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Extracorporeal shock wave lithotripsy for urinary tract stones in pediatric patients: Our 11 years of experience

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Ethical approval was obtained from the Ethics Committee of Harran University Faculty of Medicine (HRU/22/04/17).
All procedures in this study involving human participants were performed in accordance with the 1964 Helsinki Declaration and its later amendments.

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Abstract

Background/Aim: Urinary system stone disease creates a significant burden on the health system. Many treatment methods are available, including extracorporeal shock wave lithotripsy (ESWL), endourological procedures, and open and laparoscopic procedures. In recent years, in parallel with technological developments, endourological devices have become more usable in the renal system. For this reason, urologists are opting for endourological procedures more frequently. ESWL is the least invasive procedure for urinary system stone disease, and it has a higher success rate in pediatric patients than in adults. In this retrospective cohort study, we analyzed the data from the pediatric cases in which we used ESWL treatment in our clinic. We aimed to reveal the effectiveness of ESWL and the factors that will increase the success rate of this procedure in light of the current literature.
Methods: The files of patients aged 16 years and under who underwent ESWL at the Urology Clinic of University of Health Sciences Sanliurfa Mehmet Akif Inan Training and Research Hospital between January 2010 and December 2021 were retrospectively reviewed. Age, gender, stone area, stone localization, number of sessions, energy and frequency used, complete stone-free status, and secondary intervention requirement were recorded. The absence of stone fragments or the presence of fragments smaller than 3 mm only in imaging after ESWL was considered a success.
Results: This study included 433 pediatric patients. The mean age of the patients was calculated as 12.02 (4.67) (range: 1–16) years. The most important factors affecting the number of residual stones were stone localization ($P = 0.045$) and size ($P < 0.001$). When stone localization was compared according to patient age, the older patients were found to have a significantly higher rate of stones in the proximal ureter than in the lower calyx of the kidney ($P = 0.045$) and renal pelvis ($P = 0.048$).
Conclusion: Although there are continual advances in other minimally invasive surgical methods today, ESWL is a treatment method that can be safely applied in pediatric patients. Stone size and stone localization are the two most important factors affecting its success rate.

Keywords: Pediatric urolithiasis, Lithotripsy, Shock wave, Urinary stone

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Introduction

Urinary system stone disease is a common and important health problem. It is rarer in the pediatric age group than in adults. This disease is endemic in Turkey, Pakistan, and some South Asian, African, and South American countries [1]. However, in recent years, the incidence of stones has been increasing across the world, especially in the adolescent age group. There is an annual increase of 4–10% in the incidence of stone disease [2, 3]. Urinary system stone disease creates a significant burden on the health system. Many treatment methods are available, including extracorporeal shock wave lithotripsy (ESWL), endourological procedures, and open and laparoscopic procedures. ESWL is the least invasive compared to other procedures [4]. ESWL has been shown to be an effective and safe procedure in the treatment of stones smaller than 20 mm in all childhood age groups, including infants [5]. In the pediatric age group, it was first performed in 1986 by Newman et al. [6]. The success rate seems to be higher in children than in adults [7]. The higher success rate in pediatric patients has been associated with relatively softer stone composition, smaller stone volume, smaller body structure allowing better transmission of shock waves, and easier stone passage due to increased ureteral compliance [8]. As in all stone treatments, the aim of ESWL is to provide complete stone-free status. In the last two decades in particular, the frequency of endoscopic procedures has increased with developments in endoscopic equipment. However, current guidelines still recommend ESWL as the first-choice treatment method in kidney stones of <20 mm [9].

Although the literature contains large-case series on ESWL treatment in adults, there are only a few large series on the treatment in children [9]. In this retrospective study, we aimed to reveal the efficacy of ESWL in pediatric patients and factors that will increase the success rate of this procedure by evaluating the data from pediatric cases in which we performed ESWL treatment over 11 years at our clinic and discussing our findings in light of the literature.

