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ORIGINAL PAPER

Treatment of renal stones in infants: comparing extracorporeal shock wave lithotripsy and mini-percutaneous nephrolithotomy

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Abstract The objective of the study is to compare the efficacy and safety of extracorporeal shock wave lithotripsy (ESWL) and mini-percutaneous nephrolithotomy (MPCNL) in treating renal stones sizing 15–25 mm in infants <3 years. Forty-six infants with renal stones sizing 15–30 mm were treated by either ESWL (22 renal units in 22 infants) using Dornier compact delta lithotripter or MPCNL (25 renal units in 24 infants) using 14F–18F renal access under general anesthesia. The operation time, stone-free rate, re-treatment rate, and complications between the two groups were compared with the χ^2, Mann–Whitney *U*, and Student's *t* tests. No significant differences in mean age and stone size were observed between the two groups. The 1- and 3-month postoperative stone-free rates were 84 and 96 % in MPCNL group and were 31.8 and 86.4 % in ESWL group. The re-treatment and complication rates were significantly higher in ESWL group than in MPCNL group (50 vs. 12 %, $P = 0.004$; 16.0 vs. 45.5 %, $P = 0.028$). The stone recurrence rate was similar between the two groups. No significant changes of serum creatinine (Cr) level and glomerular filtration rate were observed in both groups. In conclusion, MPCNL is an effective and feasible alternative monotherapy for large renal stones (15–25 mm) in infants, with a higher stone-free rate and a lower complication rate when compared with ESWL.

Keywords Infant · Renal calculi · Shock wave lithotripsy · Percutaneous nephrolithotomy

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Introduction

The incidence of renal stones is low in infants. Evaluating and treating these cases pose a technical challenge to urologists. All available treatments aim at completely clearing stones, preserving renal function, and preventing stone recurrence. Improvements in technology and accumulated clinical experience have resulted in increasing application of mini-invasive techniques for treating stones in children, even in infants. Currently, the majority of stones in children can be treated with extracorporeal shock wave lithotripsy (ESWL), percutaneous nephrolithotomy (PCNL), and ureterorenoscopy (URS) alone or in combination, whereas a few cases need to be treated with open surgery. However, the frequently observed metabolic and anatomic abnormalities in infants (when compared with adults) may influence stone formation, treatment selection, and outcomes. To select the most appropriate treatment modality, the location, composition, size and number of stone(s), the anatomy of the renal collecting system, and the presence of obstruction along with infection of the urinary tract should be considered.

ESWL is the first-line treatment for stones in children. Previous studies have demonstrated that ESWL was safe and efficient in treating both renal and ureteral stones in children population [1–3]. Renal pelvic stones or calyceal stones up to 15 mm in diameter can be treated with ESWL, but the stone-free rate tends to decrease with the increase of stone size [1, 2, 4–7]. As reported, the stone-free rates following ESWL ranged from 57 to 97 % on short-term and 57 to 92 % on long-term follow-up [6–9]. Calyceal stones, stones located in abnormal kidneys, and large stones (>20 mm) are hard to be disintegrated and cleared by a single ESWL session. The re-treatment rates ranged from 13.9 to 53.9 % [1, 5, 10], ancillary procedures and/or additional interventions ranged from 7 to 33 % [11, 12].

PCNL has been applied commonly in adults [13]. With the increasing experience and advances in techniques, PCNL has become a suitable treatment for children with large stone burden, making it unnecessary to perform a series of ESWL sessions under general anesthesia. However, treating renal stones in infants with PCNL is still a challenge [14–18].

In the present study, we compared the efficacy and safety of ESWL and MPCNL in treating large renal stones in infants <3 years. We found that MPCNL is superior to ESWL in treating this disease.

Patients and methods

Between November 2005 and July 2011, 46 infants (<3 years of age) with renal stones sizing 15–25 mm in a total of 47 renal units were treated with either MPCNL or ESWL. Urine test, culture and sensitivity tests, serum creatinine (Cr) and hemoglobin (Hb) detection, plain abdominal radiograph, and urinary ultrasonography were performed in all infants preoperatively. Intravenous urogram (IVU), non-contrast computed tomography (CT), and renal ^{99m}Tc-DMSA scintigraphy were performed when necessary. Preoperative radiological examinations showed no anatomic abnormalities of the urinary system in all cases. After operation, stone samples were analyzed by X-ray diffraction method. Serum Cr, electrolyte, and Hb measurements along with urine test were repeated in all patients 24–48 h postoperatively.

