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ORIGINAL PAPER

Predicting ESWL success by determination of Hounsfield unit on non-contrast CT is clinically irrelevant in children

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Abstract

The necessity of determining stone density by non-contrast computerized tomography (NCCT) before extracorporeal shock wave lithotripsy (ESWL) is a controversial topic due to the radiation exposure. We aimed to investigate whether stone density is helpful in predicting the success of ESWL in pediatric patients or not. In this retrospective study, database of a single center was used to identify 232 children aged between 2 and 16 years. Patients with abnormal renal anatomy, distal obstruction, a known cystine stone disease, a previous history of an intervention regarding stone, and an insufficient follow-up period (< 3 months) were excluded from the study. A total of 209 patients were included in the study (94 with NCCT, 115 without NCCT). Groups were compared in terms of stone size, stone location, and stone-free rate at 3 months after a single ESWL session. The mean age was 6.17 ± 3.27 years and 120 (57.4%) of the patients were male and 89 (42.6%) were female. Mean stone size was 11.7 mm in NCCT group and 12.3 mm in non-NCCT group (*p* 0.128). The complete stone clearance rate in NCCT and non-NCCT group at 3 months after ESWL was 57.4% (54/94) and 54.7% (63/115), respectively, and there was no statistically significant difference (*p* 0.316). In conclusion, unnecessary NCCT use should be avoided before ESWL considering the similar success rates after ESWL and the risk of exposure to radiation.

Keywords ESWL · CT · Hounsfield unit · Stone

Introduction

Urolithiasis is a common health problem among children [1]. Extracorporeal shock wave lithotripsy (ESWL) is one of the first-line treatments in children for kidney stones smaller than 2 cm [2]. ESWL is a less invasive method compared to other options. The success rates of ESWL seemed to be higher in children compared to adults [3].

However, there are some limitations to the efficacy of treatment such as lithotripter type, stone characteristics (size, location, composition, number), and kidney anatomy [4]. Most of the studies on the use of ESWL in children are based on the results of multiple sessions, but repetitive sessions can create more stress on the child and family due to the need for additional anesthesia [5]. On the other hand, the success rates of ESWL after a single session are lower and vary between 42 and 60% [6–8]. In studies conducted for the investigation of the factors affecting the success rate of ESWL on adults, stone density above 1000 Hounsfield unit (HU) was found to be associated with the failure [4].

The use of non-contrast computerized tomography (NCCT) in children exposes the patients to a significant amount of radiation. Therefore, it is crucial to maximize the sensitivity and the specificity of the diagnosis while minimizing the radiation exposure to the patient. The number of studies on radiation exposure in pediatric patient population due to this imaging method is limited in the literature. Notwithstanding, since expected years of life is longer and there are more radiation sensitive tissue in a child, radiation exposure is an important issue to be considered in pediatric patients [9]. Limiting radiation exposure as much as possible should be the primary purpose of the clinician [10].

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Due to the concerns mentioned above, the necessity of determining stone density with NCCT before ESWL is becoming controversial. We aimed to investigate if stone density is useful in predicting ESWL success in pediatric patients.

Materials and methods

Patients and methods

In this retrospective study, the database of a single center institution was used to identify 232 children who were aged from 2 to 16 years and underwent ESWL for renal stones which are < 2 cm between January 2007 and January 2020. All procedures performed were in accordance with the 1964 Helsinki Declaration and approval of the study was obtained from the local ethics committee (2021/184). Patients with abnormal renal anatomy (pelvic kidney, horseshoe kidney, rotation anomaly) ($n = 3$), distal obstruction ($n = 6$), previously diagnosed as cystine stone disease ($n = 3$), any previous history of intervention for stone ($n = 4$), and an insufficient follow-up period (< 3 months, $n = 7$) were excluded from the study. After exclusion, a total of 209 children with complete data, including 94 children who underwent NCCT scan before ESWL and 115 children without NCCT examination were included in the analysis. Before ESWL, all children were evaluated with an at least one imaging modality. The imaging tools used were plain X-ray, renal ultrasonography (US), and NCCT. In our clinical approach, plain X-ray and renal US are preferred primarily and the use of NCCT is reserved for cases with non-informative US and plain X-ray.

