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IMPROVING THE EFFECTIVENESS OF EXTRACORPOREAL SHOCK WAVE LITHOTRIPSY IN CHILDREN WITH UROLITHIASIS

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Abstract. Summary. The primary method for treating urolithiasis in children is extracorporeal shock wave lithotripsy (ESWL), the efficacy of which depends on stone characteristics, patient sex, and age. To improve ESWL outcomes and reduce the risk of recurrence, predictive tools (nomograms) are used preoperatively, while pharmacologic expulsion therapy (PET) is applied postoperatively. However, the use of PET in Russian pediatric practice is not standardized.

Objective. To enhance the treatment of pediatric urolithiasis by improving patient selection for ESWL using a predictive nomogram and optimizing stone fragment clearance through postoperative PET with a_1-adrenergic blockers (tamsulosin, silodosin).

Materials and Methods. A single-center prospective study was conducted at the National Medical Research Center for Children's Health (October 2024 – April 2025). The first part (60 cases) evaluated the predictive accuracy of a domestic nomogram incorporating sex, age, stone location, size, volume, and density. The second part (90 cases) randomized patients into two groups: the study group (PET, n=40) and the control group (standard therapy, n=50) to assess the impact of lithokinetic therapy on ESWL efficacy, stone expulsion rate, and pain dynamics. Treatment success was defined as the absence of fragments >3 mm in the urinary tract after 3 months according to ultrasound data.

Results. ESWL efficacy using the nomogram (89.5%) was significantly higher than that achieved with EAU guidelines (63.3%) and the Russian Pediatric Union recommendations (77.8%) (p=0.013). The nomogram demonstrated high predictive accuracy: sensitivity–89.47%, specificity–81.82%. PET increased ESWL success to 87.5% (p=0.011) versus 64% in controls, reduced expulsion time (5 vs. 7 days, p=0.010), and alleviated pain (p<0.001). Adverse effects (10%) were limited to Clavien-Dindo grade I.

Conclusion. The nomogram improves ESWL efficacy through personalized patient selection. PET with a_1-blockers accelerates fragment clearance, reduces pain, and minimizes analgesic use with a low complication risk. The combination of nomogram-based selection and PET is a promising approach for optimizing pediatric urolithiasis treatment but requires further investigation.

Keywords: *urolithiasis, children, effectiveness of treatment, a_1-adrenergic blockers, nomogram, extracorporeal shock wave lithotripsy.*

Introduction. Urolithiasis (UB) is a leading cause of urinary tract disease in children. Epidemiological studies indicate that the prevalence of urolithiasis in children ranges from 15.8 to 52.7 per 100,000, depending on age group and geographic region [1, 2, 3]. A characteristic feature of urolithiasis in children is the high risk of recurrence, which requires repeated surgical interventions [4]. Therefore, selecting the optimal and most effective treatment strategy will reduce the number of medical procedures and shorten the patient's hospital stay.

Extracorporeal shock wave lithotripsy (ESWL) is the method of choice for the treatment of urolithiasis in children due to its non-invasive nature, high efficacy, and low risk of complications [5, 6]. However, the success of the procedure depends on many factors, including the location, size, and density of stones, the patient's age, and surgical history [7, 8, 9]. To optimize patient selection, prognostic tools such as nomograms that take into account the combined influence of factors with opposite effects on surgical success are being developed. In 2013 and 2015, Turkish researchers proposed the first nomograms for assessing the effectiveness of ESWL in children [10, 11], and in 2024, the first Russian nomogram was created at the National Medical Research Center for Children's Health of the Russian Ministry of Health. This nomogram takes into account gender, age, stone location, and its characteristics based on CT data [12].

