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Factors affecting extracorporeal shock wave lithotripsy (ESWL) success

Suleyman Sagir[1] - Halil Sagir[2]

1. Artuklu University Medical School, Department of Urology, Mardin, Turkey.
2. Silvan Dr. Yusuf Azizoğlu State Hospital, Clinic of Pediatrics, Diyarbakır, Turkey

Correspondence
Suleyman Sagir, Artuklu University Medical School, Department of Urology, Mardin, Turkey.

e-mail
dr.sagiroglu414@gmail.com

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ORCID ID of the author(s):
SS: 0000-0001-5300-8071
HS: 0000-0003-3725-5114

Abstract

Objective: Our aim in this study was to evaluate the predictive properties of success in patients who underwent Extracorporeal shock wave lithotripsy (ESWL).

Materials and methods: The medical records of 176 patients, who underwent ESWL for kidney stones were retrospectively reviewed. The study focused on individuals with single kidney stones measuring less than 2 cm. After the ESWL, patients who were not stone-free were evaluated as group 1, and stone free patients as group 2.

Results: The study encompassed two distinct groups: Group 1 with 67 participants and Group 2 consisting of 109 participants. In this study, which included 176 patients, the incidence of stone-free was found to be 62% (109/176). Of the patients, 56% (n=99) underwent ESWL once, 31% (n=55) twice, 8% (n=14) three times, 3% (n=5) four times, and 2% (n=3) received the treatment five times. Group 1 stones exhibited an average density of 978±357 HU, contrasting with Group 2's 784±318 HU. The disparity between these groups was significant, with a p-value of <0.001. Group 1 stones averaged 11.7±4.2 mm in size, while those in Group 2 measured 9.4±3.9 mm on average (p<0.001). According to the logistic regression test results, it was determined that stone size (p=0.007, OR: 0.89) and stone density (p=0.002, OR: 0.99) were two important independent predictors affecting the success of ESWL. Using a cut-off value of 1025 HU for stone density, we observed a sensitivity of 50% and a specificity of 82% in predicting the success of ESWL. The area under the curve (AUC) was 0.67.

Conclusions: ESWL remains a valuable, non-invasive modality for the management of kidney stones. Stone size and density stand out as key predictive parameters for its success.

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Introduction

Kidney stones represent a considerable strain on the healthcare system. In the U.S., the occurrence of kidney stones escalated from 3.8% in 1970 to 8.8% in 2010, leading to an annual healthcare expenditure of around USD 3.8 billion (1-4). Every year, over half a million individuals find themselves in emergency rooms due to complications related to kidney stones. Typical symptoms include blood in the urine (hematuria) and pain in areas like the flank, abdomen, or groin (5,6).

Various treatment methods are available for kidney stones (7). These span from non-invasive outpatient methods to more invasive treatments that necessitate hospital stays and come with elevated complication risks. Unlike other surgical interventions such as retrograde intrarenal surgery (RIRS) and percutaneous nephrolithotomy (PCNL), Extracorporeal shockwave lithotripsy (ESWL) stands out as genuinely non-invasive. ESWL's effectiveness stems from its capacity to break down kidney stones within the body into more manageable pieces, which are then naturally expelled. Here, shockwaves are produced and directed towards a specific internal point (8-10).

These shockwaves traverse the body, inflicting minimal energy loss (and thus minimal damage) due to the slight density variation of soft tissues. However, when reaching the boundary between the stone and the surrounding fluid, a marked density difference causes the concentrated shockwaves to release a significant amount of energy (11). This energy, through various means, can surpass the stone's resistance, causing it to break. Repeated applications of this method shatter the stone into fragments small enough for the body to expel without pain or issue (12,13).

Our aim in this study was to evaluate the predictive properties of success in patients who underwent ESWL.

Materials and methods

The medical records of 176 patients, who underwent ESWL for kidney stones were retrospectively reviewed. The study focused on individuals with single kidney stones measuring less than 2 cm. Those with anatomical abnormalities or with multiple, non-visible (on X-ray), stones larger than 2 cm were excluded from the study. After the ESWL, patients who were not stone free were evaluated as group 1, and stone free patients as group 2.

