PCNL rate was higher, and patient hospitalisation was shorter after surgery.[18]

Several studies, including Basiri *et al*. and our study, suggest total US-guided mini-PCNL as a safe and efficient procedure in the paediatric population.[19]

Instead of fluoroscopy, we used the US as a guiding tool during all procedure steps including access, Amplatz insertion and checking for possible residual stones. This method was similar to that of a previous study by Sharifiaghdas *et al*.[4] Futhermore, since the one-stage tract dilation technique was highly suggested in previous studies, we performed all mini-PCNL using the same technique.[4,20,21]

After PCNL, <10% of patients require blood transfusion in the paediatric population and <15% present with fever after the operation.[22] In our study, our cases neither required blood transfusions, nor presented with sepsis or organ injury; a low proportion of fever >38.5 C was reported after mini-PCNL. These findings support the safety of the mini-PCNL procedure. When stone fragments obstruct the tract, it may lead to negative pressure aspiration and high transitional pressure, causing pyelovenous or pyelosinus backflow and subsequently an increase in the risk of post-operative fever. In addition, the haemoglobin concentration was slightly decreased in most patients due to minor vessel injury. Our result was consistent with those of a previously published study.[3]

In our study, the mean access time was lower than the previously published article (1.50 ± 0.62 min vs. 4.45 ± 2.25 min).[4] Our explanation to lower access time to the stone was better visualisation of the PCS system by the US and using a one-shot dilatation technique in our study.[21] In this study, the mean operation time was similar to that of a previous article.[3]

In one study, two patients after mini-PCNL had Double J stent migration and underwent paediatric cystoscopy.[23] In the present study, two patients required Double J stent insertion. The final SFR was 96%, which was in the same line with a previously published report by Hosseini *et al*. (final SFR was 93.61%).[5]

In our study, hospital stay duration was the same as that reported in previous studies.[22] Several studies claimed that, in children, kidney function and growth were not affected by PCNL.[24] In Hong *et al*.'s study, despite the initial rise in postoperative BUN and creatinine levels, the renal function returned to normal later in the follow-ups, which is similar to our study.[14]

Despite all the mentioned benefits of using the US in mini-PCNL, the US has one major limitation. As an operator-dependent modality, the experience of a surgeon with the US is a major key factor. With a decent residency training programme, we can improve the speed of the learning curve. We suggest that this method should be performed in patients with grossly hydronephrotic systems and first in patients with simple calculi, and when fully experienced, it should be performed in patients with larger complex stones.[16]

The small sample size and retrospective nature of this study were our major limitations. Another major drawback was the US's unreliability in the detection of the residual stone when using solely. The echogenicity of the irrigation fluid in PCS may mimic the stone appearance, affecting our judgement in evaluating the residual stones at the end of the procedure, which is a significant step in mini-PCNL.[4]

Conclusions

Our study results support previous reports which highly recommended US-guided mini-PCNL as a harmless alternative to renal calculi treatment in children, with outstanding outcomes and fewer complications.

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Conflicts of interest

There are no conflicts of interest.

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