Treatment procedures

Of these cases, 25 renal units in 24 infants were treated with MPCNL at Department of Urology of the First Affiliated Hospital of Guangzhou Medical College; 22 renal units in 22 infants were treated with ESWL at Department of Urology of the Xinhua Hospital of Shanghai Jiaotong University. All operations were performed under general anesthesia. Prophylactic antibiotics were administered to all patients.

MPCNL procedure

The patient was first placed in the lithotomy position. A 4F or 5F ureteral catheter was inserted into the ureter with the assistance of a flexible 0.035-in. Zebra™ guide wire (Boston Scientific Corporation) under direct ureteroscopic vision. Then the patient was turned to the prone position. The genitalia were covered with a lead protection panel. A percutaneous access was established under fluoroscopic guidance using the “bull’s eye technique”. After the access was serially dilated to 14F, 16F, or 18F, a matched peel-away sheath (Cook Inc.) was inserted into the renal collecting system. The stones were fragmented with a pneumatic lithotripter (Jielun Medical Corporation, Guangzhou, China) under an 8F/9.8F semi-rigid ureteroscope (Richard Wolf GmbH, German). Large fragments were extracted by forceps, whereas small fragments were flushed out by a forceful pulse flow produced by an endoscopic perfusion pump (Jielun Medical Corporation, Guangzhou, China) with a pressure at 58–68 mmHg, which equals to a third of that used in adults. At the end of the procedure, residual stones were determined fluoroscopically. A pediatric JJ ureteral stent was inserted via an antegrade percutaneous access, and a 14F–18F silastic nephrostomy tube was inserted for drainage. A plain abdominal radiograph was performed on postoperative days 1 or 2 to evaluate residual fragments. A second-look MPCNL was performed to remove clinically significant residual fragments at 3–5 days after the first operation when necessary. The nephrostomy tube was removed 4 days later if no fever, urine leakage, and bleeding from the tube was observed. The double-J ureteral stent was removed 4 weeks after the procedure.

ESWL procedure

Extracorporeal shock wave lithotripsy was performed with the Dornier Compact Delta-lithotripter under ultrasonic guidance. The patient was placed in the supine position with a chest strap to protect the lungs and with a sheet lead to protect external genitalia. The number of shock waves per ESWL session varied from 300 to 1,800 (mean 956) at a rate of 60 shock waves/min. The electric discharge voltage was escalated from 8 kV to 11–12 kV. No ureteral catheterization was needed either before or after the procedure. A plain abdominal radiograph was performed to evaluate the stone-free status at 1 week postoperatively. In infants with inadequate stone disintegration, a repeated ESWL session was performed after 2 weeks.

Follow-up evaluation

A plain abdominal radiograph was performed at 1 month and a non-contrast spiral CT scan was performed at

3 months after the intervention to evaluate the stone-free status. Renal ^{99m}Tc-DMSA scintigraphy was performed to evaluate renal function when necessary.

Stone-free status was defined as no residual fragments detected with non-contrast CT at 3 months after the treatment. After complete removal of the stone(s), new stone(s) detected on abdominal sonography, plain abdominal radiograph, or a non-contrast CT scan during follow-up was defined as recurrence.

Statistical analysis

All statistical analyses were performed using SPSS 13.0 or Microsoft Excel program. Student's *t* test or Mann–Whitney *U* test was used for continuous variable analysis depending on the data normality; χ^2 or Fisher's Exact test was used for categorical variable analysis. All tests were two tailed. $P < 0.05$ was considered statistically significant.

Results

Preoperative clinical data of the patients are shown in Table 1. No significant difference was observed between the two groups with respect to all variables except for serum Hb level, which was found to be higher in ESWL group than in MPCNL group ($P < 0.001$).

In MPCNL group, the mean operation time was 76.2 ± 23.4 min (range 35–120 min); the nephrostomy tube was removed 4–6 days after operation. In ESWL group, the mean operation time was 15.6 min (range 5–30 min). The duration of hospital stay was significantly longer and the 1-month stone-free rate was higher in MPCNL group than in ESWL group (both $P < 0.001$, Table 2). Of the four renal units with residual stones in MPCNL group, three were successfully treated with a second-look MPCNL procedure; one with no symptom was managed conservatively. Of the 15 infants with residual stones in ESWL group, 11 were treated with a repeated ESWL session; 3 underwent conservative management and had stones spontaneously passed out; 1 failed to respond to ESWL and converted to undergo MPCNL. The re-treatment rate was significantly higher in ESWL group than in MPCNL cohort ($P = 0.004$), whereas the 3-month stone-free rate was similar between these two groups (Table 2). Stone analysis revealed that, in ESWL group, all 7 patients with radio-opaque stones (calcium-, cystine-, and struvite-based) required re-treatment and 4 had stone street formed; in MPCNL group, however, 18 (81.8 %) of 22 patients with radio-opaque stones were stone-free after the first procedure.

