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ORIGINAL PAPER

Extracorporeal shock wave lithotripsy in the management of pediatric urolithiasis

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Abstract The main objective of this paper was to evaluate the efficacy and safety of the management of pediatric urolithiasis by extracorporeal shock wave lithotripsy (ESWL). Between November 1988 and July 2000, 165 renal stones, 53 ureteral stones, and 5 bladder stones were treated in 126 pediatric patients using Siemens Lithostar lithotriptor. The ESWL treatments ranging from 1 to 7 were needed per patient (mean: 2.1). One ESWL session was performed for 49.6% of stones, two for 24.6%, three for 13.0 %, four for 5.6% and > 4 for 8.2%. The success rate for renal stone units (asymptomatic fragments less than 4 mm) was 88.2%, stone-free rate was 49.0%. The stone-free rate for ureteral stone units was 87.5%, but was 75% for bladder stones. The overall results of ESWL treatment in 126 children was satisfactory: the success rate was 90.5%, stone-free rate was 51.6%, residual fragments > 4 mm were 9.5%. General anesthesia was required in 65 children (136 treatments) under the age of 10, and only in 18 children (40 treatments) in the age 11–14. Auxiliary procedures, such as double J stent and percutaneous nephrostomy (PCN) were used in 19 and 7 patients, respectively. Perirenal hematoma in one patient and hematomas in enteric wall in another one patient were the only major complications managed conservatively without consequences. Low energy lithotripsy with the Siemens Lithostar in our series of pediatric patients was safe and relatively effective.

Keywords Pediatric urolithiasis · Extracorporeal shock wave lithotripsy · Effectiveness · Complications

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Introduction

Since its introduction by Chaussy et al. [1] in 1980 extracorporeal shock wave lithotripsy (ESWL) has considerably changed the management of upper urinary tract lithiasis and has become the therapeutic option in most cases. With a follow-up of over 20 years this technique is considered to be efficient, noninvasive and safe for adults and children [2–4]. However, although the efficacy of ESWL is clearly established, its safety for the renal parenchyma, particularly in young patients whose kidneys are actively growing, has not yet been confirmed.

The aim of this study was to evaluate the efficacy and safety of the management of pediatric urolithiasis by ESWL at our department, the largest lithotripter centre in Serbia.

Materials and methods

Between November 1988 and July 2000, 126 children 8 months–14 years old (mean age: 8.7 years) with renal, ureteral or bladder calculi were treated at our department. There were 90 (71.4%) boys and 36 (28.6%) girls. A history of stones was noted in 18 (14%) of patients, and 41 (33%) had a family history of urinary stone disease. All procedures were performed using a Siemens Lithostar lithotripter, a second-generation machine.

Pretreatment evaluation of these children included a history, physical examination, routine laboratory investigation (urinary deposit and serum creatinine), and minimal metabolic stone screen. Seventy-five (59.5%) patients underwent some form of metabolic evaluation.

Stone analysis and composition were determined by X-ray crystallography in 84 (66.7%) cases.

Fifty-three (42%) patients presented with hematuria, 45 (35.7%) with pain (colicky, flank pain or diffuse abdominal pain) and 29 (23%) with urinary tract infection (UTI). Forty-three percent of patients were monosymptomatic. Patients with a known UTI received culture-specific antimicrobials just before ESWL. In addition, they received a prophylactic antibiotic from pre-ESWL to 3 days after the ESWL.

Prolonged immobilization as a predisposing factor was present in one child, bowel resection in another one, diverticulum of lower calyx in one. Three children had a history of neurogenic bladder. Underlying medical conditions included diabetes mellitus in one case, coeliac disease in one and cystinuria in six patients.

Plain abdominal film of kidneys, ureters and bladder (KUB), renal ultrasonography excretory urography and renal scintigraphy were used to diagnose, locate and define the stone burden, demonstrate renal anatomical and functional alterations, and to confirm indications for the ESWL treatment modality.

During the study period, a total of 243 stones in 146 renal/ureteral tracts and urinary bladder were treated. Calculi were on the right side in 51% of patients, on the left in 46% and in the bladder in 3%.

There were 114 caliceal stones, 71 in the renal pelvis, 20 in the proximal ureter, 8 in the midureter, 25 in the distal ureter and 5 bladder stones. Stones were further subclassified according to the maximal diameter (Table 1). The greatest size was observed in stones from renal pelvis and urinary bladder.

Fifty-three (42%) patients presented with hematuria, 45 (35.7%) with pain (colicky, flank pain or diffuse abdominal pain) and 29 (23%) with UTI.

