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ORIGINAL PAPER

Shock wave lithotripsy is effective and safe for distal ureteral calculi in children

Isa Ozbey · Yilmaz Aksoy · Tevfik Ziypak · Turgut Yapanoglu · Ozkan Polat · Mehmet Aksoy

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Abstract We evaluated the effectiveness of the Siemens Lithostar Modularis lithotriptor for the management of distal ureteric calculi in children. Between 2004 and 2006, 29 children with distal ureteric calculi were treated in our stone center with the Siemens Lithostar Modularis (Siemens Medical Solutions, Inc.) Effectiveness of lithotripsy, retreatment and efficacy quotient rates, and complications were assessed. The series consisted of 18 (62%) boys and 11 (38%) girls with an age range of 1–13 years (average age 7.0 ± 3.5). Under fluoroscopic guidance, children were treated with a maximum 3,000 shocks at an average of 2.2 ± 0.3 kV. Mean stone size was 8.2 ± 3.2 mm (range 4–18). Success was defined as the lack of any visible stone fragments on posttreatment radiological evaluation. The mean number of sessions required was 1.5 ± 0.8/patient (range 1–4). Complete clearance rate at 3 months was 86.2%. Re-treatment and efficacy quotient rates for distal ureteral stones were 41.4 and 55.6%, respectively. Complications such as urinary tract infection or steinstrasse occurred in 2 (6.9%) patients. Minor complications included petechial skin hemorrhage at the site of entry of shock waves in all patients. Our results show that shock wave lithotripsy for distal ureteral calculi with the Siemens Lithostar Modularis lithotriptor has a high success rate (86.2%) and efficacy quotient (55.6%) with negligible complications in children.

I. Ozbey · Y. Aksoy (✉) · T. Ziypak · T. Yapanoglu · O. Polat
Departments of Urology School of Medicine,
Ataturk University, 25240 Erzurum, Turkey
e-mail: aksoyyilmaz@yahoo.com

M. Aksoy
Anesthesiology and Reanimation, School of Medicine,
Ataturk University, Erzurum, Turkey

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Introduction

Pediatric stone disease is rare compared to the incidence in adults. The incidence of urolithiasis in the pediatric age group is only 2–3% of all patients with stone disease [1]. Shock wave lithotripsy (SWL) was first introduced into clinical practice in 1980 by Chaussy and coworkers [2] and Newman et al. [3] presented the first report of success using SWL on children. Although SWL is a highly popular accepted modality to treat renal stones, the optimal treatment choice for distal ureteral calculi remains controversial. Recent technological developments have provided smaller endoscopic instruments and more efficient intracorporeal SWL sources, including the holmium YAG laser. For this reason, there is still a controversy over the use of ureteroscopy and SWL for the treatment of distal ureteral calculi in children [4–6].

In this study, we aimed to investigate the efficacy and safety of SWL in the management of distal ureteral calculi in children.

Patients and methods

During the last 13 years, 263 children underwent SWL in our institution with two different machines (Dornier MPL-9000 and Siemens Lithostar Modularis). SWL treatment was applied to children with distal ureteral calculi in the last 3 years. In the present study, the records of patients were analyzed from the hospital computer-generated data system between November 2004 and October 2006. In this period, 29 children (18 boys and 11 girls) with primary

distal ureteral calculi were treated at our multiuser stone center using the Siemens Lithostar Modularis (Siemens Medical Solutions, Inc.), a third-generation electromagnetic shock wave lithotriptor. All patients were in a supine position when treated.

All the procedures were carried out under biplanar fluoroscopic control and done generally as an outpatient procedure.

Seven (24.1%) patients had a medical history of urolithiasis. The presenting symptoms were colicky flank or abdominal pain in 13 (44.8%), fever due to urinary tract infection in 6 (20.7%) and gross hematuria in 5 (17.2%) children. Urinalysis, urine culture with sensitivity, serum creatinine level and coagulation profile were determined, and a plain abdominal radiograph of the kidney, ureter and bladder (KUB), excretory urography and/or ultrasonography were performed in all cases. Children with urinary tract infection (UTI) were treated according to urinary cultures with appropriate antibiotics.

The distal ureter was considered as the ureteral portion between the distal edge of the sacroiliac joint and the ureterovesical junction. The stone size was measured with a scale from the KUBs for their greatest length and width. The main indication for treatment was stone size ≥4 mm in the distal ureter. Contraindications of SWL treatment were coagulopathy, obstruction distal to calculi, pyelonephritis and nonfunctional kidney.

