Safety and Efficacy of Ultrasound-guided Percutaneous Nephrolithotomy for Treatment of Urinary Stone Disease in Children

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OBJECTIVE To present the feasibility and efficacy of ultrasound-guided percutaneous nephrolithotomy for the treatment of urinary stone disease in children.

METHODS The medical records and files of 17 patients with renal stones (17 renal units) who were aged ≤16 years who had undergone ultrasound-guided percutaneous nephrolithotomy from 2008 to 2010 were retrospectively reviewed and analyzed. Ultrasonography was used for guidance in all patients in every step of the procedure. Fluoroscopy was used to aid in tract dilation in the initial cases of the series and to evaluate for stone clearance in all cases. The operative and postoperative findings were assessed.

RESULTS The average age of the patients was 8.8 ± 2.86 years (range 5-15). The mean stone size was calculated as 337.4 ± 52.9 mm^2 (range 260-446). The mean operative time was 67.9 ± 14.58 minutes (range 45-95). Fever, urine leakage, and bleeding requiring blood transfusion were observed in 3, 1, and 1 patient, respectively. The fluoroscopic screening time was limited to 17.76 ± 15.5 seconds (range 1-54). Neighboring organ injuries were not observed. The overall success rate improved from 82.35% to 100% with additional treatment modalities (shock wave lithotripsy in 2 and ureteroscopy in 1).

CONCLUSION Percutaneous nephrolithotomy can be safely performed with ultrasound guidance in children, providing the advantages of less radiation exposure, no adjacent organ injury, and similar success and complication rates compared with fluoroscopic guidance. UROLOGY 79: 1015–1019, 2012. © 2012 Elsevier Inc.

Since the introduction of percutaneous nephrolithotomy (PNL) in 1976, the treatment of urinary stone disease has changed dramatically, especially with the technological developments in surgical instruments in recent years.[1] However, in the pediatric population, minimally invasive techniques have been popularized with the miniaturization and development of equipment and the refinement in endourologic techniques in the past 2 decades. Currently, PNL in children is recommended for the treatment of renal pelvic or caliceal stones with a diameter >20 mm (~300 mm^2).[2]

In children, the endoscopic treatment of urinary stone disease requires technical modifications and surgical skill because of the small size and mobility of the kidney, friable renal parenchyma, small collecting system, and deleterious effects of the radiation.[3] Some investigators have advocated the use of small caliber instruments and flexible endoscopes to avoid damaging the kidney in children.[4-6]

However, children with urinary stone disease are subjected to repeated radiation exposure during interventional or diagnostic procedures because of the high risk of recurrence. With the increased attention to the risks and effects of radiation exposure, x-ray-free modalities have been popularized. In recent years, ultrasonography (US) has been used alone or complementarily with fluoroscopy during PNL in adults to minimize radiation exposure.[7-12] However, the number of the studies presenting the use of US for guidance during PNL in children to reduce radiation exposure is limited.[13]

In the present study, we aimed to present the feasibility and efficacy of US-guided PNL for treating urinary stone disease in children.

MATERIAL AND METHODS

We retrospectively reviewed and analyzed the medical records and files of 17 pediatric patients with renal stone (17 renal units) aged ≤16 years who underwent US-guided PNL from 2008 to 2010. Of the 17 patients, 11 were boys and 6 were girls, ranging in age from 5 to 15 years (median 8.8 ± 2.86; Table 1).

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Table 1. Demographic and clinical features

Characteristic	Value
Age (y)	
Mean ± SD	8.8 ± 2.86
Range	5-15
Sex	
Male	11
Female	6
Side	
Left	8
Right	9
Stone size (mm^2)	
Mean ± SD	337.4 ± 52.9
Range	260-446
Stone opacity	
Opaque	15
Semiopaque	2
Stone location	
Pelvis	8
Pelvis and lower pole	7
Lower pole	2
Grade of hydronephrosis	
0	3
I	4
II	4
III	6

Data presented as mean ± SD or numbers, with percentages in parentheses.