After the ESWL treatment, routine follow-up included ultrasound, blood pressure controls, laboratory tests and eventually plain film X-ray. Stone elimination was assessed at day 1, a month and 3 months after the ESWL treatment by plain abdominal film (KUB) and ultrasound.

The ESWL treatment with no evidence of disintegration or fragmentation was considered unsuccessful, but successful treatment was considered if fragments were smaller than 4 mm and clinically asymptomatic. Stone-free rate was defined as the lack of any visible stone fragments on radiology and ultrasonography 3 months after the ESWL treatment.

Statistical analysis

Values are presented as means ± standard deviation. Student's t test for unpaired and paired data was used to estimate significance of the differences. The values were considered significant when $P < 0.05$.

Results

In 126 patients younger than 14 years, 243 renal, ureteral or bladder stones were treated in 268 ESWL sessions (Table 2). The ESWL treatments ranging

Table 1 Stone location and size in patients treated with ESWL

Stone location	Stone size (mm)						Total
	Up to 5	6–10	11–15	16–20	21–25	> 25	
Renal pelvis	8	12	25	15	6	5	71
Upper calyx	5	6	2	–	–	–	13
Middle calyx	7	21	–	1	–	–	29
Lower calyx	25	34	8	2	3		72
Renal pelvis	8	12	25	15	6	5	71
Upper ureter	–	13	7	–	–	–	20
Middle ureter	–	6	2	–	–	–	8
Lower ureter	3	13	4	2	2	1	25
Urinary bladder	–	–	–	4	1	–	5
Total	48	105	48	24	12	6	243

from 1 to 7 were needed per patient (mean: 1.8), and the average number of sessions per calculus was 1.1. One ESWL session was performed for 49.6% of stones, two for 24.6%, three for 13.0%, four for 5.6% and > 4 for 8.2%. The treatment time varied from 22 to 55 min (average duration: 38.2 min). Average postlithotripsy hospitalization was 25 h (range: 18–96 h).

A total of 65 (51.6%) patients aged < 10 years had the ESWL performed under general anaesthesia, and only in 18 children (40 treatments) age 11–14. The other children were treated under sedation with fentanyl.

A primary double-J ureteral stent was placed before performing the ESWL in 19 children during previous intervention (7 pyeloplasty, 1 UCN, 1 PCNL, 10 pyelonephrolithotomy). We did not use the double-J for hydronephrosis as complication occurs after ESWL treatment.

Steinstrasse was encountered in 22 (17.4%) patients. In situ SWL was applied in 6 of these patients, 7 were managed with percutaneous nephrostomy (5 were girls), 3 with ureteroscopy, while 6 were treated conservatively.

Post-treatment UTI were encountered in two patients. Renal colic, which was managed with prostaglandin synthase inhibitors, was observed in 24 (19%) cases. Major complications, such as significant perirenal hematoma in one patient and hematomas in enteric wall in another patient, were managed conservatively without consequences.

The mean shock number per session was 1,920 for renal pelvis stones, 1,870 for upper calyx, 1,980 for middle calyx, and 1,950 for lower calyx stones. The mean power used was 17.0, 17.9, 17.9 and 17.0 kV, respectively (Table 3). The mean number of patient treatments was 1.7 to 1.8 (from 1 to 7).

The stone-free rate for 118 kidney stones of less than 10 mm was 60.2%, but was only 26.4% for 53 stones of 10–20 mm. The success rate of these stones was 95.8 and 77.3%, respectively (Table 4). Ureteral stones of less than 10 mm had a stone-free rate of 94.3%, and stones of 10–20 mm had a stone-free rate of 73.3%. The success rate of these stones was 97.1 and 80.0%, respectively. The success rate for renal stones (asymptomatic fragments less than 4 mm) was 88.2%, stone-free rate was 49.2%. The stone-free rate for ureteral stones was 86.8%, but was 80% for bladder stones (Table 4). Residual fragments > 4 mm were demonstrated in 12 (11.8%) kidney stones, 5 (9.5%) in ureteral, and 1 (20%) in urinary bladder.

The overall result of ESWL treatment in 126 children was satisfactory: the success rate (stone elimination and asymptomatic fragments less than 4 mm) was 90.5%, stone-free rate was 51.6%, residual fragments > 4 mm 9.5% (Table 5).

Of the 84 stones analyzed, 17 (20.2%) were composed of struvite, 6 (7.1%) of cystine and the remaining 61 (72.6) were calcium based (calcium phosphate, calcium oxalate, or calcium and uric acid).

