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# Extracorporeal shock wave lithotripsy in children: equivalent clearance rates to adults is achieved with fewer and lower energy shock waves

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## OBJECTIVE

To compare the outcome, safety and efficiency of extracorporeal shock wave lithotripsy (ESWL) using an electromagnetic lithotripter for upper urinary tract stones in children and adults.

## PATIENTS AND METHODS

We retrospectively reviewed data over a 5-year period for patients with solitary, renal and upper ureteric stones measuring <2 cm in whom ESWL was the treatment method. Group A consisted of 44 children (mean [SD] age 5.9 [4.4] years) and group B of 562 adults (mean [SD] age 40.9 [13.1] years). The number and energy of SWs used was not predetermined and was tailored until adequate fragmentation was achieved. Initial stone reassessment was performed at 48 h and monthly thereafter. The number of SWs, intensity of SWs, stone-free rate, auxiliary procedure rate, re-treatment rate, complication rate and effectiveness quotient (EQ) were assessed in each group.

## RESULTS

The stone-free rate with ESWL was 84% in children and 87% in adults ($P = 0.78$). The EQ was 77% and 75% in children and adults, respectively ($P = 0.56$). The mean (SD) number of SWs and energy required per session was 950 (349) and 11.83 (0.48) kV in children and 1262 (454) and 12.36 (0.34) kV in adults ($P < 0.001$). The re-treatment, auxiliary procedure and complication rates were similar in both groups.

## CONCLUSION

ESWL is as safe and effective in children as in adults for solitary renal and upper ureteric stones that are <2 cm. Children required significantly fewer and lower energy SWs to achieve equivalent results.

## KEYWORDS

adult, children, ESWL, urolithiasis

## INTRODUCTION

Extracorporeal shock wave lithotripsy (ESWL) transformed the treatment algorithm of upper tract stones in children after the first published report in 1986 [1]. Studies confirm that ESWL is safe and effective with good stone-free rates in children [2–4]. It is the favoured treatment for most upper tract urinary stones in both adults and children [5]. But, is ESWL more effective in children than in adults? Is it as safe as it is in adults? Do children require a similar number and intensity of SWs as given in adults? To address these questions, we assessed the outcome of ESWL in children as compared with adults in a single institute using an electromagnetic lithotripter.

## PATIENTS AND METHODS

We retrospectively reviewed data over a 5-year period of ESWL performed using Dornier Compact Delta (Dornier Medical Systems, Inc., Marietta, Ga, USA) for upper urinary tract stones in whom complete follow-up data were available. Inclusion criteria included solitary renal and upper ureteric stones. Multiple stones and stones of >2 cm (longest diameter) were excluded. Contraindications for ESWL included febrile UTI, distal obstruction, bleeding diathesis and poorly functioning renal unit. Pregnancy was a contraindication in women. All patients were evaluated by urine culture, serum biochemistry, coagulation tests, ultrasonography (US) and IVU before the procedure.

Younger children were anaesthetized with i.v. ketamine and midazolam, whilst older children and adults were given sedoanalgesia with i.v. fentanyl during the procedure. The lung fields were shielded in children. Fluoroscopy and US were used to localize the stone and to monitor the fragmentation. US can accurately monitor the fragmentation in real-time. The movement of stone fragments seen with every SW is a definitive evidence of accurate stone localization. The SWs were started at level one (10 kV) and progressed to level two (11.5 kV) after 100 SWs. The energy was increased gradually to higher levels (to a maximum of level six, 16 kV) only if desired fragmentation was not visible with fluoroscopy and US. The SWs were given at the rate of 60 per minute in all patients. The

number and energy of SWs were not predetermined. The procedure concluded when there was complete fragmentation on fluoroscopy and US.

Two groups were formed. Group A consisted of children (aged ≤ 16 years) while group B were adults (aged > 16 years). There were 44 children and 562 adults in whom complete follow-up data were available and met the inclusion and exclusion criteria. In group A there were 29 boys and 15 girls with a mean (SD, range) age of 5.9 (4.4, 0.92–16) years. There were 405 men and 157 women with a mean (SD, range) age of 40.9 (13.1, 17–89) years in group B.

The patients were followed up with US and plain X-ray of the kidney, ureters and bladder. If fragmentation was not optimal, the stone was re-treated with a further session of ESWL after 48 h. The patients were reassessed monthly and re-treatment given, if needed.

The final assessment of clearance was made for the purpose of this study at 3 months. If fragments were not visualized on X-ray or US, patients were considered completely cleared or stone-free. Residual fragments of <4 mm that were not obstructive or infected were considered clinically insignificant stone fragments and categorized as treatment failures in this study. Any patient requiring a major auxiliary procedure after ESWL like percutaneous nephrolithotomy or ureterorenoscopy for clearance of the stone was categorized again as a treatment failure.