Materials and methods

This study was conducted at the Urology Clinic of University of Health Sciences Sanliurfa Mehmet Akif Inan Training and Research Hospital. Following the Declaration of Helsinki, consent was obtained from the Ethics Committee of Harran University Faculty of Medicine before the study (HRU/22/04/17). A total of 433 patients aged 16 years and younger who underwent ESWL at our clinic between January 2010 and December 2021 were included in the study. Patient files were retrospectively screened. Age, gender, stone area, stone localization, number of sessions, energy and frequency applied, complete stone-free status, and secondary intervention requirement were recorded. All of the patients were evaluated in terms of full urinalysis, hemogram, blood biochemistry, bleeding, and coagulation time before ESWL. They also underwent ultrasonography (USG) and direct urinary system graphy (DUSG) before and after ESWL. Stone size and localization and the presence of urinary system anomalies were evaluated before ESWL. Patients with solitary kidneys, congenital urinary system anomalies, bleeding disorders, and urinary tract infections were excluded from the study. All patients under the age of 12 years were evaluated by an anesthesiologist the day before the procedure to determine the American Society of Anesthesiology (ASA) score, and all had a score of either ASA 1 or ASA 2. Intravenous analgesics (paracetamol 10–15 mg/kg) were administered to the patients over 12 years of age, while general anesthesia or sedoanalgesia (ketamine 1.5 mg/kg and midazolam 0.05 mg/kg) were administered to those 12 years and under.

With the patients placed in the supine position, the procedures were performed using the Richard Wolf piezoelectric ESWL (Richard Wolf, Knittlingen, Germany). Fluoroscopic and ultrasonographic methods were used for focusing. The amplitude of shock waves was gradually increased and maintained at the point where the stone started to break. A maximum of 1,200 shocks were applied in the voltage range of 7–12 kilowatts (kW) in patients under the age of 5 years, a maximum of 2,000 shocks in the range of 12–18 kW in those aged 5–10 years, and a maximum of 2,500 shocks in the range of 12–18 kW in those over 10 years. One week later, the patients returned for a control session, during which simultaneous USG and DUSG were performed, and cases showing an absence of stone fragments or a presence of fragments smaller than 3 mm only on imaging were considered a success [10]. In the presence of fragments of 4 mm or larger, ESWL was applied again, leaving at least two weeks between the sessions. A maximum of three sessions of ESWL were undertaken. All the patients were evaluated one month after the last ESWL session. At the end of the three sessions, follow-up was recommended for clinically insignificant stones, while other endoscopic procedures were planned for patients requiring clinical intervention.

Statistical analysis

For the statistical analysis of the data obtained from the study, we used IBM SPSS Statistics v. 22.0. While evaluating the study data, the compatibility of the parameters with the normal distribution was checked with the Kolmogorov-Smirnov test. In addition to descriptive statistical methods (mean [standard deviation]), the unpaired t-test was used to evaluate quantitative parameters with a normal distribution, and Fisher’s exact test was used for the evaluation of parameters that did not show a normal distribution. Significance was evaluated at the $P < 0.05$ level.

Results

This study included 433 pediatric patients, 229 boys and 204 girls, aged 16 and under. The mean age of the patients was calculated as 12.02 (4.67) (range, 1–16) years. The number of stones, stone side (right/left), stone localization, stone area, stone length, number of ESWL sessions performed, whether ureterorenoscopy (URS) was performed, residual stone status after ESWL, applied kW, and total number of shocks applied were determined. Table 1 presents the results of parameters that contributed to the presence of residual stones. The most important factors affecting residual stone status were stone localization ($P = 0.045$) and stone size ($P < 0.001$).

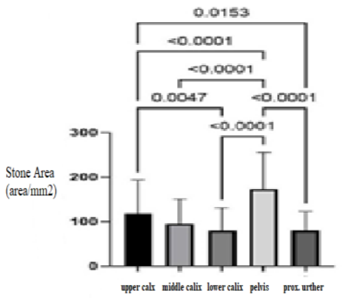
Table 1: Parameters affecting the presence of residual stones

	Total (n)	Residual stone (n) Absent	Present	*P*-value
Number	433	370	63	
Age (years)		12.14 (4.644)	11.26 (4.84)	0.17*
Gender				
Male	229	199	29	0.32**
Female	204	171	33	
Stone localization				
Upper calyx of the kidney	65	59	6	<0.001**
Middle calyx of the kidney	115	107	8	
Lower calyx of the kidney	79	73	6	
Renal pelvis	119	82	37	
Proximal ureter	54	49	5	
Stone side				
Right	251	217	34	0.58**
Left	182	153	29	
Stone area (mm^2)		100.9 (59.4)	201.0 (100.1)	<0.001*
Number of sessions				
1	61	60	1	<0.001**
2	210	206	4	
3	162	107	58	
kw		16.61 (2.7)	16.95 (2.4)	0.35*
Total number of shocks		1862 (353.8)	1939 (372.1)	0.12*
JJ -	370	328	42	<0.001**
stent +	63	41	22	