For each patient, age, gender, serum biochemistry and coagulation tests, results of urine analysis, urine culture, as well as stone size, stone side, presence of hydronephrosis grade (none, grade 1, grade 2, and grade 3), and number of stones (single, multiple) were recorded before the application of ESWL. Due to the limited details of the previous data, the new SFU grading was not used for the classification of hydronephrosis. In addition, the stone density of the patients who underwent NCCT was noted in terms of HU. The largest diameter of the stone was measured to define the stone size, and if there were multiple stones, the sum of the largest diameters was measured. The ESWL procedure was performed under sedation analgesia. The procedures were performed under outpatient conditions without hospitalization. Either US or fluoroscopy was used for focusing.

Stone location, stone size, stone-free rate at 3 months after a single ESWL session, and mean radiation exposure were compared between groups. Postoperative imaging was performed by plain X-ray and US. The success of the treatment was solely determined by the absence of stones. Any residual fragment, regardless of size, was considered as a residual stone and defined as failure after the first session.

Statistical analysis

For the statistical analysis of the study, IBM SPSS® Statistics v25 was used. The Kolmogorov–Smirnov test was used to determine whether the continuous variables had a normal distribution. For continuous variables, the student *t* test was used, and for the categorical data, the chi-squared test was used. The number of people who needed to be screened with NCCT to achieve one more ESWL success was determined. The absolute event increase was calculated with 95% confidence intervals to determine the number of people who needed to be screened with NCCT analysis. 1 divided by the absolute risk increase equals the number of people who need to be screened with NCCT [11]. In the 95% confidence interval, a p value of less than 0.05 was considered statistically significant.

Results

A total of 227 children were registered to the study, and the data of 209 children were analyzed. The mean age was 6.17 ± 3.27 years and 120 (57.4%) of the patients were male and 89 (42.6%) were female. The mean stone size was 11.7 mm in the NCCT group and 12.3 mm in the non-NCCT group (p 0.128). While the mean age was 5.82 ± 3.05 years in the NCCT group, it was 6.46 ± 3.44 years in the non-NCCT group (p 0.192). 55% of the NCCT group and 59% of the non-NCCT group was male (p 0.57). In the NCCT group, 54% of the stones were on the right side, whereas in the non-NCCT group, 51% were on the right side (p 0.58). In the NCCT group, 52% of patients did not have hydronephrosis, 23% had grade 1, 16% had grade 2, and 9% had grade 3 hydronephrosis. In the non-NCCT group, 50% of patients did not have hydronephrosis, 24% had grade 1, 17% had grade 2, and 8% had grade 3 hydronephrosis (p 0.78). While 85% of the patients had a single stone in the NCCT group, 83% had a single stone in the non-NCCT group (p 0.62). In terms of age, gender, mean stone size, stone side, hydronephrosis grade, number of stones (single/multiple), and stone focusing, there was no statistically significant difference between the groups (Table 1). The complete stone clearance rate in the NCCT and non-NCCT group at 3 months after the application of ESWL was 57.4% (54/94) and 54.7% (63/115), respectively, and there was no statistically significant difference ($p = 0.316$). Most patients completed the procedure without radiation exposure, and US scan targeting was used in these patients. Only 51 (24.4%)

Table 1 Preoperative and perioperative characteristics between NCCT and non-NCCT groups

Parameters	NCCT ($n = 94$; 45%)	Non-NCCT ($n = 115$; 55%)	*P* value*
Mean age (± SD)	5.82 ± 3.05	6.46 ± 3.44	0.192
Gender			
Male, *n* (%)	52 (55.3%)	68 (59.1%)	0.579
Female, *n* (%)	42 (44.7%)	47 (40.9%)	
Mean stone size, mm (± SD)	11.7 ± 3.05	12.35 ± 3.11	0.128
Stone side			
Right, *n* (%)	51 (54.2%)	59 (51.3%)	0.586
Left, *n* (%)	43 (45.8%)	56 (48.7%)	
Hounsfield unit (± SD)	621.4 ± 136		–
Hydronephrosis grade			
None, *n* (%)	49 (52.1%)	58 (50.3%)	
Grade 1, *n* (%)	22 (23.4%)	28 (24.3%)	
Grade 2, *n* (%)	15 (16%)	20 (17.4%)	0.778
Grade 3, *n* (%)	8 (8.5%)	9 (7.8%)	
Number of stones			
Single, *n* (%)	80 (85.2%)	95 (82.7%)	0.626
Multiple, *n* (%)	14 (14.8%)	20 (17.3%)	
Stone clearance rate, 3 months % (*n*)	57.4% (54/94)	54.7% (63/115)	0.316
Stone focusing			
Ultrasonography, *n* (%)	70 (74.5%)	88 (76.4%)	0.731
Fluoroscopy, *n* (%)	24 (25.5%)	27 (23.6%)	

SD standard deviation, *NCCT* non-contrast computerized tomography

*Student's *t* and chi-squared tests

patients, 24 in the NCCT group and 27 in the non-NCCT group, required fluoroscopic targeting with a mean exposure of 2.6 (1–3.4) mSv. Mean HU in the NCCT group was 621.4 ± 136.