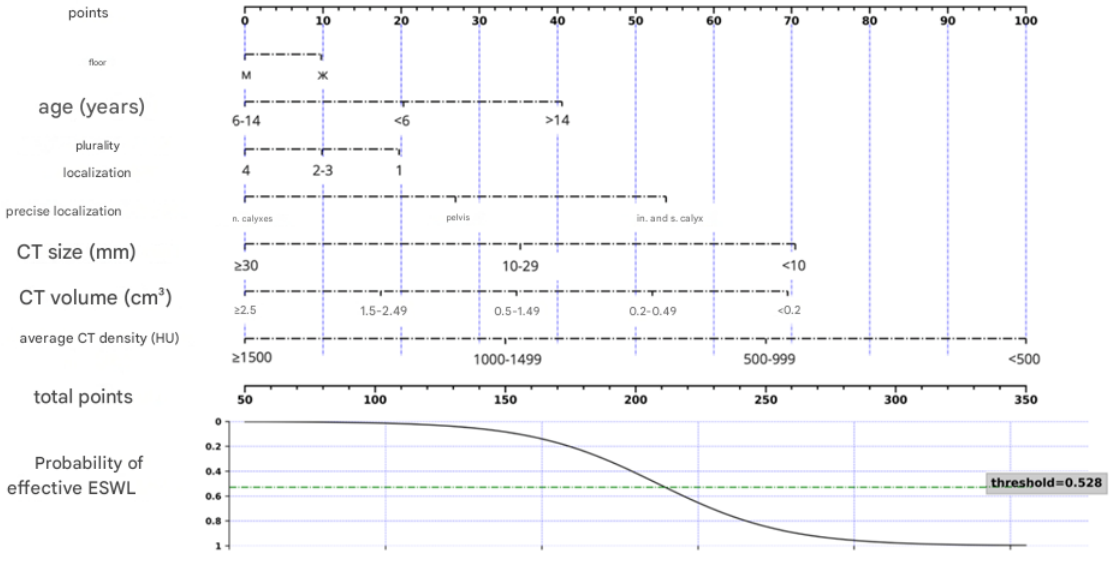
Nevertheless, the problem of residual fragments and the need for repeated interventions remains relevant. In this regard, drug expulsive therapy (MET) in the postoperative period is of particular importance. The basis for the use of a1-adrenergic blockers (tamsulosin, silodosin) as lithokinetic therapy was studies that revealed their ability to relax the smooth muscles of the ureter, facilitating the passage of

stones [13]. Meta-analyses confirm the effectiveness of these drugs in adults, but this therapy has been less studied in the pediatric population [14]. According to studies, tamsulosin increases the frequency of stone expulsion to 65.3% (versus 48.1% with placebo) and reduces the time of stone passage by 4.8 days [15]. Silodosin, having a higher selectivity for a1-adrenergic receptors, demonstrates even better results: 78.3% efficiency versus 68.5% for tamsulosin and a reduction in expulsion time to 7.2 days [16].

Of particular interest is the combination of ESWL with MET. A meta-analysis by Oestreich et al. (2020) showed that the use of a1-blockers after lithotripsy increases the likelihood of complete fragment clearance (OR 1.41; 95% CI 1.24–1.60) and reduces the time of their elimination by 2.8 days [17]. However, the use of these drugs in Russian pediatrics is limited due to insufficient study of dosages, safety, and long-term outcomes, which emphasizes the need for further research [18].

Purpose of the study. Improving the effectiveness of treatment of urolithiasis in children by differentiated selection of patients for extracorporeal shock wave lithotripsy using a prognostic nomogram and improving the passage of stone fragments using drug expulsive therapy with a_1-adrenergic blockers (tamsulosin, silodosin) in the postoperative period.