*Unpaired t-test, **Fisher's exact test, kw: kilowatt

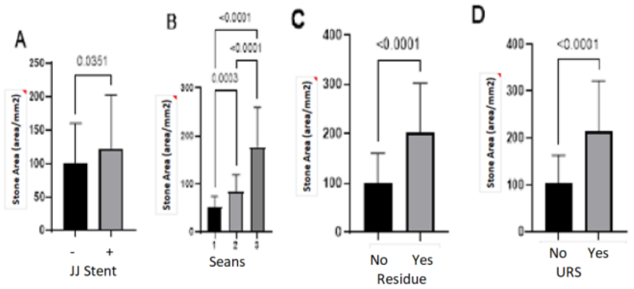
Considering the distribution of stone burden according to stone localization location, it was determined that the stones with the highest burden were located in the renal pelvis (Figure 1).

Figure 1: Results of Tukey's multiple comparison test showing the distribution of stone burden according to stone localization (*P*-values are given on the graph)



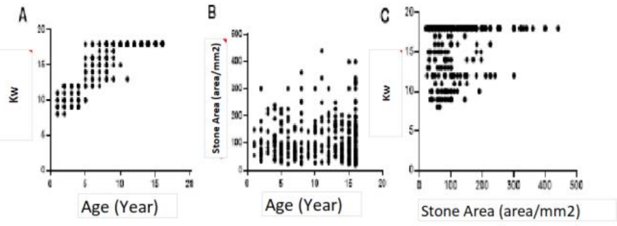
When the stone burden of the patients was compared according to their JJ stent requirement after ESWL, it was found that the stone burden of the patients with JJ stenting (122.4 (80.1) area/mm^2) was significantly higher than those without this requirement (100.9 (59.4) area/mm^2) (P = 0.035; Figure 2A). The stone burden of the patients also significantly differed according to the number of sessions (one session [51.96 (22.8) areas/mm^2] vs two sessions [84.82 (35.2) areas/mm^2], $P < 0.001$; one session vs three sessions [177.6 (82.1) area/mm^2], $P < 0.001$; and 2 sessions vs 3 sessions, $P < 0.001$, Figure 2B). As the stone burden increased, the residual stone rate ($P < 0.001$) and URS requirement also increased ($P < 0.001$). It was also determined that as the number of stones increased, the number of patients requiring a JJ stent increased (P = 0.02, Fisher's exact test) (Figure 2).

Figure 2: Comparison of the patients' stone burden according to JJ stent requirement after ESWL (unpaired t-test) (A), number of sessions (Tukey's multiple comparison test) (B), residual stone status (unpaired t-test) (C), and URS requirement (unpaired t-test) (D)



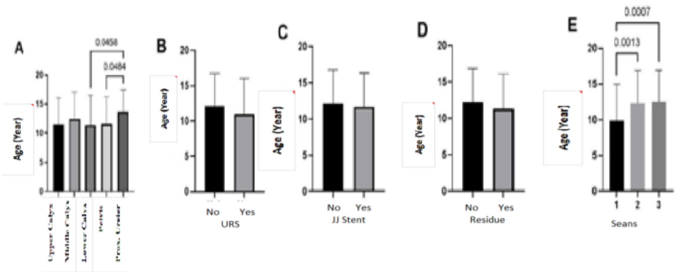
The applied kW value increased (positive correlation) as the patient age increased (r = 0.7065, $P < 0.001$). There was no correlation between patient age and stone burden (r = -0.0097; P = 0.84). A positive correlation was found between stone burden and kW (P = 0.017; r = 0.013) (Figure 3).

Figure 3: Correlation analysis. A; correlation between age and kw, B; correlation between patient age and stone burden, and C; correlation between stone burden and kw (Pearson's r correlation analysis method was used)



When URS and JJ stent requirements and residual stone status were compared according to patient age, no significant difference was found (Figures 4A, C, and D). However, the patients with a higher age were found to have a significantly higher rate of stones in the proximal ureter than in the lower calyx of the kidney (P = 0.045) and renal pelvis (P = 0.048). There was no other significant difference between the remaining groups (Figure 4).

