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ORIGINAL PAPER

Minimally invasive treatment of ureteral calculi in children

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Abstract A retrospective analysis was done to determine the efficacy of shock wave lithotripsy (SWL) and ureteroscopy in the treatment of paediatric ureteral calculi. We reviewed the records of 67 (35 boys, 32 girls) children (71 ureters) admitted to our clinic for treatment of ureteral calculi during 1990–2005. The initial treatment method was SWL in 80.3% (57 ureters), ureteroscopy in 11.3% (eight ureters) and open surgery in 8.5% (six ureters) of the renal units. The mean age of the patients was 10.67 ± 4.4(1–16) years. The stone-free rates after SWL for upper, middle and lower ureteral calculi were 74.1, 100 and 75.9%, respectively. Increased stone diameter ($P = 0.014$) and/or burden ($P = 0.002$) were found to be significant factors that had an adverse affect on the stone-free rate after SWL while the success rates of SWL were independent of location. Including six patients (seven ureters) with failed SWL, a total of 14 patients (15 renal units) subjected to ureteroscopy for lower ureteral calculi yielded a stone-free rate of 93.3%. Thus, the overall stone-free rates after SWL, ureteroscopy and open surgery were found to be 75.4, 93.3 and 100%, respectively. Depending on the stone burden, SWL might be a good option for initial treatment of most ureteral calculi in children. Ureteroscopy offers a high success rate for lower ureteral calculi, including SWL failures.

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Introduction

The introduction of shock wave lithotripsy (SWL) has provided a shift from invasive classic stone surgery to a minimally invasive and effective treatment approach for patients with urinary tract calculi [1–3]. Although SWL was considered a safe and effective treatment in adults, a longer period had to be awaited to see its efficacy and morbidity in children. The introduction of second-generation lithotripters provided less painful lithotripsy, eliminating the need for the water tank and modifications of the equipment for paediatric patients. The use of a small focusing area also offered less damage to surrounding organs. Through the minimally invasive treatment era, SWL was generally accepted as the first-line treatment for upper ureteral stones; however, there was some controversy for the middle ureteral and lower ureteral stones owing to the difficulties in visualising stones overlying the sacrum and relatively lower success rates than ureteroscopy especially in the adult population [4, 5]. Recently, with the advent of small-sized ureteroscopes, laser technology and growing experience, the initial consensus that accepts SWL as the initial treatment for most paediatric ureteral calculi has also become questionable. However, ureteral and urethral instrumentation have serious potential hazards especially in small children, particularly in boys, and the safety of ureteroscopy in the paediatric age group has not been fully established. This report provides a retrospective analysis to determine the efficacy of SWL and ureteroscopy in the treatment of paediatric ureteral calculi.

Materials and methods

We reviewed the records of 67 (35 boys, 32 girls) children (71 ureters) admitted to our clinic for treatment of ureteral calculi during 1990–2005. The patients' ages varied between 1 and 16 years. The initial treatment method was SWL in 80.3% (57 ureters), ureteroscopy in 11.3% (eight ureters) and open surgery in 8.5% (six ureters) of the renal units. The indications for open surgery were a coexistent anomaly (like ureterovesical junction obstruction), high stone burden, failure of SWL or ureteroscopy and inadequate endoscopic equipment available for small children.

Standard evaluation of the patients before SWL included renal function tests, urinalysis, urine culture and intravenous pyelography (IVP). Patients with urinary tract infection were treated according to urinary cultures with appropriate antibiotics. Most patients were referred to our clinic from certain centres for SWL and metabolic evaluation for the aetiology of urolithiasis was conducted by the paediatric nephrology unit or by the centres referring the patient. Contraindications of SWL treatment were coagulation disorders, pyelonephritis, obstruction distal to calculi, non-functional kidney and hypertension. SWL was performed with a Siemens Lithostar plus device in the prone position usually under dissociative anaesthesia using ketamine (0.5 mg/kg) for most children, though sedation was sufficient for some children over 14 years of age. The device is a second-generation lithotripter in which shock waves are delivered by an undertable electromagnetic shock head module. All treatments were carried out under fluoroscopic control and done generally as an outpatient procedure. The shock wave number and voltage were limited to a maximum of 2,500 shock waves/session and 17.2 kV, respectively, for patients under 12 years of age. This limitation was the policy of our clinic considering the debate on the long-term effects of SWL. The stone diameter was accepted as the transverse diameter of the stone with respect to the vertical axis of the ureter and the stone burden was defined as the stone area that was calculated by multiplying the largest length and width of the individual stones measured from the plain abdominal X-ray.

