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

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 (Türk et al., 2021). 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 (Bowen & Tasian, n.d.). Urinary system stone disease creates a significant burden on the health system. For treatment, many 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 (Wiesenthal et al., 2011). 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 (Turna et al., 2016). In the pediatric age group, it was first performed in 1986 by Newman et al. (Newman et al., 1986). The success rate seems to be higher in children than in adults (Akinci et al., 2022). 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 (Gerber et al., 2005). As in all stone treatments, the aim of ESWL is to provide complete stone-free status. Especially in the last two decades, 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 (Grivas et al., 2020).

Although the literature contains large case series on ESWL treatment in adults, there are only few large series in children (Grivas et al., 2020). 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 of pediatric cases in which we performed ESWL treatment over 11 years at our clinic and discussing our findings in light of the literature.

Method

This study was conducted at the Urology Clinic of University of Health Sciences Sanliurfa Mehmet Akif Inan Training And Research Hospital According to the Declaration of Helsinki, consent was obtained from the Ethics Committee of Harran University Faculty of Medicine before the study (HRU/22/04/17). Between January 2010 and December 2021, 433 patients aged 16 years and younger who underwent ESWL at our clinic 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 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 the 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 ASA 1 and 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 patient placed in the supine position, the procedure was 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 five 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. The patients were called for a control session one week later, during which simultaneous USG and DUSG were performed, and the absence of stone fragments or the presence of fragments smaller than 3 mm on imaging was considered a success (Shouman et al., 2009). In the presence of fragments of 4 mm or larger, ESWL was applied again, leaving at least weeks between the sessions. A maximum three sessions of ESWL were undertaken. All the patients were evaluated at 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 those requiring clinical intervention.

Statistical Analysis

For the statistical analysis of the data obtained from the study, 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 and standard deviation), the unpaired t-test was used for the evaluation of quantitative parameters with a normal distribution, and Fisher's exact test 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 ($p < 0.0001$).

Table1.

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.

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 [1 session (51.96 ± 22.8 areas/mm^2) vs 2 sessions (84.82±35.2 areas/mm^2), $p = 0.0003$); 1 session vs 3 sessions (177.6 ± 82.1 area/mm^2), $p = 0.0001$; and 2 sessions vs 3 sessions, $p < 0.0001$, Figure 2B]. As the stone burden increased, the residual stone rate ($p < 0.0001$) and URS requirement also increased ($p < 0.0001$). 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.

The kw value increased (positive correlation) as the patient age increased ($r = 0.7065$, $p = 0.0001$). 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 ($p = 0.0173$; $r = 0.013$) (Figure 3).

Figure 3.

When URS and JJ stent requirement and residual stone status were compared according to patient age, no significant difference was found (Figure 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.

As the stone area increased, the presence of residual stones ($p < 0.0001$). However, the total number of shocks and kw were not found to be associated with the presence of residual stones (Figure 5).

Figure 5.

According to stone localization, the highest rate of residual stones was found in the renal pelvis ($p \leq 0.0001$) (Figure 6).

Figure 6.

Discussion

In our clinic, ESWL was applied to 433 patients aged 16 years and under due to urinary tract stones over 11 years. Although our stone-free rate (SFR) was low in the first session, it increased in 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-year data with the literature.

Pediatric nephrolithiasis is a rare urinary system disease, but the incidence of kidney stones in children has increased two to three times in the last decade, with a dramatic rise of 10% per year (Baum, 2020). Stone disease prevalence studies report the prevalence of stone disease as 5.2% in patients under 18 years and 1-3% in the pediatric age group (Altintaş et al., 2013). 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 (Zhao et al., 2020). Among early complications are steinstrasse, decreased oral intake, pain requiring parenteral analgesics, gross hematuria, fever, and hematomas (Lu et al., 2015). 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 in the treatment of kidney stone disease in children aged up to 16 years of age, with no adverse effects being observed on long-term kidney function (Fayad et al., 2010).

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 (Hassouna et al., 2011; Madbouly et al., 2005). 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 (Ather & Noor, 2003; Muslumanoglu et al., 2003; Raza et al., 2005). Increased shock frequency and energy level have been associated with lower stone clearance among adults (Ozkan et al., 2015). 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 (Kaygısız et al., 2017). 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 ($r = 0.7065$, $p = 0.0001$). There was no correlation between patient age and stone burden ($r = -0.0097$; $p = 0.84$). 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 consider 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 SFR 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 (Badawy 15 et al., 2012; Dogan et al., 2015; Habib et al., 2013). 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 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, depending on the location and size of the stone. Therefore, repeated procedures mean repeated general anesthesia and further associated risks (Aldridge et al., 2006). 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 the meta-analysis published by Lu et al. 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 (Lu et al., 2015). 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 the literature.

One of the important factors in breaking a stone is the localization of the stone. Especially the infindibular angle between the lower calyx and the proximal ureter is an 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 (Deem et al., 2011). In the study published by Srisubat et al. 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 (Srisubat et al. , 2014). In our study, it was found 68.9%, 90.7%, 93% and 92.4%, respectively. We consider that the reason why our complete stone-free rate in the renal pelvis is lower than the literature is due to 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 (Tekgül et al., 2021). Stone density can be found by calculating the HU value on non-contrast tomography (Wagenius et al., 2022). However, due to the high radiation risk, non-contrast tomography is not recommended in pediatric patients unless it is necessary (Oner et al., 2004). 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. in 2017 stated that pediatric ESWL complications ranged from 1.5% to 35% (Silay et al., 2017). Mild complications, such as skin ecchymosis, hematuria, infection, and renal colic are frequently observed (D'Addessi et al., 2008; Grivas et al., 2020). 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 (Kızılay et al., 2020; Tan et al., 2004). 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 JJ in the group with residual stones. Fedulo et al. reported that 26.25% of patients who developed steinstrasse required endoscopic intervention (Fedullo et al., 2012). In another study, Badawy et al. performed endoscopic intervention on 1.2% of patients (Badawy et al., 2012). Habib et al. detected steinstrasse in 6.66% of patients and treated 20% of these patients endoscopically (Habib et al., 2013). Our results on post-ESWL intervention requirement are in agreement with the literature.

In 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 our 11-year pediatric ESWL experience in our clinic, our SFR increased compared to the first years we started to perform 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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Conflict of Interest

The authors declare no conflict of interest.

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