It was found that 37 patients before the application of ESWL had to be screened with NCCT to achieve 1 additional success in all treatments by ESWL compared to non-NCCT. The absolute risk increase was found to be 2.7%. Compared to the non-NCCT group, 37 patients needed to be screened with NCCT to achieve 1 additional patient success with ESWL. In other words, it was determined that 36 children were unnecessarily exposed to NCCT (Table 2). Only 22 (23.4%) patients had HU > 1000 stone density and 10 of them (45.4%) were stone-free at 3 months after ESWL. Of the 72 patients with HU < 1000, 44 (61.1%) were completely stone-free and no statistically significant difference was observed between the two groups (p 0.194) (Fig. 1).

Discussion

The success rate of a single session of other endoscopic methods in children was higher than ESWL [12]. However, since ESWL is the least invasive method, it is more frequently preferred in children. After an unsuccessful ESWL monotherapy, residual fragments are associated with the higher recurrence in children compared to adults. As a

Table 2 Number needed to be screened with NCCT analysis to achieve one additional success compared to non-NCCT group

Measures	NCCT ($n = 94$; 45%)	Non-NCCT ($n = 115$; 55%)
Stone clearance rate (%)	54 (57.4%)	63 (54.7%)
No stone clearance (%)	40 (42.6%)	52 (45.3%)
Relative risk increase (%) (95% Cl)	4.9 (1.72–13.1)	
Absolute risk increase (%) (95% Cl)	2.7 (1.2–5.2)	
Number needed to be screened with NCCT	37	

NCCT non-contrast computerized tomography, *CI* confidence interval

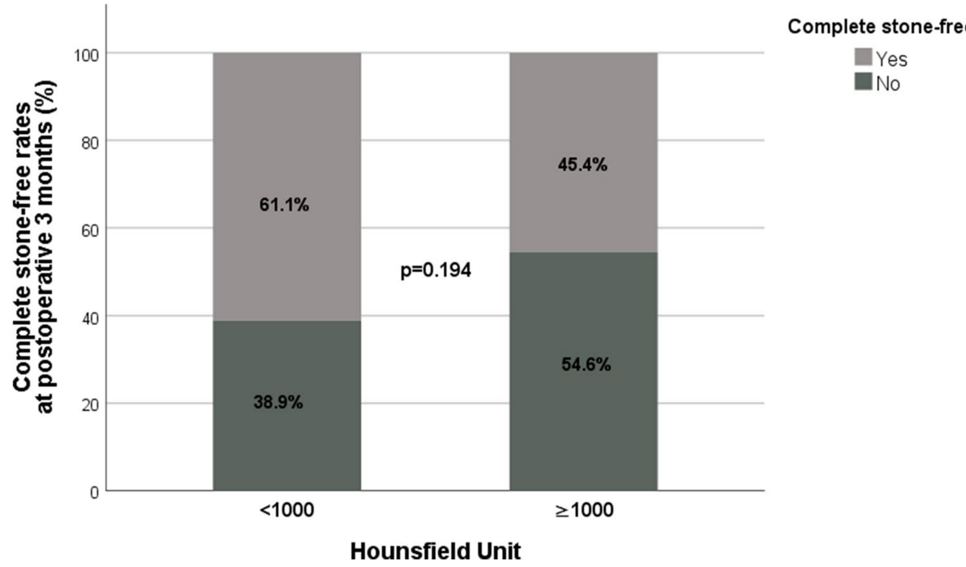

Fig. 1 Complete stone-free rates at postoperative 3 months after ESWL in patients with Hounsfield unit ≥ 1000 and < 1000

result, in children, complete stone-free status after treatment is critical [13].