No major perioperative complication occurred and no patient required blood transfusion. Postoperative complications were more frequently reported in ESWL group than in MPCNL group ($P = 0.028$, Table 2). Four patients in ESWL group had stone street formed and were treated under a 4.5F semi-rigid ureteroscope with double J stent indwelling. The stone fragments passed spontaneously during follow-up. Other complications were treated with symptomatic treatment.

Fourteen infants in MPCNL group and 18 in ESWL group underwent renal ^{99m}Tc-DMSA scintigraphy before and after the treatment for renal functional evaluation. Serum Cr level significantly decreased ($P = 0.03$) and unilateral GFR significantly increased ($P = 0.002$) in MPCNL group after the treatment; no significant changes were observed in ESWL group (Table 2). The recurrence rate was similar between these two groups.

Table 1 Demographic and preoperative clinical data of infants with renal stones treated by either MPCNL or ESWL

Variable	MPCNL group	ESWL group	*P*
No. of infants	24	22	
Diseased renal units	25	22	
Age (months)	23.08 ± 9.56	23.5 ± 6.64	0.866
Median			
Range	7–39	13–36	
Gender			0.277
Male	15	17	
Female	9	5	
Stone size (mm)			0.728
Average	21.4 ± 3.5	21.7 ± 1.7	
Stone type			0.271
Pelvic	6	5	
Multiple	4	2	
Partial staghorn	12	15	
Complete staghorn	3	0	
Serum Cr level (μmol/L)	48.5 ± 10.4	53.6 ± 7.3	0.07
Hemoglobin (g/L)	114.8 ± 12.5	135.0 ± 13.7	<0.001
Unilateral GFR (mL/min)	48.2 ± 1.8	49.3 ± 11.9	0.722
Degree of hydronephrosis			0.702
No/mild	13	17	
Moderate/gross	12	5	

MPCNL mini-percutaneous nephrolithotomy, *ESWL* extracorporeal shock wave lithotripsy, *Cr* creatinine, *GFR* glomerular filtration rate

Discussion

Extracorporeal shock wave lithotripsy is currently the first-line mini-invasive treatment of most upper urinary tract stones in children, even in infants [1, 19, 20]. However, we

Table 2 Postoperative clinical data of infants with renal stones treated by either MPCNL or ESWL

Variable	MPCNL group	ESWL group	*P*
Hospital stay (days)			<0.001
Mean	14.13 ± 5.8	6.64 ± 2.28	
Range	4–33	7–32	
Stone-free status [cases (%)]			
1 week			
1 month	21 (84)	7 (31.8)	<0.001
3 months	24 (96)	19 (86.3)	0.328
Re-treatment [cases (%)]	3 (12)	11 (50)	0.004
Complications [cases (%)][a]			0.028
Fever	4 (16)	4 (18.2)	
Severe hematuria	0	1 (4.6)	
Stone street formation	0	4 (18.2)	
Renal colic	0	5 (22.7)	
Anuria	0	1 (4.6)	
Stone composition [cases (%)]			0.002
Calcium-based	12 (48)	4 (18.2)	
Cystine-based	6 (24)	2 (9.1)	
Uric acid-based	3 (12)	15 (68.2)	
Struvite-based	4 (16)	1 (4.6)	
Hemoglobin drop (g/L)	8.54 ± 4.4	10.64 ± 12.67	0.469
Unilateral GFR (mL/min)	50.61 ± 11.89	50.19 ± 9.68	0.897
GFR drop (mL/min)	2.36 ± 2.34	0.72 ± 3.25	0.127
Serum Cr level (μmol/L)	44.77 ± 9.57	52.63 ± 8.74	0.216
Cr drop (μmol/L)	3.72 ± 7.66	0.91 ± 7.22	0.216
Follow-up (months)			0.903
Median	21	23	
Range	4–60	7–32	
Recurrence [cases (%)]	2 (8)	2 (9.1)	>0.99

[a] Some infants in ESWL group developed more than one complication

should render the infants stone-free over a short period of time with reasonable number of SWL and limited auxiliary procedures. Because of the high incidence of metabolic and anatomic abnormalities in infants, residual fragments after ESWL may lead to recurrent urolithiasis and, thus, these patients should be followed closely [19, 20]. Currently, PCNL is a commonly applied alternative treatment in pre-school children [15–18]. However, its application in infants has only been reported in a few cases. In this study, we compared the efficacy and safety of ESWL and MPCNL in treating a cohort of infants with large renal stones and found that MPCNL was more effective than ESWL.