The surgeon had gained significant experience with US-guided nephrostomy tube replacement and PNL in adults before performing US-guided PNL in children. The indications for PNL were listed as large pelvic or caliceal stones, stones resistant to shock wave lithotripsy (SWL), complex renal stones, or obstructed and dilated kidneys.

A preoperative complete blood count, serum creatinine levels, a platelet count, a bleeding and coagulation profile, and a urine culture were obtained from all patients. The radiologic evaluation included plain film of the kidney, ureter, bladder and US, with the addition of intravenous urography in selected cases. The stone burden was determined by radiographic studies. The degree of hydronephrosis was assessed according to the Society for Fetal Urology Classification.[14]

Operative Technique

With the patient under general anesthesia in the lithotomy position, a 3F or 4F ureteral catheter was inserted into the affected kidney and secured to a urethral Foley catheter in patients with mild or no hydronephrosis. This procedure was not applied to the patients with grade II or III hydronephrosis. The patient was then turned to the prone position, and all pressure points were padded. The patient and the surgical team were protected with lead aprons and thyroid shields because of the probability of using C-arm fluoroscopy as an axillary guide for US. The renal and pelvicaliceal system anatomy, adjacent organs and relationships, and calculi were initially identified using a Toshiba SSH-140A US machine with a 3.75-MHz sector probe. The pelvicaliceal system was distended with a saline injection through the ureteral catheter if visualization of the caliceal anatomy was not clear. Punctures to the tip of the desired calix were performed with an 18-gauge access needle, and a sensor guidewire was inserted through the needle to the collection system under US guidance (Fig. 1). In the initial cases, the position of the guidewire was checked with single-shot fluoroscopic screening. The nephrostomy tract was dilated ≤20F using fascial dilators (Cook Surgical, Bloomington, IN) in preschool children and ≤26F in those aged 8-16 years (Fig. 2). A 17F or 24F nephroscope was inserted into the collection system. Stone fragmentation and removal were performed with pneumatic or US (EMS Swiss Lithoclast, Nyon, Switzerland) energy. The stone-free status was assessed with US and direct visualization using a nephroscope. In addition, single visualization with fluoroscopy was used to confirm stone clearance at the end of the procedure. A 14F Foley or nelaton catheter was inserted as a nephrostomy tube in all patients. The ureteral catheter was removed at the end of the procedure in uncomplicated cases.

The patients were evaluated with plain film of kidney, ureter, bladder, US, and laboratory tests on postoperative day 1 to assess stone clearance and hematocrit changes. The Foley catheter or ureteral catheter was removed on postoperative day 1, and the nephrostomy tube was removed on postoperative day 2. The patients were discharged in the absence of fever, urine leakage from the tract, or any complaints on postoperative day 2, with oral antibiotic and analgesic regimens. The patients were evaluated for complications and wound healing in the postoperative second week. The second follow-up visit at 3 months postoperatively included urinary US, chemical analysis of the extracted stones, and metabolic analysis of the 24-hour voided urine specimens. All the children were treated accordingly, and additional follow-up was individualized.

RESULTS

Of the 17 patients, the stones were in the right kidney in 9 and in the left in 8. Of the 17 stones, 14 were radiopaque and the others were semiopaque. The stones were located in the renal pelvis, lower pole, and pelvis and lower pole in 8, 2, and 7 patients, respectively. The mean stone size was calculated as 337.4 ± 52.9 mm^2 (range 260-446). The degree of hydronephrosis detected was grade I, II, and III in 4, 4, and 6 patients, respectively. No hydronephrosis was present in 3 patients. The demographic features of the patients are summarized in Table 1.

Percutaneous renal access was achieved through the fornix of the lower pole calix in all patients with US guidance using the subcostal approach. No anatomic abnormalities were observed in the perioperative evaluation. Tract dilation was performed ≤20F and ≤26F in 7 and 12 patients, respectively. The mean operative time was 67.9 ± 14.58 minutes (range 45-95). The average fluoroscopic screening time was 17.76 ± 15.5 seconds (range 1-54). The postoperative mean hematocrit decrease was 3.94% ± 2.15% (range 0.2%-8.6%).