Determining the predictive importance of NCCT performed regarding the success of ESWL, reduces the risk of unnecessary NCCT imaging and the radiation exposure in children. Previous studies have shown that the most important predictor of the success of ESWL is young age, while preoperative NCCT is not an independent predictor of the success of ESWL [6, 7, 14]. In our study, the success rate after one session of ESWL was 55.4%, which is similar compared to the literature [6–8], and there was no difference in terms of success rates between the groups with and without NCCT before ESWL. In addition, it was determined that preoperative NCCT imaging was required in 37 patients to achieve additional success in 1 patient with NCCT, in other words, unnecessary NCCT was performed in 36 children for complete stone-free status.

Proper imaging in children is important for minimizing the radiation exposure. Although studies of ESWL in children often focus on success rates and predictive factors, there is very limited literature questioning the radiation exposure and the need for NCCT before ESWL treatment. Considering the higher recurrence and intervention rates of the stone disease in children, repeated imaging increases the risk of exposure to radiation [15]. In a prospective study, it has been shown that NCCT has higher sensitivity in the stone detection compared to US (> 95% vs 70%), but this difference is not clinically significant due to the small size of the stones (mean size 3–4 mm) missed by US which were managed conservatively [16].

Clinicians have supported the ALARA (As low as reasonably achievable) principle to reduce the radiation exposure, especially for the pediatric population [17–19]. This principle means that if receiving that dose has no direct benefit, the clinician should try to avoid it regardless of the dose.

Although US is the most common examination used in pre-ESWL evaluation, NCCT is increasingly preferred by clinicians in the pediatric population due to its rapid diagnosis and high sensitivity. Children have longer expected years of life and more radiosensitive tissues than adults. Therefore, previous studies have indicated that radiation exposure in children is a major problem [20]. The 2009 National Council on Radiation Protection and Measurements expressed concerns about the risk of children's exposure to radiation [21]. Although low-dose radiation NCCT protocols are used in pediatric patients, there is radiation exposure up to 0.5 mSv [17, 20]. The high-radiation hazard and the need for anesthesia for valid imaging are the main disadvantages of NCCT. US is an important diagnostic tool which is non-invasive, does not carry radiation risk and can define anatomical and physiological changes due to the obstruction, as well as being a useful a parameter in the stone detection with its sonographically evaluated "the twinkling artifact" appearance [22].

There are some factors that affect the success of ESWL and stone composition is one of them. HU is known to be an independent predictor of ESWL success in adults [23, 24]. El-Assmy et al. showed that ≤ 600 HU is an independent predictor for ESWL success in children [8], McAdams et al. divided the patients into two groups (< 1000 and ≥ 1000 HU) and concluded that < 1000 HU is an important predictor of ESWL success [25]. However, in these studies, it was seen that the percentage of patients with ≥ 1000 HU in NCCT imaging is less than patients with < 1000 HU. The fact that there was no significant difference between success rates in terms of HU in our study, may be associated with lower mean HU (621.4 ± 136). In addition, in our study, only

22 (23.4%) patients had HU > 1000 stone density. Although HU is considered an important predictor, the presence of most stones < 1000 HU may not make a significant difference in success rates that would require NCCT imaging.

The composition of kidney stones in pediatric patients differs from adults and metabolic problems may be more prominent in this population [26]. In the retrospective study of Kirejczyk et al. [27], it was seen that most of the stones in children were of mixed type. The combined form of calcium oxalate and calcium phosphate is also quite common among children. In a recent study by Altan et al. [28]; cystine stones were found between 222 and 979 HU, calcium oxalate stones were found between 415 and 1633 HU, struvite stones were found between 401 and 1065 HU. Additionally, Alsagheer et al. reported the mean HU as 571–656 in their study [6]. In our study, the mean HU was 621; the stone analysis could not be evaluated because of the limited data.

Our study had potential limitations. First of all, the study had a retrospective design and was single centered, which may be associated with misclassification or selection bias. Second, the number of patients in the subgroups was small, which may affect the statistical power. Evaluation of the stone-free rate with US or X-ray was also another limitation of the study. There is a possibility that ESWL success may be overestimated. However, we think that our study will raise awareness of unnecessary NCCT before ESWL in the pediatric population.

Besides NCCT imaging not providing a higher success rate in ESWL treatment, raising awareness of the potential radiation risk may limit the radiation with the use of sonographic methods before ESWL, especially in children with a recurrent stone disease.

Conclusion

In the pediatric population, unnecessary NCCT use should be avoided before ESWL due to similar success rates after ESWL and the risk of radiation exposure.

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Declarations

Conflict of interest None to declare for all authors.

Ethics approval All procedures performed were accordance with the 1964 Helsinki Declaration and approval was obtained from the local ethics committee (2021/184).

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