Ethical approval was obtained from Mardin University local ethical committee (no: 2023/8-5, date: 07.08.2023).

Parameters like gender, age, stone size and location, treatments post-ESWL complications were analyzed. All patients underwent urine tests, complete blood counts, and biochemical examinations. Patients diagnosed with urinary tract infections received treatment before the ESWL procedure. Initial diagnostic tools were ultrasonography (USG) and abdominal X-rays, with some patients also undergoing CT scans. In cases where severe hydronephrosis and pyonephrosis were detected, a double-J (DJ) stent was inserted.

The ESWL was carried out using the Modularis VarioStar lithotripter by Siemens Medical Solutions Inc. Patients were sedated using ketamine and Dormicum (midazolam) and placed in a supine position. Shock waves were initially administered at a rate of 60 per minute, with the rate progressively increasing. If the stone remained intact after 2,000 shock waves, the procedure was deemed unsuccessful. Post-procedure, stone fragmentation was confirmed through fluoroscopy. After undergoing a post-procedure USG of their urinary system, patients were discharged and scheduled for a follow-up USG two weeks later. For those with previously placed catheters, the DJ stents were removed typically a month after the procedure once USG confirmed fragmentation. For patients with stones in both kidneys, the side with the larger stone was treated first.

For statistical evaluation, the study utilized SPSS for Windows (version 25.0 by IBM Corp.). Continuous data points are expressed as mean ± standard deviation (SD), and categorical data is shown in terms of numbers and percentages (%). The independet t-test was used for the data with continue and normal distribution, and the Chi-square test was used for the categorical data. While the logistic regression test was used to determine the predictor, ROC analysis was used to evaluate the specificity and sensitivity of the achievement status.

Results

The study encompassed two distinct groups: Group 1 with 67 participants and Group 2 consisting of 109 participants. In this study, which included 176 patients, the incidence of stone-free was found to be 62% (109/176). Group 1 had an average age of 43.6±13.5 years, while Group 2's mean age was 39.4±12.1 years (p=0.031). In Group 1, 44 participants (66%) were male, whereas Group 2 had 79 male participants, accounting for 73% of the group (p=0.339). In terms of side, the difference between the two groups was not statistically significant with a p-value of 0.490. Group 1's average skin-to-stone distance was 10.1±2.6 cm and Group 2's was 10.5±2.2 cm (p=0.281). Group 1 stones exhibited an average density of 978±357 HU, contrasting with Group 2's 784±318 HU. The disparity between these groups was significant, with a p-value of <0.001. Group 1 stones averaged 11.7±4.2 mm in size, while those in Group 2 measured 9.4±3.9 mm on average (p<0.001). The WBC count for Group 1 averaged 8.4±2.6 x10^3/μL, closely mirroring Group 2's 8.5±2.5 x10^3/μL (p=0.733). Neutrophil-to-Lymphocyte Ratio (NLR) in Group 1 was 3.1±2.6, while Group 2 averaged 2.6±1.7 (p=0.211). Monocyte-to-Lymphocyte Ratio (MLR) in Group 1 average was 0.4±0.3, with Group 2 at 0.3±0.1 (p=0.064). In Group 1, the average urea level was 32.8±12.4 mg/dL, as opposed to Group 2's 30.6±8.3 mg/dL (p=0.146). Group 1 had 0.9±0.3 mg/dL creatinine (CRE) levels, while Group 2 presented with 1.1±0.9 mg/dL (p=0.477). Both groups had a similar urine pH, with Group 1 at 5.9±0.3 and Group 2 at 5.9±0.5 (p=0.542). Group 1's average urine density was 1015±7, slightly less than Group 2's 1017±6 (p=0.242) (**Table 1**).

