

Pediatric Urology

# Factors Affecting the Outcome of Extracorporeal Shock Wave Lithotripsy for Unilateral Urinary Stones in Children: A 17-Year Single-Institute Experience

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**Purpose:** Extracorporeal shock wave lithotripsy (ESWL) is a first-line treatment for pediatric urinary stone disease. We aimed to determine the factors affecting the outcome of ESWL for unilateral urinary stones in children.

**Materials and Methods:** A total of 81 pediatric patients aged 0 to 16 years with urinary stones treated by ESWL from January 1995 through May 2012 were retrospectively reviewed. All patients were required to have unilateral urinary stone disease. Children who underwent other surgical procedures before ESWL were excluded. Outcomes evaluated after ESWL were the stone-free rate at 3 months after ESWL, success within a single session, and success within three sessions. Factors affecting the success within three sessions were also analyzed.

**Results:** The final analysis was for 42 boys and 22 girls (mean age, 9.2±5.2 years). Of these 64 patients, 58 (90.6%) were treated by ESWL without other surgical procedures and 54 (84.4%) were successfully treated within three ESWL sessions. In the multivariate analysis, multiplicity (odds ratio [OR], 0.080; 95% confidence interval [CI], 0.012 to 0.534; p=0.009) and large stone size (> 10 mm; OR, 0.112; 95% CI, 0.018 to 0.707; p=0.020) were significant factors that decreased the success rate within three ESWL sessions.

**Conclusions:** Most of the pediatric urinary stone patients in our study (90.6%) were successfully treated by ESWL alone without additional procedures. If a child has a large urinary stone (> 10 mm) or multiplicity, clinicians should consider that several ESWL sessions might be needed for successful stone fragmentation.

**Keywords:** *Lithotripsy; Pediatrics; Treatment outcome; Urinary calculi*

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**Article History:**

received 2 April, 2013  
accepted 30 April, 2013

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## INTRODUCTION

Pediatric urinary stones are rare but have lifelong consequences. Because children have a small body size and delicate tissues, and because the use of general anesthesia is likely, treatment for pediatric stone disease requires thoughtful consideration and individualized therapy [1,2]. Since extracorporeal shock wave lithotripsy (ESWL) for pediatric urinary stones was first introduced by Newman et al. [3] in 1986, numerous reports have demonstrated the

efficacy and safety of ESWL in the pediatric population [4-20]. ESWL is now considered a first-line treatment for pediatric stone disease because of its minimal invasiveness and high success rate [7,21].

Recent reductions in the size of endourological instruments, improvements in electronic video imaging systems, and advancements in endourological skill have given clinicians alternative surgical options such as ureteroscopic surgery (URS) or percutaneous nephrolithotomy (PCNL) for first- or second-line treatment of pediatric urolithiasis,

including in cases of ESWL failure [2]. Nevertheless, the identification of variables that predict successful outcomes of ESWL in the pediatric population would be useful. Therefore, we aimed to determine the factors affecting the outcome of ESWL for unilateral urinary stones in children by reviewing 17 years of experience at Samsung Medical Center.

## MATERIALS AND METHODS

### 1. Study design and patients

A total of 81 pediatric patients with urinary stones treated by ESWL from January 1995 through May 2012 at Samsung Medical Center were retrospectively reviewed. The following clinical data were documented: age and gender of patients, laterality and location of stones, maximum size of stones, number of ESWL sessions, and treatment outcomes after ESWL. Evaluated treatment outcomes after ESWL were stone-free rate at 3 months after ESWL, success within a single session, and success within three sessions. We investigated treatment outcomes according to stone location and analyzed the factors affecting success within three sessions.

### 2. Inclusion and exclusion criteria

Patients aged 0 to 16 years were eligible for enrollment. All patients were required to have unilateral urinary stone disease. Exclusion criteria were disorders of the kidney, liver, intestine, or cardiovascular system; congenital anomalies of the urinary tract or nervous system; or psychological problems. Children who underwent other surgical procedures such as PCNL or endoscopic treatment before ESWL were also excluded.