For SWL treatment, sedo-analgesia was given to all children. While pentothal sodium 3–4 mg/kg and fentanyl 1–2 μg/kg were administered in children aged ≤5 years (10 patients), propofol 1–2 mg/kg and fentanyl 1–2 μg/kg were chosen for children aged >5 years (19 patients).

Therapy protocol was initiated by administering 2,000–3,000 shock waves at 1–3 kV with gradual escalation. Stone clearance was assessed the following day using KUB and the treatment was repeated 1 week later if there was an incomplete fragmentation seen on a repeated KUB.

Children with adequate stone fragmentation were followed at monthly intervals with KUB for 3 months. Stone-free status was defined as the absence of any visible stone fragments on a good quality KUB obtained 3 months after SWL treatment. No fragmentation or presence of any residual calculi is accepted as an unsuccessful SWL treatment. An interval of at least 1 week was maintained between SWL sessions.

Ureteroscopic lithotripsy (ULT) was performed in four cases with failed SWL treatment. ULT comprised ureteroscopy (8F rigid ureteroscope with a 4F operative channel; Storz, Germany) and the Ho:YAG laser (Auriga, Wavelight Laser Technologie AG, Germany) with a 365-μm-wide probe tip for lithotripsy.

Efficacy quotient (EQ) was calculated as stone-free percentage × 100/(100% + re-treatment rate percentage + auxiliary procedure percentage) [7]. Voided stone fragments were analyzed by X-ray diffraction crystallography.

Results

During the study period, we treated 29 children with distal ureteral calculi by SWL. The age range was from 1 to 13 years (mean 7.0 ± 3.5). The stone was located on the right side in 19 (65.5%) and on the left side in 10 (34.5%) ureters. The male:female ratio was 1.6 (18/11). The average stone size was 8.2 ± 3.2 mm (range 4–18). The mean number of shock waves was 2,358.7 ± 295.8 (range 2,000–3,000) at a mean power setting of 2.2 ± 0.3 kV (range 1–3) per session. The mean number of treatment sessions required was 1.5 ± 0.8 (range 1–4). While one SWL session was adequate in 17 patients (58.6%) and 2 in 9 patients, 3 or more sessions were required for the remaining patients (3 cases).

Table 1 contains the information on stone and treatment characteristics of patients with respect to the age groups. The stone free rate for the younger group of children, namely, ≤5 years old, is slightly better than for the older children. As can be seen from Table 1, the difference between the rates was statistically insignificant ($P = 0.67$). Figure 1a–c shows successfully fragmented and passaged right distal ureteral calculi required only one session of SWL in one child aged 9 years old.

The treatment time varied from 14 to 35 min (average duration 20.4 ± 5). Mean fluoroscopy time per session was 1.6 ± 0.3 min. Average postlithotripsy hospitalization duration was 7.6 ± 11.9 h (range 1–48). After a mean follow up of 4.2 ± 2.1 months (range 3–9), a stone-free rate was achieved in 25 of 29 patients (86.2%), with a re-treatment rate of 41.4%. EQ rate was calculated as 55.6%.

Shock wave lithotripsy failed in only four (13.8%) children, and these children were successfully treated with

Table 1 Stone and treatment characteristics of patients according to age groups

	n (%)	Stone size (mm) (mean ± SD)	Session (mean ± SD)	Stone-free rate %	Auxillary procedure (*n*)	Complication (*n*)
5 years≥	10 (34.5)	7.4 ± 2.5	1.3 ± 0.5	90	1	1
5 years<	19 (65.5)	8.6 ± 3.5	1.7 ± 0.9	84.2	3	1
P value		0.35	0.27	0.67	0.67	0.63