No major intraoperative complications occurred. No adjacent organ injuries were observed. Only 1 patient who had significant hemorrhage and hematocrit decrease during the procedure received a blood transfusion (Clavien grade IIIa complication[15]).

Fever (Clavien grade I complication[15]) occurred in 3 patients on the first day after PNL, which resolved spontaneously in 1 patient. The fever was controlled with third-generation cephalosporin in the remaining 2 pa-

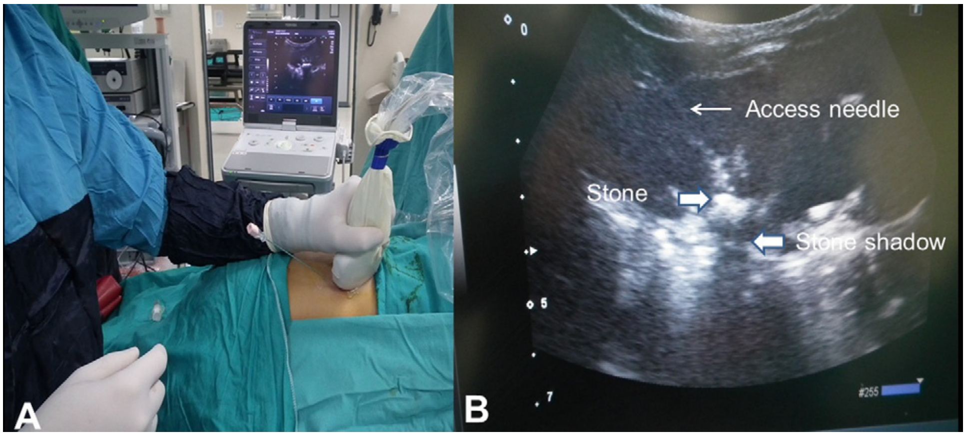

Figure 1. Percutaneous renal access is performed with US guidance in prone position **(A)**. The access needle, stone and its shadow is clearly seen on US screen **(B)**.

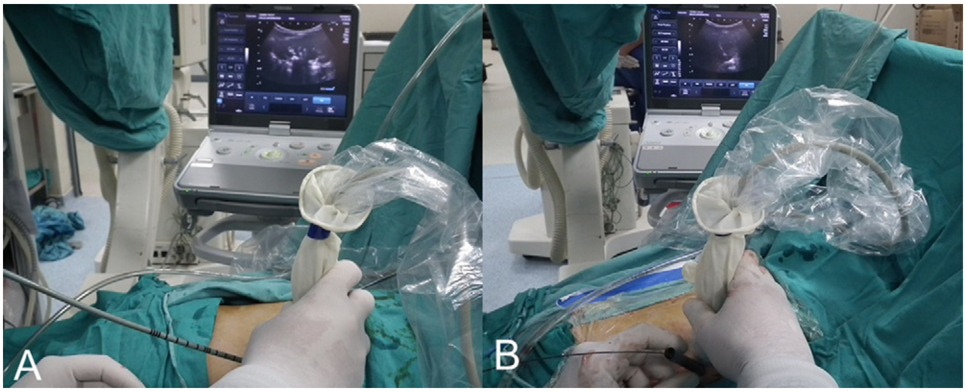

Figure 2. The nephrostomy tract dilation was done with fascial dilators **(A)**. Finally Amplatz sheet is inserted under US control. The insertion is clearly seen on US screen **(B)**.

tients. The mean hospitalization time was 2.8 ± 1.18 days (range 2-6).

In 3 patients, residual fragments were detected postoperatively. Two patients with residual fragments of 10 and 8 mm underwent SWL. Urine leakage was observed on postoperative day 3 in the patient with renal calculi with a diameter of 7 mm (Clavien grade IIIb[15]). US revealed a 7-mm stone located at the distal ureter. After stone fragmentation, a ureteral double-J stent was inserted endoscopically on postoperative day 4. The overall complication rate was 29.4% (n = 5).