### 3. Patient preparation and ESWL procedure

All stones were identified by simple kidney-ureter-bladder X-ray, ultrasonography, or computed tomography scan if necessary. Stone size was measured as the maximal stone length on imaging study. Before treatment, all patients were routinely evaluated through a medical history, a physical examination, urinalysis, urine culture, serum chemistry profile, and coagulation profile. Children with poor cooperation were treated under general anesthesia; others were treated with analgesia without general anesthesia. The position for treatment was decided on the basis of stone location. Children with renal stones or upper ureteral stones were treated in the supine position, whereas children with mid or distal ureteral stones were treated in the prone position. The MPL-9000 lithotripter (Dornier Medizintechnik, Germering, Germany) was used from January 1995 to May 2008, and the MODULITH SLX-F2 lithotripter (Storz Medical AG, Tägerwil, Switzerland) was used from June 2008 to May 2012. Fluoroscopic or ultrasonographic imaging systems were used to locate the stone during the procedure. Treatment was initiated at 8.2 kV, which was gradually increased up to 17.0 kV with a maximum of 3500 shocks. The shockwave frequency was

1 Hz. The interval between treatment sessions was 2 to 4 weeks to allow passage of fragmented debris and kidney recovery.

### 4. Treatment outcomes measurement

Patients were evaluated 1 and 3 months after the last session by imaging modalities such as kidney-ureter-bladder X-ray, ultrasound, or computed tomography scan, if necessary. Success was defined as stone-free status or clinically insignificant residual fragments (CIRFs). Stone-free status indicated no evidence of residual stones on imaging studies. CIRFs were asymptomatic noninfectious and non-obstructive fragments smaller than 3 mm. Children who underwent additional procedures (URS or PCNL) were not counted as a success.

### 5. Statistical analysis

Statistical analyses were performed by using SPSS ver. 18.0 (SPSS Inc., Chicago, IL, USA). A chi-square test and a t test were used to analyze the related parameters and treatment outcomes according to the method of anesthesia. A t test and logistic regression analysis were used to evaluate the factors affecting the outcome of ESWL. A p-value of less than 0.05 was considered to be statistically significant.

### 6. Ethics statement

This study was approved by the Institutional Review Board of Samsung Medical Center. Under the board's approval, all study participants were exempt from written, informed consent.

## RESULTS

The study population was 64 children, 42 boys and 22 girls (mean age,  $9.2 \pm 5.2$  years; range, 0.5 to 15.9 years). Calculi were on the right side in 34 cases (53.1%) and on the left side in 30 cases (46.9%). Of the 64 patients, 5 (7.8%) had urinary stones in the upper or mid calyx, 5 (7.8%) in the lower calyx, 9 (14.1%) in the renal pelvis, 15 (23.4%) in the upper ureter, 17 (26.6%) in the lower ureter, and 13 (20.3%) in multiple locations. Stone size ranged from 4 to 38 mm with a mean of  $10.2 \pm 5.7$  mm. The mean number of ESWL sessions was  $1.7 \pm 1.7$  (Table 1).

Of the 64 patients, 58 (90.6%) were treated by ESWL without other surgical procedures and 54 (84.4%) were successfully treated within three ESWL sessions. Treatment outcomes according to stone location are shown in Table 2. The percentage of treatment success for a single ESWL session was 80.0% when the stone was solitary and located in the upper or mid calyx, 80% if in the lower calyx, 77.8% if in the renal pelvis, 93.3% if in the upper ureter, and 70.6% if in the lower ureter. The percentage of treatment success for a single ESWL session in patients with stones in multiple locations was 30.8%, which was significantly lower than that for patients with a stone in a single location. The success rate within three ESWL sessions was 100% (5 of