Discussion

Only 2–3% of cases of urolithiasis occur in the pediatric age group. Meanwhile, the potential morbidity

Table 2 Number of ESWL treatments related to stone location

Stone location	No. of units	Treatment sessions						
		1	2	3	4	5	6	7
Kidney	102	85	27	4	5	1	1	1
Ureter	40	46	4	1	1	1	–	1
Urinary bladder	5	2	3	–	–	–	–	–
Total number of treatments		133	68	15	24	10	6	14

Table 3 Stones location and size, and parameters of ESWL treatment

Stone location	No. of stones	Mean stone size (mm)	Mean (kV)	Mean shock	No. of treatments
Kidney	185	(5 to > 25)	(15.6–19.0)	(1,000–3,640)	(1–7)
Renal pelvis	71	18.8	17.0	1,920	1.7
Upper calyx	13	16.2	17.9	1,870	1.7
Middle calyx	29	15.6	17.9	1,980	1.8
Lower calyx	72	16.8	17.0	1,950	1.8
Ureter	53	(5 to > 25)	(17.0–19.1)	(1,440–5,000)	(1–7)
Upper ureter	20	9.6	18.9	1,800	1.8
Middle ureter	8	10.6	18.3	1,990	1.7
Lower ureter	25	9.2	17.9	2,100	1.7
Urinary bladder	5	(16–25)	(17.6–19.0)	(1,880–2,100)	4.0

Table 4 Results of ESWL treatment related to the stone location and size

Location	Stone size (mm)	No. of stones	Stone free: No.	Stone free %	Success: No.	Success (%)
Kidney	< 10	118	71	60.2	113	95.8
	11–20	53	14	26.4	41	77.3
	21–25	9	4	44.4	6	66.7
	> 25	5	2	40.0	3	60.0
Total		185	91	49.2	163	88.2
Ureter	< 10	35	33	94.3	34	97.1
	11–20	15	11	73.3	12	80.0
	21–25	2	1	50.0	1	50.0
	> 25	1	1	100.0	1	100.0
Total		53	46	86.8	48	90.5
Urinary bladder	16–20	4	3	75.0	3	75.0
	21–25	1	1	100.0	1	100.0
Total		5	4	80.0	4	80.0

Table 5 Success of ESWL treatment related to patients treated

Stone location	No. of patients	Success	Stone free	Residual fragments	
				< 4 mm	> 4 mm
Total	126	114 (90.5%)	65 (51.6%)	49 (38.9%)	12 (9.5%)

and the recurrent character of the illness encourage special attention to pediatric patients with urolithiasis. Starting in the 1980s, treatment of urolithiasis has gone through significant changes. The use of methods, such as extracorporeal lithotripsy, percutaneous nephrolithotripsy and urethroscopy, called minimally invasive, have become routine, reducing open surgery to only 1 to 4% of cases.

The clinical status of the child with urolithiasis is more variable than that of an adult. The more frequent signs and symptoms in our study were: hematuria (42%), flank pain (36%) and urinary infection (23%). In other studies up to 58% of children had flank pain, while up to 30% had either gross or microscopic hematuria [5–7].

Calcium-based stones are the most common in children, with rates of 52–80% of the analyzed stones being calcium oxalate–phosphate in composition [5, 6]. In our study 72.6% of the 84 stones available for analysis was calcium based (calcium oxalate, calcium phosphate, or calcium plus uric acid).

In the past the reported incidence of UTIs has been as high as 80%. A recent study from Turkey reported that 33% of children had associated infections and 10% had underlying congenital urological malformations [6]. Perrone et al. [8] reported that 34% of children in Brazil had associated urinary infections. In a Korean study Choi et al. [7] reported associated infections in 42% of children and associated congenital urological malformations in 35%. Similarly, we had 10% of patients with underlying structural urological abnormalities, and 23% of children with urinary tract infection.