Stone-free status was achieved in 14 patients (82.35%). After the additional treatment modalities (SWL and ureteroscopy), all patients were stone free by the third month of follow-up. The perioperative and postoperative values are summarized in Table 2.

COMMENT

PNL was first introduced in 1976 for adults[1] and in 1984 for children,[16] and the emergence of SWL has revolutionized the treatment of renal stone disease in the past 3 decades. With the miniaturization of endoscopic instruments and advances in lithotripters, PNL has been a commonly performed technique in monotherapy and combined with SWL with high stone-free and acceptable complication rates in children with large stones.[17]

Although computed tomography, US, and magnetic resonance imaging are commonly used imaging modalities, fluoroscopy is the most used guidance method for all PNL steps. However, fluoroscopy is associated with the potential deleterious effects of ionizing radiation. Despite protective measures, the stochastic effects of ionizing radiation, which are not dose-dependent, can lead to genetic mutations and cancer.[12] It is well known that children who undergo radiographic examination are potentially at a greater risk of the deleterious effects of radiation exposure than adults. The mean radiation dose per diagnostic intervention is 0.05 mSv for anteroposterior and lateral abdomen radiograph (equal to the dose of 2.5 chest x-rays), 0.33 mSv for fluoroscopic cystogram (equal to the dose of 16 chest x-rays) and 5 mSv for abdomen computed tomography (equal to the dose of 250 chest x-ray) for a 5-year-old child.[18] It has been highlighted that a single abdomen computed tomography scan in a 1-year-old child would result in 1 computed tomography-related death per 550 scans.[19]

Table 2. Perioperative and postoperative findings

Characteristic	Value
Operation time (min)	
Mean ± SD	67.9 ± 14.58
Range	45-95
Fluoroscopic screening time (s)	
Mean ± SD	17.76 ± 15.5
Range	1-54
Duration of hospitalization (d)	
Mean ± SD	2.8 ± 1.18
Range	2-6
Success rate (%)	82.35 (14/17)
Hematocrit decrease (%)	
Mean ± SD	3.94 ± 2.15
Range	0.2-8.6
Additional treatment (n)	3 (17.64)
Ureterorenoscopy	1
Shock wave lithotripsy	2
Complications (n)	5 (29.4)
Fever	3 (17.64)
Urine leakage	1 (5.88)
Blood transfusion	1 (5.88)

Data in parentheses are percentages.

With the increase in concern for radiation exposure, alternative radiation-free imaging modalities can be used to minimize the radiation exposure in children with urinary stone disease or vesicoureteral reflux that require repeated imaging throughout life.[13,20] US is the most popular radiation-free imaging method used for the diagnosis or follow-up of childhood conditions. Desai et al[13] first reported the results of a US-guided pediatric PNL series in 1999. Although the renal puncture was performed with US guidance, tract dilation was performed with a fluoroscopic control in that study. Many studies have presented the results of US-guided PNL in adults, with similar success and complication rates.[7-10,12] In addition to being radiation-free, the advantages of US include the ability to evaluate the pelvicaliceal system in a 3-dimensional orientation, fewer adjacent organ injuries, shorter operative times, the lack of a need for contrast agent administration, and fewer punctures.[7,9,21] Furthermore, US is a feasible guidance method for kidney transplant recipients and patients with ectopic or anomalous kidneys.[13,22] US-guided percutaneous renal access is also preferred for pregnant women and patients with failed ureteral catheter replacement.[7] In our series, we did not insert ureteral catheters in the patients with moderate or severe hydronephrosis (n = 10). The shorter operation time observed in the other series could be attributed to this.

In the series of US-guided pediatric PNL, the average hemoglobin decrease was reported to be 1.6 g/dL, and blood transfusion was not required.[13] Although many factors affect blood loss, such as the access number, stone type and burden, operation time, and type and caliber of the dilatator,[23,24] Desai et al[13] emphasized that US-guided percutaneous access through the cup of the desired calix that transverses minimal renal parenchyma will avoid injuries to major intrarenal vessels. In recently published studies presenting the results of color-Doppler US-guided PNL, the mean hemoglobin decrease and transfusion rates were significantly diminished[25,26]; however, these studies were designed for adult patients, not for children. In our study, the average hematocrit decrease was 3.94% ± 2.15%. A blood transfusion was required for only 1 patient (5.88%). However, prospective randomized studies are required to compare the guidance methods in terms of blood loss in children.