5 patients) when the stone was solitary and located in the upper or mid calyx, 100% (5 of 5 patients) if in the lower calyx, 88.9% (8 of 9 patients) if in the renal pelvis, 100% (15 of 15 patients) if in the upper ureter, and 88.2% (15 of 17 patients) if in the lower ureter. To avoid possible injury to developing reproductive systems, 2 of 17 patients (11.8%) with a solitary lower ureter stone were treated with additional URS after a single ESWL session. Stones in multiple locations were treated successfully within three sessions in 46.2% of cases. Four of 13 patients (30.8%) with stones

in multiple locations were treated with additional surgical treatments: two with URS, one with PCNL, and one with URS and PCNL. When the shockwave-related parameters and treatment outcomes were analyzed according to the method of anesthesia, the general anesthesia group was younger ( $p < 0.001$ ) and was more likely to have multiple stones ( $p = 0.005$ ). The success rate was not significantly different between the two groups (Table 3). Early hematuria was noted in most of the patients. Transient renal colic, which was managed by antispasmodic and anti-inflammatory treatment, was observed in 3 patients (4.7%). Steinstrasses occurred in 2 of 13 patients (15.4%) with stones in multiple locations and was treated successfully by URS. No other complications occurred in any patients, such as hemorrhage that necessitated transfusion, infection, or injury of other organs.

**TABLE 1.** Demographic characteristics and baseline parameters of the patients

Parameter	Value
No. of patients	64
Age at the time of treatment start (y)	9.2±5.2
Gender	
Male	42 (65.6)
Female	22 (34.4)
Laterality	
Right	33 (51.6)
Left	31 (48.4)
Stone location	
Upper/mid calyx	5 (7.8)
Lower calyx	5 (7.8)
Renal pelvis	9 (14.1)
Upper ureter	15 (23.4)
Lower ureter	17 (26.6)
Multiple	13 (20.3)
Maximum stone size (mm)	
< 5	9 (14.1)
5.1-10	34 (53.1)
10.1-15	11 (17.2)
15.1-20	7 (10.9)
> 20	3 (4.7)
Stone size (mm)	10.2±5.7
No. of ESWL sessions	1.7±1.7

Values are presented as mean±standard deviation or number (%). ESWL, extracorporeal shock wave lithotripsy.

In the univariate analysis, multiplicity ( $p < 0.001$ ) and large stone size ( $> 10$  mm) ( $p = 0.001$ ) significantly decreased the success rate within three ESWL sessions (Table 4). In the multivariate analysis, multiplicity (odd ratio [OR], 0.080; 95% confidence interval [CI], 0.012 to 0.534;  $p = 0.009$ ) and large stone size (OR, 0.112; 95% CI, 0.018 to 0.707;  $p = 0.020$ ) also decreased the success rate within three ESWL sessions (Table 5).

**DISCUSSION**

Since the first report of success of ESWL in a pediatric population by Newman et al. [3], numerous reports have shown the safety and efficacy of ESWL for treating pediatric urinary stones [4-20]. The joint European Association of Urology/American Urological Association Nephrolithiasis Guideline Panel's 2007 Guideline for the Management of Ureteral Calculi states, "Treatment choices should be based on the child's size and urinary tract anatomy. The small size of the pediatric ureter and urethra favors the less invasive approach of ESWL" [22]. Therefore, ESWL remains a first-line treatment option for most pediatric cases of urinary stone disease.

In addition to its noninvasive nature, ESWL has other

**TABLE 2.** Treatment outcomes according to stone location

Stone location	Patient	Success within 1 session	Success within 3 sessions	Treatment session	Stone-free rate at 3 months after ESWL	Patients underwent auxiliary procedure	Steinstrasse
Upper/mid calyx	5	4 (80.0)	5 (100)	1.2±0.4	5 (100)	0 (0)	0 (0)
Lower calyx	5	4 (80.0)	5 (100)	1.2±0.4	5 (100)	0 (0)	0 (0)
Renal pelvis	9	7 (77.8)	8 (88.9)	1.6±0.1	9 (100)	0 (0)	0 (0)
Upper ureter	15	14 (93.3)	15 (100)	1.1±0.2	15 (100)	0 (0)	0 (0)
Lower ureter	17	12 (70.6)	15 (88.2)	1.4±0.7	15 (88.2)	2 (11.8)	0 (0)
Multiple	13	4 (30.8)	6 (46.2)	3.2±3.0	9 (69.2)	4 (30.8)	2 (15.4)
Total	64	45 (70.3)	54 (84.4)	1.7±1.7	58 (90.6)	6 (9.4)	2 (3.1)

Values are presented as number (%) or mean±standard deviation. ESWL, extracorporeal shock wave lithotripsy.