Materials and methods. The study was conducted as a single-center prospective, analytical, comparative study in the Urology Department with the Reproductive Medicine and Transplantation Groups of the National Medical Research Center for Children's Health of the Ministry of Health of the Russian Federation from October 2024 to April 2025 inclusive. The study consisted of two independent arms, conducted on two different patient samples. The first part of the study assessed the prognostic ability of a previously developed nomogram for determining the outcome of ESWL in children with urolithiasis, while the second part was devoted to studying the effectiveness of a1-blockers after an extracorporeal shock wave lithotripsy session. Inclusion criteria included the presence of a renal pelvis-calyceal calculus less than 20 mm in size, confirmed by ultrasound and non-contrast computed tomography (CT), lithotripsy performed using the Dornier Compact Sigma device, and



Points corresponding to the values of each parameter:

Floor:	male (0); female (10)
Age (years):	6-14 (0); <6 (20); >14 (41)
Multiple localizations:	4 (0); 2-3 (10); 1 (20)
Exact localization:	lower group of calyces (0); renal pelvis (27); upper and/or middle group of calyces (54)
Size according to CT (mm):	≥30 (0); 10-29 (35); <10 (71)
Volume by CT (cm³):	≥2.5 (0); 1.5-2.49 (18); 0.5-1.49 (34); 0.2-0.49 (52); <0.2 (69)
Average CT density (HU):	≥1500 (0); 1000-1499 (33); 500-999 (67); <500 (100)

Fig. 1. Nomogram for determining the effectiveness of DUVL

written informed consent from the patient and/or their legal representative. Patients with congenital anomalies of the urinary tract, obstructive uropathies, children with chronic renal failure (SCF <60 ml/min/1.73 m²), and concomitant cardiovascular or immobilizing pathologies were excluded from the study. In the group of patients taking a1-adrenergic blockers, additional exclusion criteria included age under 2 years and medications affecting smooth muscle tone. Given that urolithiasis can be either unilateral or bilateral, kidneys were considered independent units in the study. Therefore, the first part of the study included 60 renal units (RU), and the second, 90 RU.

Methodology of the first part of the study. The developed nomogram for determining the effectiveness of ESWL takes into account the following parameters: patient gender, age, precise location of stones and their multiplicity, size, volume, and density of the stone based on CT data [12]. Depending on the value of each parameter, the patient is assigned a certain number of points (Fig. 1). The higher the score, the higher the likelihood of successful lithotripsy. The cutoff point is 53%; that is, if the score is 210 or higher, ESWL is recommended for the patient.

In our study, the probable outcome of lithotripsy was assessed by a single specialist using a nomogram. The values for each parameter were calculated as described in the original study. Regardless of the outcome, the patient underwent a lithotripsy session. Postoperatively, all children received infusion therapy with isotonic solutions and a fluid regimen at a rate of 50 ml/kg/day, followed by furosemide 0.3 mg/kg to promote diuresis. The effectiveness criterion was stone disintegration and the absence of fragments larger than 3 mm in size within the urinary tract, as determined by renal ultrasound three months after surgery. We then compared the predicted and actual results of lithotripsy and assessed the potential effectiveness of ESWL depending on adherence to the recommendations of the European Association of Urology (EAU), the clinical guidelines of the Union of Pediatricians, or the results obtained using the nomogram.

Methodology of the second part of the study. Patients included in the second part of the study were randomly divided into two groups: the main group (40 p.u.), which received drug lithokinetic therapy, and the control group (50 p.u.), which received infusion and diuretic therapy in the postoperative period, as described above. Due to the lack of data on the use of silodosin in patients under 5 years old, tamsulosin was prescribed to children aged 2 to 5 years. The dosage of tamsulosin was 0.2 mg/day (n=10), silodosin - 4 mg/day (n=30). All patients underwent ultrasound examination of the kidneys and urinary tract on days 3, 5 and 7 after the ESWL session, pain syndrome was assessed using a visual analogue scale (VAS) and the need for analgesic therapy was recorded. In addition, adverse effects of a1-blockers were recorded. We then performed a comparative analysis of the effectiveness of lithotripsy in the MET group and the control group, as well as the rate of stone fragment passage (per day), changes in pain according to the VAS scale, the need for analgesic therapy, and the incidence of complications according to the Clavien-Dindo classification. The criterion for the effectiveness of ESWL, as in the first part of the study, was the absence of stones larger than 3 mm in the urinary tract on a follow-up renal ultrasound three months after surgery.