The follow up after SWL consisted of plain abdominal radiographs usually taken 1–2 weeks after treatment and continued according to disintegration and clearance. Retreatments were done after a minimum of 3 weeks for the same location. Complete stone clearance was accepted as stone-free and confirmed with IVP (majority) and/or abdominal X-ray and ultrasonography in all patients. No fragmentation or presence of any residual calculi is accepted as unsuccessful treatment.

Ureteroscopy was performed using the 7.5 Fr semirigid ureteroscope (Storz) and/or in older children a 10 Fr ureteroscope (Storz) that both allow a 1 mm pneumatic lithotripsy probe and grasping forceps. For pneumatic lithotripsy a Swiss Lithoclast device was used. None of the cases required dilation of the orifice. We used this equipment as we did not have laser lithotripsy available in our clinic. The indications for ureteroscopy were high stone burden, failure of SWL, significant obstruction and/or an acutely symptomatic patient and an urgent treatment request for children referred from an urban area.

Statistical analysis was done with the SPSS (statistical program for social sciences) program. The groups were compared using Mann–Whitney *U* test or Kruskal Wallis analysis for numerical variables, chi-square test for categorical ones and a Spearman correlation test. A two tailed *P* value of <0.05 was accepted as statistically significant.

Results

The mean age of the patients was 10.67 ± 4.4(1–16) years. The stone-free rates after SWL for upper, middle and lower ureteral calculi were 74.1, 100 and 75.9%, respectively.

Shock wave lithotripsy (SWL)

Table 1 shows stone location and descriptives in patients subjected to SWL. Most calculi were located at either the upper or lower ureter. A total of 57 ureters (54 children, 27 boys and 27 girls) were subjected to SWL as the first line therapy. The stone was present on the right side in 30 (52.6%) and on the left in 27 (47.4%) ureters. Two cases had bilateral ureteral calculi. One child had recurrent ureteral calculi while another patient who had SWL for a ureteral calculus previously had a recurrent ureteral calculus after 2 years that was treated with ureteroscopy at first. The mean stone diameter and burden were 5.23 ± 1.4 (3–8) mm and 49.98 ± 27.2 (16–128) mm^2, respectively, and the mean shock wave number per session and power were 2581.6 ± 546.5 (1,500–4,000) and 17.06 ± 1.4 kV (13.6–19) respectively. Most ureters had only one (68.5%) session of SWL (Table 2). There were no major complications. Minor complications included skin ecchymosis at the site of entry of shock waves in almost all cases and renal colic that responded to analgesics and emetics in three (5.6%) patients. The stone-free rates after SWL for upper, middle and lower ureteral calculi were 74.1, 100 and 75.9%, respectively (Table 3). No significant difference was found between

Table 1 Stone localisation and descriptives in patients subjected to SWL

Localisation	*n* (%)	Mean diameter (mm)	Mean burden (mm^2)
Upper	27 (47.4)	5.44 ± 1.4	48.74 ± 23.6
Middle	1 (1.8)	4	32
Lower	29 (50.9)	5.07 ± 1.5	51.76 ± 30.7
Total	57 (100)	5.23 ± 1.4	49.98 ± 27.2

n represents number of ureters

Kruskall Wallis test $P = 0.38$ for diameter

Kruskall Wallis test $P = 0.81$ for burden

Table 2 SWL treatment sessions

Session	Frequency (*n*)	%
1	37	64.9
2	12	21.1
≥3.00	8	14

n represents number of ureters

Table 3 SWL treatment results according to localisation

Localisation	Stone-free (%)	Residual (%)	Failure (%)	Total (%)
Upper	20 (74.1)	4 (14.8)	3 (11.1)	27 (100
Middle	1 (100)	–	–	1 (100)
Lower	22 (75.9)	2 (6.9)	5 (17.2)	29 (100
Total	43 (75.4)	6 (10.5)	8 (14)	57 (100

Chi-square test $P = 0.84$

upper, middle and lower ureteral calculi for stone diameter (Kruskall Wallis test, $P = 0.38$), burden (Kruskall Wallis test, $P = 0.81$) and clearance (chi-square test, $P = 0.84$) (Tables 1, 3). Four (7.4%) cases have residual fragments that escaped to lower calices after lithotripsy for upper ureteral calculi and are still being followed. The case (1.9%) with bilateral ureteral calculi had bilateral stone street formation that was not cleared spontaneously and he was subjected to bilateral ureteroscopy. In one (1.9%) case a pushback procedure using an indwelling stent was performed.