**TABLE 3.** Analysis of the parameters and treatment outcomes according to the method of anesthesia

Parameter	General anesthesia		p-value
	Yes	No	
Patients	37 (57.8)	27 (42.2)	
Age at the time of treatment start (y)	5.3±3.7	13.5±2.8	<0.001
Gender			0.495
Male	23 (62.2)	19 (70.4)	
Female	14 (37.8)	8 (29.6)	
Laterality			0.968
Right	19 (51.4)	14 (51.9)	
Left	18 (48.6)	13 (48.1)	
Stone location			0.006
Upper/mid calyx	3 (8.1)	2 (7.4)	
Lower calyx	4 (10.8)	1 (3.7)	
Renal pelvis	7 (18.9)	2 (7.4)	
Upper ureter	6 (16.2)	9 (33.3)	
Lower ureter	5 (13.5)	12 (44.4)	
Multiple	12 (32.4)	1 (3.7)	
Multiplicity			0.005
Yes	12 (32.4)	1 (3.7)	
No	25 (67.6)	26 (96.3)	
Stone size (mm)	10.8±6.4	9.4±4.8	0.319
No. of ESWL sessions	1.7±1.9	1.7±1.4	0.898
Success within 1 session			0.586
Yes	27 (73.0)	18 (66.7)	
No	10 (27.0)	9 (33.3)	
Success within 3 sessions			0.122
Yes	29 (78.4)	25 (92.6)	
No	8 (21.6)	2 (7.4)	
Steinstrasse			0.220
Yes	2 (5.4)	0 (0)	
No	35 (94.6)	27 (100)	

Values are presented as number (%) or mean±standard deviation. ESWL, extracorporeal shock wave lithotripsy.

advantages in the treatment of pediatric urinary stones. For younger patients, stones seem to be more susceptible to shockwaves because of the short indwelling time. The pediatric ureter is more elastic, more distensible, and shorter, which facilitates the passage of stone fragments and compensates for the narrower lumen. The small body volume of children allows the shockwaves to be transmitted with minimal energy loss. However, the application of many ESWL sessions is a burden to pediatric patients because of the likely use of general anesthesia during the procedure and the increased susceptibility of children to radiation exposure.

Until now, studies on ESWL for pediatric urinary stone disease have reported a wide variation in success rate resulting from variation in the methods of different studies, the age of included patients, the machines used, the definition of success, and stone characteristics including size, location, and multiplicity (Table 6) [4-20]. Thus, care must be taken in interpreting the success rate of different series, because 1) some reports on ESWL monotherapy report suc-

**TABLE 4.** Univariate analysis of treatment outcomes of ESWL in three sessions

Variable	Success within three sessions without auxiliary procedure		p-value
	Yes	No	
Patients	54 (84.4)	10 (15.6)	0.394
Age (y)	9.4±5.8	7.7±5.2	0.472
Gender			
Male	34 (81.0)	8 (19.0)	
Female	20 (90.9)	2 (9.1)	
Laterality			1.0
Right	28 (84.8)	5 (15.2)	
Left	26 (83.9)	5 (16.1)	
Location			0.546
Upper/mid calyx	5 (100)	0 (0)	
Lower calyx	5 (100)	0 (0)	
Pelvis	8 (88.9)	1 (11.1)	
Upper ureter	15 (100)	0 (0)	
Lower ureter	15 (88.2)	2 (11.8)	
Multiplicity			<0.001
Yes	6 (46.2)	7 (53.8)	
No	48 (94.1)	3 (5.9)	
Size (mm)			0.001
≤ 10	41 (95.3)	2 (4.7)	
> 10	13 (61.9)	8 (38.1)	
General anesthesia			0.170
Yes	29 (78.4)	8 (21.6)	
No	25 (92.6)	2 (7.4)	

Values are presented as number (%) or mean±standard deviation. ESWL, extracorporeal shock wave lithotripsy.