We calculated the mean (SD) total SWs, and energy of SWs, the number of sittings, stone-free rates, auxiliary procedure rates, re-treatment rates and complication rates. The effectiveness quotient (EQ) was calculated [6]. Statistical analysis was performed using chi-square and student's *t*-test.

## RESULTS

The patient and stone demographics are given in Table 1. The SW characteristics required for fragmentation varied for both groups (Table 2). The mean total number and energy of SWs required for fragmentation was lower in children. The stone-free rates, auxiliary procedure rates, re-treatment rates, complication rates and EQs were similar for both groups (Table 2). Both the groups were also compared for stone-free rates according to stone location, stone size, side and gender of patient (Table 3). In the present series, the stone-free rates were better in children when stones were located in the mid and upper calyces while adults fared better for ureteric stones. Gender, side and size affected stone-free rates similarly in both the groups.

The patients in both groups required various auxiliary procedures for clearance including insertion of JJ stents, ureteroscopy and percutaneous nephrolithotomy. The need for auxiliary procedures was similar in both the groups. The re-treatment rate was higher resulting in a lower EQ in adults, but was not statistically significant. Complications seen in adults included steinstrasse, fever, oliguria and pain requiring re-admission. None of the children had any complication.

## DISCUSSION

ESWL has been used extensively in children for fragmentation of both renal and ureteric

*TABLE 1 The patients' characteristics*

| Variable | Group A, children | Group B, adults |
|---|---|---|
| Total number | 44 | 562 |
| Gender, *n*: | | |
| Male | 29 | 405 |
| Female | 15 | 157 |
| Mean (SD) age, years | 5.9 (4.4) | 40.9 (13.1) |
| Location, %: | | |
| Pelvis | 56.82 | 37.01 |
| Lower calyx | 15.91 | 25.62 |
| Middle calyx | 9.09 | 8.19 |
| Upper calyx | 11.36 | 5.34 |
| Upper ureter | 6.82 | 23.84 |
| Left side, % | 45.45 | 53.56 |
| Right side, % | 54.55 | 46.44 |
| Mean (SD) stone size, cm | 1.00 (0.26) | 1.14 (0.35) |

*TABLE 2 The SW characteristics and stone-free rates, auxiliary procedure rates, re-treatment rates, complication rates and EQs*

| Variable | Group A, children | Group B, adults | *P* |
|---|---|---|---|
| Mean (SD): | | | |
| No. of SWs per session | 950 (349) | 1262 (454) | <0.001 |
| Total no. of SWs per stone | 993 (455) | 1419 (703) | <0.001 |
| SW energy, kV | 11.83 (0.48) | 12.36 (0.34) | <0.001 |
| Number of sessions | 1.05 (0.21) | 1.12 (0.37) | 0.11 |
| %: | | | |
| Stone-free rate | 84.09 | 86.48 | 0.78 |
| Re-treatment rate | 4.55 | 11.39 | 0.13 |
| Auxiliary procedure rate | 4.55 | 4.63 | 0.75 |
| Complication rate | 0.00 | 3.20 | 0.21 |
| EQ | 77.08 | 74.54 | 0.56 |

*TABLE 3 Stone-free rates according to stone location, stone size, side and gender of patient*

| Variable | Stone-free rates, % | |
|---|---|---|
| | Group A, children | Group B, adults |
| Stone location: | | |
| Pelvis | 92.00 | 86.54 |
| Lower calyx | 85.71 | 84.72 |
| Middle calyx | 50.00 | 80.43 |
| Upper calyx | 60.00 | 80.00 |
| Upper ureter | 100.00 | 91.79 |
| Gender: | | |
| Male | 86.21 | 87.41 |
| Female | 80.00 | 84.08 |
| Side: | | |
| Left | 85.00 | 85.44 |
| Right | 83.33 | 87.38 |
| Size, cm: | | |
| ≤1 | 85.71 | 88.24 |
| 1–2 | 81.25 | 84.83 |

stones. Although ESWL has been utilized for paediatric stones of all sizes and positions, it has been shown that factors affecting stone-clearance rates after fragmentation are the same as in adults [7,8]. Despite this, some authors have recommended ESWL as first-line therapy for all paediatric urolithiasis [9], whilst others advise it only for a stone burden of <2 $cm^2$ providing the stone can be readily visualized using X-ray or US [8,10]. In the present study, large stones (>2 cm) and multiple stones were both exclusion criteria, as they adversely affect stone-free rates [8].