Figure 4: Comparison of stone localization (Tukey's multiple comparison test) (A), URS requirement (unpaired t-test) (B), double-J stent requirement (unpaired t-test) (C), residual stone status (unpaired t-test) (D), and number of sessions (Tukey's multiple comparison test) (D) according to patient age (years)



As the stone area increased, the presence of residual stones increased ($P < 0.001$). However, the total number of shocks and kWs were not found to be associated with the presence of residual stones (Figure 5).

According to stone localization, the highest rate of residual stones was found in the renal pelvis ($P < 0.001$) (Figure 6).

Figure 5: Comparison of residual stone status according to stone area (A), kw (B), and total number of shocks (C) (unpaired t-test)

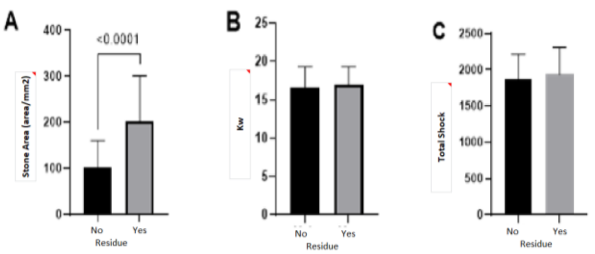
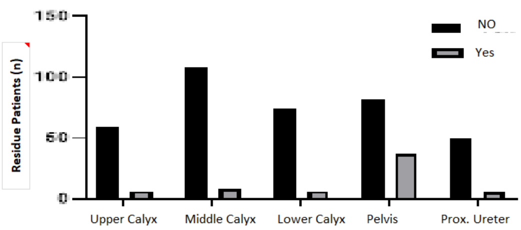


Figure 6: Comparison of stone localization according to the patients' residual stone status after ESWL



Discussion

In this study, the experiences of 433 patients aged 16 years and under who underwent ESWL due to urinary tract stones were evaluated. Although our stone-free rate (SFR) was low in the first session, it increased in the repeated sessions. We found that the need for a JJ stent increased as the stone size increased. We did not experience any major complications after ESWL. We compared our 11 years of data with the literature.

Pediatric nephrolithiasis is a rare urinary system disease, but the incidence of kidney stones in children has increased in the last decade, with a dramatic rise of 10% per year [11]. Stone disease prevalence studies report the prevalence of stone disease at 5.2% in patients under 18 years and 1–3% in the pediatric age group [12]. The 2019 pediatric urology guidelines of the European Association of Urology (EAU) recommend ESWL as the first-line treatment option for 10–20 mm kidney stones due to the minimally invasive nature of this intervention [13]. Among early complications are steinstrasse, decreased oral intake, pain requiring parenteral analgesics, gross hematuria, fever, and hematomas [14]. No statistically significant change has been reported in terms of renal parenchymal scarring in dimercapto-succinic acid screening or diethylenetriamine pentaacetic acid screening and glomerular filtration rate for up to six months after ESWL. Therefore, ESWL is considered to be a safe method for the treatment of kidney stone disease in children aged up to 16 years, with no adverse effects being observed on long-term kidney function [15].

ESWL is a procedure in which shock waves are used to break down kidney and ureteral stones into smaller pieces, which can then be spontaneously expelled from the urinary system. It is known that many factors, including patient selection, stone size, localization and composition, lithotripter type, operator experience, total number of shocks, energy delivered, and shock frequency, affect the final outcomes of ESWL [14, 15]. The average number of shock waves per ESWL session is approximately 1,800 to 2,000 (up to 4,000 if needed), and average power settings range from 14 kW to 21 kW. The use of USG and digital fluoroscopy has significantly reduced radiation exposure, and it has been shown that children are exposed to significantly lower radiation doses compared to adults [16–20]. Increased shock frequency and energy level have been associated with lower stone clearance among adults [21]. A retrospective cohort study of children treated with ESWL reported similar stone clearance and complications for the shock frequencies of 60 and 90 per minute [22]. In our study, the amplitude of shock waves was increased gradually until the stone started to break. It was determined that the kW value increased (positive correlation) as the patient age increased. There was no correlation between patient age and stone burden. A positive correlation was observed between stone burden and kW. When the groups with and without residual stones were compared, no statistically significant difference was found in relation to kW and the total number of shocks. We believe that this is related to the lack of a homogeneous distribution among the age groups. We attributed the increase in the kW value as the patient age increased to the shorter stone-skin distance in younger age groups. Since there is no study using a similar application method in the literature, we were not able to make a comparison in this regard.