**TABLE 5.** Multivariate analysis of treatment outcomes of ESWL within three sessions

Factor	Odds ratio (95% CI)	p-value
Multiplicity	0.080 (0.012-0.534)	0.009
Size (> 10 mm)	0.112 (0.018-0.707)	0.020
General anesthesia	0.818 (0.096-6.958)	0.854

ESWL, extracorporeal shock wave lithotripsy; CI, confidence interval.

cess rates resulting from a single session and others report results from several sessions, and 2) some series define success as only a stone-free state whereas others include CIRFs. In our study, we analyzed results by several definitions, namely, stone-free rate at 3 months after ESWL, success within a single session, and success within three sessions. Most previous studies defined success as a stone-free rate at 3 months after ESWL, reporting success rates of 71% to 97% [7,10,13,14,16,17,19,20]. In our study, the stone-free rate at 3 months after ESWL was 90.6%.

We believe that our analysis of treatment success within one or three ESWL sessions is an innovative approach. In clinical practice, an important issue during ESWL treatment for pediatric urinary stone disease is the number of ESWL sessions required for success. Because ESWL in pe-

**TABLE 6.** Studies on ESWL for pediatric urolithiasis

Study	Year of publication	No. of patients	Age of patients (y)	Definition of success	Treatment outcomes				
					% Success within specified no. of sessions			% SF at 3 months after ESWL	% Steinstrasse
					1	2	3		
Lee et al. [4] <sup>a</sup>	1994	17	0.5-16	NR	66.7	NR	85.7	87.5	0.0
Ahn et al. [5] <sup>a</sup>	1997	43	2-18	SF	37.2	NR	72.1	95.3	9.3
Cho et al. [6] <sup>a</sup>	2002	57	<18	SF	NR	NR	NR	94.4	0.0
Rodrigues Netto Jr et al. [7]	2002	86	3-14	SF	NR	NR	NR	97.6	0.0
Ather and Noor [8]	2003	105	<14	<3 mm	NR	NR	NR	95.0	1.9
Musulmanoglu et al. [9]	2003	344	0.5-14	<4 mm	NR	NR	NR	93.1	7.8
Aksoy et al. [10]	2004	129	1.7-14	SF	NR	NR	NR	85.0	5.4
Tan et al. [11]	2004	100	0.8-16	SF	60.2	68	NR	NR	0.0
Defoor et al. [12]	2006	88	0.5-20	SF	68	74	NR	NR	NR
Musulmanoglu et al. [13]	2006	192	0.5-14	SF	NR	NR	NR	91.1	NR
Demirkesen et al. [14]	2006	126	1-16	SF	46.4	NR	NR	71.5	6.3
Wadhwa et al. [15]	2007	106	3-16	<3 mm	NR	NR	NR	87.0	3.8
Raza and Ather [16]	2008	98	1-14	SF	NR	NR	NR	88.8	6.1
Aksoy et al. [17]	2009	263	0.8-14	SF	NR	NR	NR	90.9	4.9
Kim et al. [18] <sup>a</sup>	2010	30	0-6	<5 mm	NR	NR	NR	67.6	6.7
He et al. [19]	2011	311	0.5-16	SF	NR	NR	NR	95.8	1.0
Badawy et al. [20]	2012	500	0.8-17	SF	NR	NR	NR	89.0	1.2
Present study	-	64	0.5-16	<3 mm	70.3	NR	84.4	90.6 <sup>b</sup>	3.1

ESWL, extracorporeal shock wave lithotripsy; NR, not reported; SF, stone free.