Statistical data processing. Statistical analysis was performed using StatTech v. 4.6.3 and v.4.8.3 (developer: StatTech LLC, Russia). The normality of distribution of quantitative indicators was assessed using the Shapiro-Wilk test or the Kolmogorov-Smirnov test. In the absence of a normal distribution, quantitative data were described using the median (Me) and the lower and upper quartiles (Q1–Q3), and their comparison was performed using the Mann-Whitney U test. Comparison of percentages in the analysis of four-field contingency tables was performed using the Pearson chi-square test or Fisher's exact test. Differences were considered statistically significant at $p<0.05$.

Results. The predictive accuracy of the nomogram was assessed on a group of patients consisting of 60 renal units. The average age of the patients was 12 (6.25–15) years, and the gender distribution was as follows: 32 girls (53.3%) and 28 boys (46.7%). The average calculus size was 8 (6.05–13) mm, with a maximum of 18.7 mm.

The effectiveness of ESWL in this group of patients was 63.3%. Considering the compliance of the EAU clinical recommendations with the inclusion criteria for the study, the obtained effectiveness value reflects the significance of two criteria, namely, the renal localization of the calculus and its size of less than 20 mm [6]. Taking into account the clinical recommendations of the Union of Pediatricians of Russia for the treatment of urolithiasis from 2024, ESWL is indicated in the presence of a renal calculus with a density ≤1200 HU and a size of less than 15 mm in children under 12 years of age and less than 20 mm in adolescents [5]. After excluding patients who did not meet these criteria from the sample, we obtained 45 children, and the percentage of successful lithotripsy was 77.8%. In addition, the outcome of ESWL was predicted for each patient using a nomogram. If ESWL were prescribed only

in cases where the chance of successful lithotripsy was equal to or greater than 53%, the operation would be performed in 38 cases with 89.5% effectiveness.

As can be seen from Table 1, when following the indications determined using the nomogram, the effectiveness of ESWL is significantly higher than in other cases (p=0.013).

Table 1. Analysis of the effectiveness of ESWL depending on the indications for surgery

Indications for ESWL	n	Effective DUVL	Ineffective DUVL	p
KR EAU	60	38 (63,3)	22 (36,7)	0,013*a
KR RF	45	35 (77,8)	10 (22,2)	
Nomogram	38	34 (89,5)	4 (10,5)	

* – differences in indicators are statistically significant (p < 0.05)
a – Pearson chi-square
CR – clinical guidelines
RF – Russian Federation

In addition to assessing the likely effectiveness of ESWL depending on the method for determining surgical indications, we evaluated the predictive accuracy of the nomogram. The obtained data are presented using a confusion matrix (Table 2).

Table 2. Confusion matrix of the nomogram for determining the effectiveness of extracorporeal shock wave lithotripsy

Indicator	Categories	Actual outcome	
		effective ESWL	ineffective ESWL
Predicted outcome	effective ESWL	34 TP	4 FP
	ineffective DUVL	4 FN	18 TN

TP (True positive) – true positive decisions;
TN (True negative) – true negative decisions;
FP (False positive) – false positive decisions;
FN (False negative) – false negative decisions.

Analysis of the data presented in the table showed that the proportion of correctly predicted outcomes was 86.67% (error-free), the positive predictive value was 89.47% (accuracy), the nomogram sensitivity was 89.47%, and the specificity was 81.82%. The F-measure of the model, which combines accuracy and sensitivity and is a harmonic mean between them, was 0.89. These results confirm the high prognostic accuracy of the nomogram and its important role in improving the effectiveness of ESWL in children.

The average age of patients included in the second part of the study was 9.4±2.2 years in the main group (n=40) and 9.2±2.8 years in the control group (n=50). Girls also predominated in both groups: 57.5% and 56%, respectively. No statistically significant differences in anthropometric parameters and calculus characteristics were found between the groups (p>0.05).