When the three studies evaluating the largest series in the literature are examined, it is seen that the complete SFRs vary between 70 and 89.2% after repeated sessions of ESWL. The success rate after the first session was found to be between 50.5 and 82.4% in the same studies [21–25]. In our study, SFR was 13% after the first session and 85.9% after repeated sessions. While our results after multiple sessions were similar to those in the literature, our first session success rate was found to be much lower. This may be related to the higher mean age and higher stone area of our cohort.

In children, it is widely preferred to perform ESWL under general anesthesia to achieve a better focus and reach high shock frequencies. The rate of stone clearance after a single session of ESWL is low and depends on the location and size of the stone. Therefore, repeated procedures mean repeated general anesthesia and further associated risks [26]. In our clinical practice, we accepted the age of 12 years as the limit and applied general anesthesia or sedation in younger children and muscular or intravenous analgesics in older patients. Of the patients that received anesthesia, 20% (n = 36) were stone-free after a single session, and 48% (n = 87) achieved stone-free status after the second session.

In a meta-analysis published by Lu et al. [14] in 2015, it was found that ESWL was statistically significantly more successful in stones smaller than 10 mm than in those larger than 10 mm. When evaluated according to stone burden, the mean stone area of 85.9% (n = 370) of the patients without residual stones was 100.9 (59.4), while the mean stone area of 14.1% (n = 63) of those with residual stones was 201.0 (100.1). Our results on stone burden are consistent with those in the literature.

One of the important factors in breaking a stone is the localization of the stone. The infundibular angle between the lower calyx and the proximal ureter is an especially effective factor in stone removal. Lower calyx stones have the lowest clearance, while the highest stone-free rates are in the renal pelvis and ureteropelvic junction [27]. In a study published by Srisubat et al. [28] in 2009, ESWL success rates were found to be 86–89% in the renal pelvis, 71–-83% in the upper calyx, 73–84% in the middle calyx, and 37–68% in the lower calyx, according to stone locations. In our study, the rates were 68.9%, 90.7%, 93% and 92.4%, respectively. We believe that our complete stone-free rate in the renal pelvis is lower than that in the literature because of our high renal pelvis stone load.

Stone density and composition are other factors affecting the success of ESWL. While calcium apatite stones and struvite stones are sensitive to ESWL, cystine stones are resistant [29]. Stone density can be found by calculating the HU value on non-contrast tomography [30]. However, due to the high radiation risk, non-contrast tomography is not recommended for pediatric patients unless it is necessary [31]. Since stone analysis and non-contrast tomography were not performed in the patients in our study, stone composition and HU values could not be determined. This is an important limitation of our study.

The update on urinary system stone disease in children published by Silay et al. [32] in 2017 stated that pediatric ESWL complications ranged from 1.5% to 35%. Mild complications, such as skin ecchymosis, hematuria, infection, and renal colic, are frequently observed [7, 31]. In our series, skin ecchymosis and infection were not observed in any of the patients. Steinstrasse is another important complication that requires intervention. The rate of stenting before ESWL is 15.4% in the literature [32-34]. In our study, we did not apply a JJ stent to any of the patients before the procedure. A JJ stent was used in cases that developed steinstrasse or had colic pain after the procedure. Our rate of JJ stent insertion was 14.5% after the procedure, and we also determined that the JJ stent requirement was statistically significantly higher in the group with residual stones. Fedulo et al. [35] reported that 26.25% of patients who developed steinstrasse required endoscopic intervention. In another study, Badawy et al. [25] performed endoscopic intervention on 1.2% of patients. Habib et al. detected steinstrasse in 6.66% of patients and treated 20% of these patients endoscopically [23]. Our results on the post-ESWL intervention requirements are in agreement with the literature.

Conclusion

The success of ESWL in the pediatric age group depends on factors such as stone size, type, and localization, characteristics of the device used, distance of the stone to the skin, and operator experience. Based on 11 years of pediatric ESWL experience in our clinic, our SFR increased compared to the first years we performed this procedure. In light of our experience, we recommend that the applied energy and the number of shocks be kept within ideal limits. Despite advances in laser lithotripsy technology and micro and ultra-thin endoscopic instruments developed for stone intervention, ESWL can still be safely recommended as the first-choice treatment in stones smaller than 20 mm.

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