Complete stone clearance is a major indicator of treatment success. As reported, the stone-free rate varied from 52.63 to 100 % in children treated with ESWL [2, 3, 19–22], but decreased to 33–44 % for children with large (staghorn) stones (especially >15 mm in diameter) or stones located in the lower calyx [1, 2]. In our present study, the stone-free rate in ESWL group was 31.8 % after the first session and was 86.3 % at 3 months with 11 cases underwent a second ESWL session. PCNL has shown a better efficacy on pre-school children with stone-free rates of 60–94.1 % [16–18, 22–24], even in the cases of large and complex stones with stone-free rates of 86–89 % [23, 24]. In our study, a stone-free rate of 84 % was achieved after the first MPCNL session and 96 % after a second-look procedure, significantly higher than the rates after ESWL. The stone composition differed significantly between the two groups. More uric acid stones were noted in ESWL group (68 vs. 12 %), which explained the lower success rate of ESWL because uric acid stones are less sensitive to ESWL.

The reported rates of complications, including fever, renal colic, stone street formation, and hematuria, ranging from 5.26 to 30 % after ESWL [1–3, 15, 21, 23], and from 0 to 25 % after PCNL [16–18, 23–26]. In the present study, the overall complication rate after ESWL was 45.5 %, higher than those reported in the literature. This may partly be due to that 77.3 % (17/22) of our patients had either a staghorn stone or multiple stones. Complications of PCNL were reported to be closely related to the number and caliber of established percutaneous accesses [18, 23, 26–29]; what's more, large accesses did not improve the stone-free rates [23]. Gunes et al. [27] have reported a high rate of complications in children younger than 7 years with the use of adult size instruments. The small size and the more compact structure of the infantile urinary system necessitate the use of the smallest and least injurious instruments to reduce the likelihood of bleeding and renal trauma [15, 18, 28]. A comparative study showed that children treated with 26F or 20F accesses required blood transfusion more frequently, whereas no blood transfusion was needed in children treated with a 14F access [26]. In the present study, the mean postoperative Hb drop was 8.54 g/L and no patient required blood transfusion in MPCNL group.

In most cases, residual stones require re-treatment. Re-treatment rates ranging from 13.9 to 53.9 % have been reported for ESWL [1, 5, 10]. High stone-free rates would be the results of repeated ESWL sessions, whereas the stone-free rate after the first session may be as low as 44 % [1]. In our present study, the stone-free rate after the first ESWL session was 31.8 %. Multiple ESWL sessions, particularly for small children, generally result in prolonged discomfort as well as increased use of analgesics and antibiotics which in turn causes stress in patients and families.

Pulsatile high-pressurized endoscopic perfusion pump has been used to remove stone fragments. This equipment efficiently shortened the operation time when compared with forceps. In the present study, the mean operation time of MPCNL was 76.2 ± 23.42 min, which was equivalent to that of a standard PCNL procedure. In a previous study, we have demonstrated that the average renal pelvic pressures were 24.85, 16.23, and 11.68 mmHg with the use of 14F, 16F, and 18F percutaneous accesses, respectively, which were significantly lower than the pressure level needed for a backflow (30 mmHg) during standard PCNL procedure [30]. In addition, small percutaneous accesses with high pressure may not result in systemic absorption of irrigation fluid containing bacteria or endotoxin which could lead to bacteremia or even sepsis. In the present study, fever occurred only in 4 of 25 cases after MPCNL.

Conclusion

Although ESWL is considered a more invasive procedure than PCNL, our findings clearly show that MPCNL in experienced hands could be a feasible and effective treatment of large renal stones (15–25 mm) in infants. When compared with ESWL, MPCNL resulted in a higher stone-free rate, a lower complication rate, and a lower re-treatment rate. Our observations on this small cohort of patients need to be verified by a prospective randomized trial with more cases.

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