Comparison of the effectiveness of ESWL between patients receiving drug therapy and patients with standard treatment in the postoperative period revealed statistically significant differences (p=0.011), the effectiveness of ESWL in the main group was 87.5%, while in the control group it was 64%. The rate of passage of stones in the group of patients taking a1-adrenergic blockers was significantly higher (p=0.010) and amounted to 5 (4–7) days versus 7 (5–9) days in the control group. The level of pain syndrome in the group with standard therapy was significantly higher than that in patients taking silodosin or tamsulosin, almost twice (p<0.001), which led to a reduced need for analgesia in patients from the main group (p=0.02).

A safety analysis demonstrated good tolerability of a1-blockers in children after ESWL. During the entire observation period, only four adverse events were reported (two patients experienced nasal congestion, one experienced episodes of severe dizziness, and another experienced nausea). All complications corresponded to grade I according to the Clavien-Dindo classification, did not require discontinuation of therapy, and resolved spontaneously.

Discussion. In pediatric practice, extracorporeal shock wave lithotripsy is considered preferable due to its low invasiveness and reduced hospitalization time. However, according to modern research, its effectiveness is lower than that of alternative surgical interventions such as retrograde intrarenal surgery and percutaneous nephrolithotripsy [19].

To improve the results of ESWL and reduce the number of invasive interventions associated with a higher risk of intraoperative and postoperative complications [20], it is necessary to take into account not only existing clinical guidelines, but also the created preoperative planning tools – nomograms.

Our study, which compared the effectiveness of ESWL depending on adherence to the clinical guidelines of the European Association of Urologists, the Union of Pediatricians, or the data of a domestic nomogram, showed that the most relevant way to determine the treatment tactics for patients with renal urolithiasis is to predict the effectiveness of ESWL using a nomogram (p=0.013).

Interestingly, patients selected using the nomogram differ from those recommended for ESWL according to ICD-10 clinical guidelines. For example, in three cases, the nomogram predicted effective ESWL with 80% probability in patients with a stone density greater than 1200 HU, which was confirmed by the actual success of the surgery. Conversely, in 12 patients selected according to the CG, the nomogram predicted a low probability of successful ESWL and was correct in eight cases. Importantly, the existing nomogram does not contradict clinical guidelines but rather complements them, increasing the effectiveness of ESWL. Its feasibility was demonstrated using a confusion matrix, which demonstrated high model quality metrics.

The second part of the study, aimed at optimizing postoperative therapy for patients with urolithiasis, confirmed the high efficacy of a1-adrenergic blockers in accelerating the removal of stones in children. The median expulsion time was reduced to 5 days (versus 7 in the control), which is consistent with the hypothesis of the antispasmodic effect of the drugs on the ureter. The use of silodosin (highly selective for a1a-adrenergic receptors) provided better results compared with data on tamsulosin [21]. In addition, a pronounced analgesic effect was noted as early as the 2nd day, which reduced the need for pain relief (1 dose/day versus 2 in the control). This effect may be associated not only with improved urine outflow, but also with modulation of pain transmission [22]. The use of a1-adrenergic blockers after extracorporeal shock wave lithotripsy accelerated the removal of fragments, and the incidence of side effects did not exceed 10%. All cases were reversible, which confirms the safety of therapy with the correct selection of drug dosages and is consistent with the data of Ellison et al., 2017 [23].

Thus, we have demonstrated increased lithotripsy efficacy using both the nomogram and medical expulsive therapy in the postoperative period. The combined use of these two approaches and the impact of a1-blockers on lithotripsy outcomes predicted by the nomogram require further research. It is possible that the 210-point threshold required for prescribing ESWL may be lowered, expanding the indications for this safe treatment method for urolithiasis in children.

Conclusions. Extracorporeal shock wave lithotripsy is the treatment of choice for urolithiasis in children. Its effectiveness can be enhanced by an objective approach to choosing a treatment strategy for patients with urolithiasis, using a nomogram to determine the likelihood of successful ESWL, and by using lithokinetic medication therapy in the postoperative period.

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