In addition to site, size and number, stone-clearance rates after ESWL depend on the definition used for 'clearance'. This definition varies greatly within both the adult and paediatric stone literature. Some authors define clearance as the complete absence of stone fragments on either X-ray or US, whilst others will include residual fragments up to 4 mm in the definition of stone free. For the purposes of the present study, we defined stone clearance as no evidence of residual fragments on both X-ray and US. The presence of any residual fragments was classified as a treatment failure. Osman *et al.* [11] showed that only a fifth of patients with such clinically insignificant stone fragments would form recurrent symptomatic stones requiring re-treatment. However, this statistic does not appear to hold true in the paediatric population. Studies of ESWL in children have shown that such residual fragments tend to grow or become symptomatic in up to 69% of patients when followed and have a proven clinical significance [12,13]. This adds further weight to the argument for aiming at complete stone clearance in the paediatric population, and for a strict definition of treatment success.

Employing a strict definition of treatment success, Tan *et al.* [14] reported only moderate efficacy of ESWL in the paediatric population. In a study of 100 patients with a mean (range) stone size of 7.8 (2–23) mm, 60% of patients were stone free after initial ESWL and after a second treatment, the stone-free rate increased to 68%; the EQ was 54.3. At 84%, the present overall stone-free rate was greater than that reported by Tan *et al.* despite a larger mean stone size; this might be explained by the inclusion of multiple stones in the study of Tan *et al.* One further study also defining success as the complete absence of stone fragments reported a much higher overall stone-free rate of 95% in the paediatric group [15]. That study, which was designed to compare the effects of ESWL in children with adults, concluded that the stone-free rate in young children is higher compared with that in adults with a matching stone size ($P = 0.086$). In the present analysis, the stone-free rate and re-treatment required was comparable in children and adults. The EQ, perhaps a more objective parameter that takes into account not only stone-free rate, but also the re-treatment rate as well as the need for auxiliary procedures has been used to calculate the efficacy of ESWL in both children and adults [14,16,17]. The EQs of paediatric and adult ESWL were also comparable in the present study.

However, there was a significant difference between the number of SWs required for stone clearance in the paediatric and adult groups in the present study. Children required a mean of only 993 SWs compared with 1419 in the adult group ($P < 0.001$). The intensity of SWs used to fragment the stones was also significantly reduced in children as compared with adults ($P < 0.001$). This corroborates the theory that SWs are better transmitted through the smaller body wall of children with minimal energy loss [2].

ESWL in children was complication free in the present study. Other studies have also shown a good safety profile [18–23]. Steinstrasse was seen in 12 adults (2.1%) but in none of the paediatric population undergoing ESWL in the present study. Only one child required ureteroscopy for a nonprogressive asymptomatic ureteric fragment. Other studies have also reported the absence of steinstrasse after ESWL in children [15,23,24]. Possible explanations for this finding have been proposed. Gofrit *et al.* [15] noted that despite the ureter in children being narrow, it is also short with less distance for stones to travel. The ureter may also be more distensible and elastic, helping in the passage of large stone fragments [24]. In the present study, the difference in incidence of steinstrasse and overall stone-clearance rates between children and adults was not statistically significant. However, there was a marked reduction in the re-treatment rate in the paediatric group as compared with adults. In a larger paediatric group this difference, as well as the incidence of steinstrasse, may prove significant.

Concerns have been raised regarding the effects of SWs on the immature kidney [25]. Minimizing the energy in kilovolts and the number of SWs may decrease the deleterious effect [26]. Some authors have concluded that ESWL is safe with no long-term bio-effects on the function or morphology of the growing kidney [27–29]. However, a decrease in renal plasma flow has been well demonstrated after ESWL and animal studies investigating chronic renal injury suggest that there can be long-term functional consequences to a clinical dose of ESWL, and that the young or immature kidney is at great risk for such complications [30]. Considering that further long-term data are still awaited, it would seem prudent to shock the paediatric kidney as little as possible. Furthermore, having the facility of US to localize and monitor the stone fragmentation will help in reducing the dose of potentially harmful X-rays. We feel that our protocol for ESWL in paediatric patients helps to maximize the effectiveness of the given SWs in a number of ways: anaesthesia immobilizes the patient and avoids pain related increased respiratory movement, whilst combined fluoroscopy and US provide accurate real-time localization and monitoring of stone fragmentation. The number and energy of SWs can thus be reduced when efforts are taken to minimize 'shock loss'.

In conclusion, ESWL in children is as safe and efficient as it is in adults. In children, ESWL accomplished equivalent stone-clearance rates with fewer and lower energy SWs. Thus, it is possible to treat children much more gently and safely without compromising the efficiency of ESWL.

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## CONFLICT OF INTEREST

None declared.

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Abbreviations: **(E)SW(L)**, (extracorporeal) shock wave (lithotripsy); **EQ**, effectiveness quotient; **US**, ultrasonography.