<sup>a</sup>.Korean data. <sup>b</sup>.Stone-free rate at 3 months after ESWL.

diatric patients frequently requires general anesthesia, the number of ESWL sessions for treatment success is particularly important in children. When a clinician encounters a pediatric patient with stone disease, several factors affect success, such as stone location, size, and multiplicity. We surmised that three sessions of ESWL would be a generally acceptable number for patients and their parents; thus, we analyzed factors affecting treatment success within three ESWL sessions. The overall success rates were 70.3% for a single session and 84.4% for three ESWL sessions. When urinary stones were not found in multiple locations, the success rate was 80.4% for a single ESWL session and 94.1% for three sessions. Few data have been published on ESWL success within one or three sessions. The definition of CIRFs also differs among studies. Some studies suggest that no urinary stones in children are insignificant; others define CIRFs as 3 or 4 mm [8,9,15]. Although children's ureters are more elastic, more distensible, and shorter than the ureters of adults, thus permitting easier passage of stone fragments, the narrow lumen of the pediatric ureter interferes with the expulsion of stone fragments. Therefore, we defined CIRFs as 3 mm.

Our analysis revealed that factors lowering the treatment success rate were stone multiplicity and large size (> 10 mm), as expected from the results of previous reports [15,23]. When patients with multiple stones were excluded, three patients did not achieve success within three ESWL sessions. Of these three, one had a 22-mm staghorn stone in the renal pelvis that completely fragmented with-

out complication in 5 ESWL sessions. The remaining two patients had lower ureteral stones that were not fragmented in a single ESWL session. We did not attempt further ESWL because of difficulties with localization over the sacroiliac joint and to avoid possible injury to the developing reproductive systems. These patients received URS.

An interesting finding of this study was that the success rate did not differ by stone location. When stones are in the lower pole calyx, the success rate of ESWL depends not only on successful fragmentation but also on stone fragment clearance. ESWL treatment for lower pole calyceal stones is controversial. Several studies have demonstrated a significantly lower success rate after ESWL for lower pole stones than for other kidney locations [24,25]. However, a recent study by Goktas et al. [26] reported that ESWL was highly successful for lower calyceal stones in pediatric patients compared with adults. The study suggested that ESWL can be a first-line treatment for managing lower calyceal stones in children. The authors hypothesized that the high success rate of ESWL treatment of pediatric lower calyceal stone resulted from 1) less shockwave energy loss during travel through the small body volume of a child, 2) the shorter ureter length in children, and 3) the more elastic and distensible ureters in children. In our study, the success rate for stones in the lower pole calyx was not significantly different from that of stones in other kidney locations: 80% for a single ESWL session and 100% for three sessions. Concurring with previous reports, we recommend ESWL as a first-line treatment, even for stones lo-

cated in the lower pole calyx. However, our results were from a retrospective analysis with a small number of patients (n=5); thus, definite conclusions cannot be drawn about the success of ESWL for lower calyceal stones.

In our study, 2 of 64 patients (3.1%) experienced steinstrasse, which was treated by URS without sequelae. Both patients initially had multiple urinary stones. Of the possible complications after ESWL for pediatric stone disease, steinstrasses seem to be most challenging and mainly results from large fragments or multiplicity [9,27]. However, with advances in medical technology, the miniaturization of ureteroscopes has made treatment of steinstrasses easier, resulting in fewer complications. Therefore, we recommend ESWL as a first-line treatment even for large or multiple stones, although this results in a risk of steinstrasse.

A potential limitation of this study is the retrospective cohort design. However, during the study period, our interpretation of stone characteristics including stone location and size did not change. Neither did the ESWL protocol for stone treatment. To the best of our knowledge, this study includes the largest number of pediatric stone patients in Korea. We think that the results could be a useful reference for pediatric stone treatment. If a child has a large urinary stone (> 10 mm) or multiplicity, the parents should be informed of the probability of needing several ESWL sessions for complete stone fragmentation.

## CONCLUSIONS

In our 17-year single-institution experience, most pediatric urinary stone patients (58 of 64 [90.6%]) were successfully treated by ESWL alone without additional procedures. The factors decreasing the success rate within three ESWL sessions were multiplicity or large stone size (> 10 mm). No significant difference in success rate was observed by stone location for patients without multiplicity.

## CONFLICTS OF INTEREST

The authors have nothing to disclose.

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