US allows clear visualization of the adjacent organs during the percutaneous renal access. Gedik et al[27] reported open conversion because of colon perforation during fluoroscopic-guided PNL in 1 patient who was preoperatively evaluated with urography in their series of pediatric patients. Gredik et al[27] also emphasized that the risk of colon injury, especially increases in unsuitable lateral access, in hypermobile kidneys and in the presence of a retrorenal colon. Children without a retrorenal colon have the same risk because of hypermobile kidneys in the tract dilation phase of PNL. We used short fluoroscopy screening periods to ensure the directions of the dilators to prevent organ injury. In another series of US-guided PNL, renal access could have been achieved by creating a safe intercostal window far from the colon in patients with retrorenal colons.[20] We did not encounter any cases with retrorenal colons, which has a reported incidence rate of 1%.[28]

Another advantage of US compared with fluoroscopy is the visualization of nonopaque or semiopaque stones not visible with fluoroscopy. In these cases, the assessment of stone-free status at the end of the procedure might be more accurate with US. Stone-free status assessment is very important for children because residual fragments of any size are significant risk factors for stone recurrence. Although computed tomography[29] is accepted as the reference standard diagnostic modality for detecting residual stones or clinically insignificant residual fragments postoperatively, fluoroscopy, US, and nephroscopy are the main tools used in the intraoperative assessment of stone clearance. In a recent study, Portis et al[29] concluded that flexible nephroscopy combined with high magnification rotational fluoroscopy is an effective method for intraoperative residual fragment detection and clearance assessment. In the present study, stone-free status was evaluated with US, rigid nephroscopy, and single-shot fluoroscopic screening. We detected residual stones of 10, 8, and 7 mm in 3 patients, respectively. However, in these patients, aggressive nephroscopy could not be performed because of visual impairment owing to bleeding.

Although the mean fluoroscopic screening time has not been reported, fluoroscopy is used for tract dilation,[8] the assessment of stone-free status, and the localization or puncturing of the pelvicaliceal system in obese patients in studies presenting the results of US-guided PNL in adults.[10] We did not encounter any difficulty during the localization or puncturing of the kidney and pelvicaliceal system. In the absence of hydronephrosis, the collecting system was distended with a saline injection through the ureteral catheter. In addition to this method, Agarwal et al[7] reported the use of a diuretic to transiently dilate the calices and facilitate the US-guided puncture. Fluoroscopic guidance aided during the tract dilation and the stone-free status assessment in the initial cases of our series. The mean fluoroscopic screening time was limited to 17.76 ± 15.5 seconds (range 1-54).

In the present study, the success rate of achieving access to the collection system was greater than in other studies. In the study by Basiri et al,[21] the lower success rate of gaining access was attributed to the low degree of hydronephrosis in patients enrolled in the study. Although Basiri et al[7] injected saline when hydronephrosis was minimal, obtaining sufficient dilation can be difficult for inelastic adult kidneys. Our high success rate could have resulted from the high elasticity of pediatric kidneys. In terms of the success and complication rates, our results are comparable to the results obtained from either US- or fluoroscopic-guided pediatric PNL series.[13,4,30]

One limitation of our study was the small number of cases. Prospective and comparable trials are necessary before a consensus regarding the most effective and harmless guidance method can be reached. Experience appears to be a great limitation of this technique in children.

CONCLUSIONS

Urologists should consider the deleterious effects of radiation exposure and choose the appropriate imaging method for the diagnosis, treatment, and follow-up of urinary stone disease in children, who are more sensitive to the effects of radiation. Our results demonstrated that PNL can be safely performed with US guidance in children, providing the advantages of less radiation exposure, less adjacent organ injury, and similar success and complication rates compared with fluoroscopy guidance. However, US-guided pediatric PNL requires more experience just as do other surgical procedures performed in children.

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