The overall stone-free rate after SWL was found to be 75.4%. Increased stone diameter (Mann–Whitney *U* test $P = 0.014$) and/or burden (Mann–Whitney *U* test $P = 0.002$) were found to be significant factors that had an adverse affect on the stone-free rate after SWL while the success rates of SWL were independent of location (Table 4).

SWL failures were treated with ureteroscopy or ureterolitotomy. After a mean follow-up period of 25.79 ± 23 (1–118) months, 2(3.7%) patients had recurrence. Two (3.7%) patients had parathyroidectomy because of hyperparathyroidism. There was neither evidence of growth retardation nor any other

Table 4 SWL treatment results according to stone diameter and burden

Localisation	Mean diameter (mm)	Mean burden (mm^2)
Stone-free	4.95 ± 1.3	42.86 ± 21.4
Unsuccessful*	6.07 ± 1.4	71.86 ± 31.83
P value**	0.014	0.002
P value***	0.015	0.002

*Residual + fragmentation

**Mann–Whitney *U* test

***Spearman correlation analysis

complication in any of the treated cases. Stone analysis, which was available only in a small number of patients because of smaller fragments and inability to collect them in uncooperative parents, was predominantly calcium oxalate. None of the patients in this series was found to have cystinuria or cystine calculi.

Ureteroscopy

Including six patients (seven ureters) with failed SWL, a total of 14 patients (15 renal units) (mean age = 11.27 ± 3.3, range 4–16 years) were subjected to ureteroscopy with the diagnosis of lower ureteral calculi and a stone-free rate of 93.3% was achieved. The mean stone diameter and burden were 5.77 ± 1.4 (4–8) mm and 68.15 ± 36.1 (25–128) mm^2, respectively. As stated before, ureteral dilation was not done in any of the cases. In one (6.7%) of the initial cases ureteroscopy was technically unsuccessful. Because of instrument calibre we could not reach the stone in the ureter and avoided hazardous instrumentation; thus, ureterolithotomy was done. After ureteroscopy, all patients had a 3 or 4 Fr ureteral catheter inserted and removed after 24–48 h, except two (14.3%) children. In two (14.3%) children a JJ indwelling stent was left in place and then removed after 1–3 months. The indications for JJ stents were a high stone burden in one child while the other had a ureteral narrowing faced during the procedure that was dilated by the passage of the ureteroscope. There were no complications related to ureteroscopy; reflux was not assessed.

Discussion

Urolithiasis is an important health problem in the paediatric age group. The revolutionary invention of extracorporeal shock wave lithotripsy (ESWL) has provided a non-invasive treatment method for urolithiasis in both adult and paediatric patients [1–3]. Since its introduction, ESWL has been accepted as the initial option for the majority of renal and ureteral calculi.

Short- and long-term studies mostly agree that SWL is safe with regard to scar formation, renal growth and function; linear growth is not affected and there is no risk of hypertension [6–10]. The concern about damage to reproductive organs in children subjected to SWL for ureteral calculi has been disproved by most animal experiments that showed no long lasting permanent effect on the female reproductive system, particularly the ovaries [11, 12]. The pregnancy rate of the animals was not affected and no gross teratogenic effects were observed [11]. Similarly no detrimental effect was produced by shock waves on sperm morphology and testis [13, 14]. However transient changes in sperm quality were observed [15]. The use of ultrasound for positioning the patient and focusing the calculi could aid in minimal radiation exposure though probably not associated with potential hazards.

Paediatric urolithiasis is usually associated with underlying metabolic problems such as hypocitraturia, hypercalciuria and hyperoxaluria. The primary goal of treatment in children with stones should be the stone-free state and treatment of underlying metabolic abnormalities is of utmost importance for prevention of regrowth and recurrence. Nijman et al. [16] reported an increase in size in 33% and a recurrence rate of 10% in the long term for patients with retained renal stone fragments. Recently Afshar et al. [17] pointed out that residual fragments in the kidney could cause symptoms or increased stone burden in 69% of children.

During the SWL era, however, parallel development of endoscopic techniques and instruments providing excellent stone-free rates has eventually raised some debate about the choice for initial therapy of urolithiasis, including the ureteral calculi [4, 5]. Ureteroscopy could be performed as an outpatient procedure and the cost-effectiveness was similar or even less than SWL using a first-generation lithotripter [2, 3]. However this is rather controversial as there is wide variability in the success rate, the type of equipment, experience and medical expenses among different countries and even different institutions. The AUA guidelines for adults expected stones <5 mm to pass spontaneously and larger ones were offered treatment using ESWL or ureteroscopy depending on the burden [18]. In a small number of children Van Savage et al. [19] adapted the guidelines to paediatric patients and suggested that distal ureteral calculi ≥4 mm were unlikely to pass spontaneously through the paediatric ureter and should be treated endosurgically.