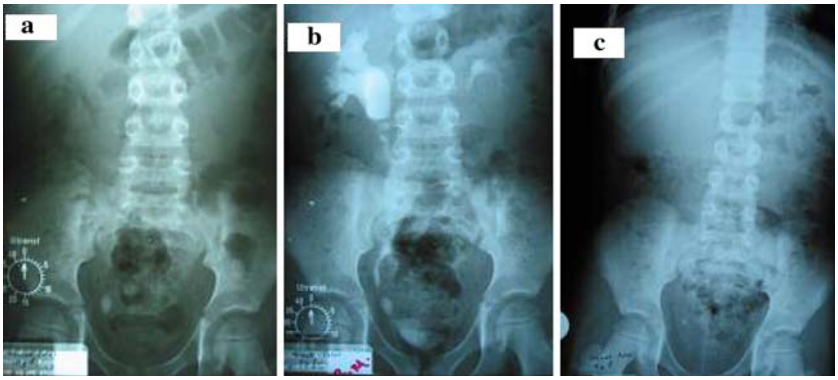

Fig. 1 **a** KUB shows right distal ureteral calculi before SWL. **b** Intravenous urography shows right ureterohydronephrosis caused by ureteral calculi. **c** KUB shows small fragments of calculi after 3 days of first session of SWL

ureteroscopic intervention. These four cases are shown in Table 2. It should also be pointed out that severe edematous ureteral mucosa has been observed in three cases during ULT intervention. One case, a 6-year-old male, with a stone size of 10 mm, was successfully treated by three consecutive SWL sessions. None of the patients required open surgery.

Major complications such as steinstrasse and UTI without urosepsis were seen in only two patients (6.8%). Steinstrasse resolved spontaneously, and symptomatic UTI was successfully treated with oral antibiotics.

Minor complications were skin bruising (100%), seen at the site of entry of shock waves and resolved spontaneously, and renal colic (13.7%), responding to analgesics and antiemetics.

Stone analysis was available only in a small number of patients because collection of smaller stone fragments is difficult. Stones were predominantly calcium oxalate. None of the stones was cystine calculi.

Discussion

Since 1980, technological developments in both the design of shock wave lithotripters and advances in endourological equipment have precipitated a dramatic change in the treatment modalities of pediatric urolithiasis. As a result of these developments, the role of open surgery in managing ureteral calculi has greatly diminished over the last 25 years [5]. SWL has been shown to be safe in the pediatric age group and in infants [3, 8]. Experimental and clinical studies mostly agree that SWL is safe with regard to scar formation, ovarian and epiphysial damage [9–11]. Many distal ureteral calculi, due to their topographical location, have a high chance of spontaneous passage. But, spontaneous passage of stones $\geq$4 mm is unlikely in children, and about 40% may impact in the distal ureter for a year or more [12].

Therefore, our general preference is to treat such stones in the distal ureter with SWL without any delay. The minimally invasive nature of SWL with the obvious advantages of outpatient procedure, low morbidity and complication rate make it the first line treatment choice for patients and urologists [13].

Shock wave lithotripsy provided good results varying from 76 to 90.1% in pediatric distal ureteral calculi [14–16]. Nabi et al. [13] reported that stones up to 10 mm were easily fragmented, and the clearance rate was found to be 90%. In the present study, the success rate was 86.2%, which compares favorably with those reported in other pediatric series (Table 3).

The improvements in the miniaturization of ureteroscopes and using the holmium:YAG laser for intracorporeal stone treatment have made the endosurgical intervention in the pediatric ureter much easier; however, the safety of ureteroscopy in children has not been fully established [18]. El-Assmy et al. [19] and Thomas et al. [20] reported that ureteroscopy was successful and safe in children with distal ureteral calculi. Success rates of ureteroscopy varied from 96.9 to 100% in pediatric ureteral calculi [19, 20]. Additionally, Lahme [21] suggested that distal ureteral stones should be treated primarily with an endoscopic retrograde approach in his review article.

However, ureteroscopy in the pediatric age group requires greater technical skill and a higher level of endosurgical expertise because of the potential risks of traumatic complications [22]. Endoscopic manipulation is invasive, prone to complications and requires longer anesthesia [23]. Additionally, in up to 20% of cases, stone bypass may fail

Table 2 The cases treated by ULT after unsuccessful SWL treatment

Age	Sex	Stone size (mm)	No. of sessions	Auxillary procedure
2	M	15	3	ULT
9	M	10	4	ULT
5	F	7	2	ULT
13	M	8	1[a]	ULT

ULT Ureteroscopic Lithotripsy

[a] Severe ureterohydronephrosis

Table 3 Literature review of reported series of children with distal ureteral calculi with various machine models illustrating success rates