Despite major concerns about potential hazards of the ESWL in the growing child, highly satisfactory results are being reported. The ESWL is the first option for the treatment of most renal or ureteric stones [9–11]. In 1989, Nijman et al. [12] reported a success rate of 79% in 6 months after the ESWL in a series of 73 children. Myers et al. [13], in a multicenter study involving 446 children treated for renal (238) or ureteric (208) stones reported a 68% success rate after one session and 78% after several sessions (with multiple sessions used in 7–35% of the patients, depending on the treating center). In the study of Muslumanoglu et al. [14], 408 urinary tract calculi in 344 children, age 6 months to 14 years, were managed with the Lithostar Plus. There were 57 calyceal stones, 167 in the renal pelvis, 31 in the proximal ureter, 16 in the midureter and 121 in the distal ureter, and 16 bladder stones. Overall, a stone-free rate of 79.9% and clinically insignificant residual fragments in 13.2% of cases were observed at a 3-month follow-up with a re-treatment rate of 53.9%. Overall efficacy quotient was 50.9%. Significantly more favourable results were achieved in ureteral calculi and stones 2 cm or smaller. Complications were observed in 33 patients (9.6%). The study indicates that the ESWL, with satisfactory stone-free rates and efficacy quotients in stones 2 cm or smaller, can be offered to children as a first-line treatment [14]. Apart from this, the stone-free rates in our study are lower than that documented in two recent publications

[15, 16]. Raza et al. [15] stated a stone-free rate of up to 84% for cases involving stones smaller than 20 mm, and 54% for those involving stones 20 mm or greater. For complex calculi 40% of patients were stone free and 45% required ancillary procedures, with an overall complication rate of 26%. In the study of Tan et al. [16], following initial SWL treatment, 60.2% of patients were stone free. The retreatment rate was 13.9%. Following a second treatment, the stone-free rate increased to 68%. Risk factors were identified in 31 children (27.0%), including metabolic and anatomic abnormalities. Patients with a risk factor were less likely to be stone free after one SWL session than those without risk factors (31.7% vs. 64.7%; $P < 0.001$). However, in their study the mean stone size was 7.8 mm (range 2–23 mm).

Most authors consider the ESWL to be particularly well suited for use in children because the stones are relatively soft in this age group and the urinary tract is compliant, which allows relatively large fragments to be eliminated easily [9–11, 13]. It was determined whether the thin ureter of the young child transports stone fragments after the ESWL as efficiently as the adult ureter does. The pediatric ureter was at least as efficient as the adult for transporting stone fragments after the ESWL [17, 18].

The ESWL has become the first-line treatment for upper ureteral stones in children; however, there is still 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 [19, 21].

Patients with residual fragments had a significant increase in adverse clinical outcome compared to stone-free subjects, with an odds ratio of 3.9 (95% CI 1.5–9.6) [21]. The presence of metabolic disorders was associated with residual fragments growth (odds ratio 11.4, 95% CI 1.5–79). Small residual fragments after the ESWL are clinically significant in children and increase the chance of adverse clinical outcome. These patients require close follow-up, particularly those with identifiable predisposing disorders. Abe et al. [22] have found the recurrence rates of 7.5, 24.1, and 33.0% after 1, 3, 5 years, respectively. Multiple stones, a history of urolithiasis, and stones located in the kidney or both kidneys plus the ureter significantly influenced recurrence. The number and location of stones and a history of urolithiasis significantly influence recurrence. Further studies of prophylactic therapy are required, especially for patients with these factors. Our results on cystine urolithiasis treatment in 6 children have shown that the ESWL, as an auxiliary procedure, was safe and effective in pelvis stone but failed in caliceal stones [23]. Medical dissolution for retained fragments was found effective.

A controversial issue involves stent placement to prevent steinstresses. In adults there is no difference in outcome after the ESWL whether or not a stent is used [24, 25]. In fact, unstented patients may have a more comfortable postoperative course, since they do not have the discomfort associated with the stent. The dispensability of the pediatric ureter permits stone fragments to pass more easily in children and, thus, stents are not needed in most pediatric patients [26].

Long-term studies indicate that after the ESWL in children renal scars do not develop, renal function and linear growth are not affected and there is no increased risk of hypertension or other medical renal disease [27, 28]. In our previous study, the long-term functional outcome of kidneys in children with urolithiasis treated by means of the ESWL using Siemens Lithostar lithotripter was positive [29]. Dynamic kidney scintigraphy using ^{99m}Tc-DTPA was performed prior to, immediately following the ESWL treatment, 3 months later, and again after an observation period of 12–67 months (38 ± 13 months). The ESWL treatment in children with acute obstruction was associated with an immediate increase in GFR; however, in chronic calculous disease a decrease in the GFR was found. A return of the GFR to the pretreatment level was observed at the 3-month control in these patients. In patients with acute stone obstruction, at 3 and 12–67 months after the ESWL treatment, the GFR of the treated kidney was found to be significantly increased compared to the pretreatment level. In contrast, in children with chronic calculous disease this increase was modest [29].

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