The favoured management of ureteral calculi in children is either SWL and/or ureteroscopy [2, 3]. The introduction of smaller endoscopic instruments and increased expertise with larger series would determine the ideal first line treatment for lower ureteral calculi. Although SWL has been available for about 25 years the series for treatment of paediatric ureteral calculi hardly exceed 100 cases (Table 5). Similarly, even the most recent reports concerning endoscopic treatment of ureteral stones in children consist of less than 50 cases (Table 6). Despite the absence of fluid in the ureter, the stone-free rates of SWL are reported between 75–100% with minimal or no morbidity [20–28]. In our series the overall stone-free rate was 75%. Various reports have confirmed that the success rates of SWL in the treatment of paediatric ureteral calculi are markedly affected by stone diameter rather than the location within the ureter [25, 28]. Similarly, increased stone diameter (Mann–Whitney *U* test $P = 0.014$) and/or burden (Mann–Whitney *U* test $P = 0.002$) were found as significant factors that had an adverse affect on the stone-free rate after SWL while the success rates of SWL were independent of location. Pace et al. [29] have shown that stone-free rate significantly decreases after initial treatment of ureteral calculi. In our series, the majority of the patients, 65%, received only one SWL session.

The development of small-sized ureteroscopes and laser technology has enabled the use of ureteroscopy also in the paediatric age group; however, the safety of ureteroscopy in the paediatric age group has not been fully established. Nevertheless, advanced technology and increased technical expertise have provided excellent results for ureteroscopic treatment of ureteral calculi [30–32]. Recent series report stone-free rates of more than 90% mostly using laser technology (Table 6) [32–38]. Unlike SWL, adult series have documented that [4, 5] ureteroscopy could offer higher stone-free rates for both upper and lower ureteral calculi independent of stone size. In a recent study by de Dominics et al. [39] children with lower ureteral stones were randomised to either SWL or ureteroscopy and the initial success rates were markedly different, such as 42.9 and 94.1%, respectively. However, the number of patients was small and even the final success rate of SWL was unexpectedly low (64%). The application of ureteroscopy to the upper ureter is difficult and the treatment of impacted calculi might be more complicated. Thus, SWL still appears to be a good initial option for upper ureteral calculi. Ureteroscopy could be used for the initial treatment of middle ureteral calculi overlying the sacrum which could not be visualised by SWL and lower ureteral stones.

The potential hazards of ureteroscopy in children might be urethral and/or ureteral damage with/without

Table 5 Analysis of SWL treatment results for ureteral calculi in children

Series-year	No. children	Mean age (years)	Location	Mean stone size/burden	Overall stone-free rate
Myers et al. 1995 [20]	47	0–14	NA	7.3 × 4.6	80–100%
Landau et al. 2001 [25]	38	8 (1–14)	44.7% lower 5.3% mid 50% upper	9.5 × 6.5 (3–32) mm	97.3% dm < 10 mm 100%
Netto et al. 2002 [26]	18	8.2	27.8% lower 22.2%mid 50% upper	94% < 10 mm	94.4%
Muslumanoglu et al. 2003 [27]]	168	8.7	72% lower 9.5% mid 18.5% upper	NA	Lower 90% mid 100% upper 100%
Aksoy et al. 2004 [28]	20	8.7	40% mid 60% upper	10.7 mm mid 9.7 mm upper	dm < 10 mm 100% dm ≥ 10 mm 67% overall 75%
Present series	54 (57 ureters)	11.3	51% lower 2% mid 47% upper	Lower 5.1 mm mid 4 mm upper 5.4 mm	Lower 76% mid 100% upper 74%

NA not available, *dm* stone diameter

Table 6 Analysis of recent ureteroscopy treatment results for ureteral calculi in children