Authors [References]	Patients	Machine	Stone free rates (%)	Re-treatment rates (%)	Efficacy quotient (%)
Muslumanoglu et al. [7]	134	Siemens Lithostar plus	89	49.6	60
Landau et al. [12]	16	Dornier HM3	100	18.4	NA
Nabi et al. [13]	26	Dornier Compact Delta	79	26	51.6
Al Busaidy et al. [14]	41	Wolf 2500 Piezolith	85	36	NA
Tan et al. [16]	29	Siemens Lithostar plus	76	NA	NA
Tan et al. [17]	22	Siemens Lithostar plus	84	NA	NA
Present study	29	Siemens Lithostar modularis	86	41.4	55.6

NA Not available

[24]. During the ureteroscopic intervention, pneumatic, ultrasonic, electrohydraulic and laser lithotripsy were used. Electrohydraulic lithotripsy has a significant risk of ureteral damage. The other methods are less invasive.

Currently, laser lithotripsy is the best choice for pediatric ureteroscopy, but it is expensive [6, 22]. The patients whose stones were not successfully treated with SWL were additionally treated with ureteroscopic intervention. It should also be pointed out that severe edematous ureteral mucosa was observed in three cases during ULT intervention. The failure of the SWL for the distal ureteral calculi cases can be attributed to a stone impaction.

The complication rate of SWL was much lower than that of ureteroscopy in Ather's series (13.3 vs. 32%) [5]. Al Busaidy et al. [25] and Thomas et al. [26] reported that low grade vesicoureteral reflux has been shown in their series after rigid ureterorenoscopy in 11 and 17%, respectively. Another factor is the potential damage to the ureter and urethra especially in boys [16, 27]. Schuster et al. [27] reported the incidence of ureteral injury and stricture formation in 221 cases as 1.4 and 1%, respectively. Internal ureteric stents were commonly used after ureterorenoscopy in children [25, 26]. Stent placement in children leads to discomfort named "stent syndrome", migration and will require repeated anesthesia for removal [18]. Additionally, ureteroscopy requires a significant learning curve by the surgeon [28], while SWL is much simpler because it is a noninvasive outpatient procedure and has minimal morbidity [15]. In our study, complications of SWL were generally minor and infrequent.

Several anesthetic techniques have been used in previous series of children undergoing SWL, e.g., general anesthesia, regional anesthesia or intravenous sedation. Older children often tolerate treatment under intravenous sedation using pharmacological agents such as midazolam, ketamine or fentanyl [12]. SWL with minimal anesthesia is applicable to the preponderance of pediatric patients treated with second and third generation lithotriptors [14]. Most of the patients, including children $\geq$10 years of age, are treated in outpatient clinics [8, 14].

About 80% of our patients (26/29) were treated as outpatients, while the majority of previous series reported that variable inpatient postoperative hospitalization duration was required [1, 14]. Our anesthesia preference in the management of SWL in children was particularly sedo-analgesia.

The hospital stay was shorter for SWL than for ULT. Dominicis et al. [29] reported that while hospital stay was 55 h for ULT, this duration was shorter at 30 h for SWL. Hospital stay was 7.6 h on average for our patients undergoing SWL.

Digital fluoroscopy enables precise location of the stones at a lower radiation exposure. The fluoroscopic screening time in children during treatment for ureteral stones has been reported as an average of 1.5 min [30]. In the present study, average fluoroscopic screening time was 1.6 min. Using third generation lithotriptors with smaller focal areas, possible damage to neighboring organs is minimized. Additionally, new generation lithotriptors have fewer side effects due to low radiation exposure and low voltage in the focal zone. Use of the Siemens Lithostar Modularis device for the treatment of children is advantageous in that there is no need for gantry modification, and it reduces the possible risk of trauma to adjacent organs [15, 31]. Kroovand et al. [32] estimated that the radiation exposure during SWL treatment was typical of other diagnostic abdominal radiographical procedures like voiding cystourethrography.

It has been reported that the success rate for SWL was higher in children than in the adult population. Investigators speculated that calculi in children could be fragmented more easily because the dwelling time of stones is short, and the shock wave effect is stronger. Additionally, despite their smaller anatomy, children are able to pass stones more readily, quickly recuperate, and have rapid and better mobilization after treatment than adults [1, 3, 12].

In conclusion, our experience has confirmed that SWL was a minimally invasive, effective and safe treatment modality, and together with no need for general anaesthesia, SWL should be considered the first-line therapy for distal ureteral calculi in children. Because the high success rate of SWL is comparable with that in the best series of ureteroscopic stone treatment, ULT, with an invasive nature, can be second choice for such patients.

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