Series-year	No. children	Mean age (years)	Location	Mean stone size/burden	Overall stone-free rate	Dilatation (JJ) stents	Major complications (per patient)
Schuster et al. 2002 [32]	25	9.2	71% lower 18% mid 3.6% upper	6 (2–12) mm	92%	56% 70%	Ureteral perforation 8% Low grade VUR 8% Stent migration 4%
Al-Busaidy et al. 2004 [33]	26	6.5	58% lower 19%mid 23% upper	12 (4–22) mm	88% initial 92% final	61% 81%	Ureteral perforation 3.8% Low grade VUR 7.7%
Satar et al. 2004 [34]	33	7.4 (1–15)	74% lower 9%mid 17% upper	5.3 (3–10) mm	%94	100% 30.3%	None
Dogan et al. 2004 [35]	35	6.2 (1–14)	94.3% lower 5.7% upper	8 (4–15) mm	82% initial 97% final	100% 88.6%	Ureteral perforation 5.7%
Minevich et al. 2005 [36]	58	7.5 (1–12)	43.1% lower 21.5%mid 24.6% upper	NA	98% final	32% 85%	Distal ureter stricture 1.7%
Tan et al. 2005 [37]	23	9.1 (1.5–14)	70.4% lower 18.5% mid 7.4% upper	9 mm	91.3%	17.4% 91.3%	Pyelonephritis 4.3%
Thomas et al. 2005 [38]	29	7.8 (1–12)	73% lower 15% mid 9% upper	6 (3–14) mm	88%	27.6% NA	Ureteral perforation 3.4%
Present series	14	11.3 (4–16)	100% lower	5.7 mm 68.2 mm^2	93.3%	0% 14%	None

NA not available

perforation and stricture formation, necessity of indwelling stents and possible vesicoureteric reflux due to dilation. Internal stents are very rarely used in children subjected to SWL. The usual indication might be a pushback procedure for obstructing upper ureteral calculi. However JJ stents are commonly inserted after ureteroscopy, particularly after ureteral dilation (Table 6) [32–37]. This might cause additional problems such as the so-called stent syndrome, migration (4%)[32] and removal under anaesthesia.

Although the dilation procedure is generally accepted as safe in terms of vesicoureteric reflux (VUR) and stricture formation, there might be damage to the ureterovesical junction [32, 33, 35, 36, 38]. Despite the common statement "we do not recommend or do routine screening for VUR after ureteroscopy" we know that some children suffer from post-ureteroscopy reflux with potential hazards [32, 33]. The use of small calibre instruments that avoid ureteral dilation might abolish the problem.

Another problem is the potential damage to the ureter. Schuster et al. [32] reviewed 221 cases and reported the incidence of ureteral injury and stricture formation to be 1.4 and 1%, respectively. Similar to adults, electrohydraulic lithotripsy has a significantly higher risk of ureteral damage than the other methods [40]. Laser lithotripsy is better than ultrasonography due to the development of smaller probes that enables working through paediatric ureteroscopes; however it is expensive. Basket extraction of paediatric calculi requires radiation exposure and might be hazardous in inexperienced hands. The success rates and morbidity of ureteroscopy are highly dependent on the experience of the surgeon and the available equipment. However SWL is surely easier to learn and apply. Thus it might be a good option to use SWL as a first line treatment for ureteral calculi in children and save ureteroscopy for treatment failures.

Our series lacks randomisation and selection bias in terms of initial choice for treatment. However our clinic is a referral centre especially for the treatment of paediatric urolithiasis and most of our patients live in an urban area. Our SWL unit is among the first centres developed in our country so that the majority of our patients were treated with SWL. The availability of 7.5 and 10 Fr ureteroscopes and Swiss lithoclast has enabled us to perform endoscopy in relatively older children as an initial treatment or after failed SWL. We used this equipment, as we did not have laser lithotripsy available in our clinic. Accordingly we did not treat small children with this device. Despite the similarity in age and stone diameter with the SWL group our stone-free rate after ureteroscopy was comparably higher than SWL (99.3 vs. 76%). However, no direct comparison was made as the ureteroscopy group includes SWL treatment failures, confirming the efficacy of ureteroscopy for lower ureteral calculi, the lack of randomisation and selection bias.

It appears that SWL could be used for the initial treatment of most ureteral calculi in children as it is less invasive than ureteroscopy and has a high success rate as a first-line therapy with minimal or no morbidity. In the minimally invasive treatment era for urolithiasis, complications such as ureteral perforation and vesicoureteric reflux, despite a low percentage of occurrence, might be rather unacceptable. Increased expertise with larger series and well developed available equipment would lead future trials to determine the best initial treatment method for ureteral calculi in children. Ureterolithotomy is still an option in cases which failed both treatments or in the presence of other congenital abnormalities necessitating surgical treatment such as ureterovesical obstruction, VUR, ureterocele and so on.

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