Table 1: Comparison of the groups in terms of items

	Group 1 (n=67)	Group 2 (n=109)	p-value
Age	43.6±13.5	39.4±12.1	0.031
Gender (M)	44(66%)	79(73%)	0.339
Side (right)	38(57%)	56(51%)	0.490
Skin-to-stone distance	10.11±2.6	10.5±2.2	0.281
Density	978±357	784±318	<0.001
Stone size	11.7±4.2	9.4±3.9	<0.001
WBC	8.4±2.6	8.5±2.5	0.733
NEU	5.3±2.7	5.4±2.3	0.834
LYM	2.2±0.8	2.3±0.7	0.196
MONO	0.7±0.6	0.6±0.2	0.233
NLR	3.1±2.6	2.6±1.7	0.211
MLR	0.4±0.3	0.3±0.1	0.064
UREA	32.8±12.4	30.6±8.3	0.146
CRE	0.9±0.3	1.1±0.9	0.477
Urine pH	5.9±0.3	5.9±0.5	0.542
Urine density	1015±7	1017±6	0.242

Of the patients, 56% (n=99) underwent ESWL once, 31% (n=55) twice, 8% (n=14) three times, 3% (n=5) four times, and 2% (n=3) received the treatment five times (**Figure 1**).

Figure 1: ESWL season number

Table 2: Risk factor analysis for ESWL success

Predictor	Estimate	SE	Z	p	Odds ratio
Intercept	-25.86138	24.6503	-1.049	0.294	-------
Urine pH	0.21612	0.3705	0.583	0.560	1.241
Urine density	0.02661	0.0243	1.093	0.274	1.027
Stone size	**-0.11431**	**0.0424**	**-2.699**	**0.007**	**0.892**
Skin-to-stone distance	0.05530	0.0704	0.786	0.432	1.057
Stone density (HU)	**-0.00155**	**5.11e-4**	**-3.028**	**0.002**	**0.998**

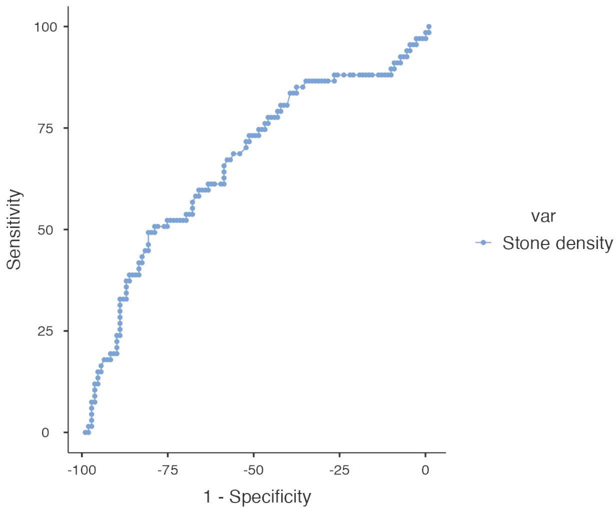

Figure 2: Stone density (HU) for success of ESWL.

In our study, we performed the Logistic regression test to calculate the actual risk factors affecting the success of ESWL. According to the logistic regression test results, it was determined that stone size (p=0.007, OR: 0.89) and stone density (p=0.002, OR: 0.99) were two important independent predictors affecting the success of ESWL (**Table 2**).

Using a cut-off value of 1025 HU for stone density, we observed a sensitivity of 50% and a specificity of 82% in predicting the success of ESWL. The AUC was 0.67 (**Figure 2**).

Table 3: Alternative interventions after unsuccesfull ESWL

	n	%
URS	32	60%
URS+DJ replacement	14	26%
RIRS	4	8%
PCNL	3	6%
Total	53	100%

There were 67 patients for whom ESWL proved unsuccessful, necessitating an alternative intervention. This indicates an ESWL failure rate of 38% (67/176). Of these 67 patients, 14 opted out of further treatment. The remaining 53 patients underwent procedures, with their respective surgeries as follows: URS was the most common, accounting for 60% (n=32) of the procedures. URS combined with double-J catheter (DJ) replacement followed, representing 26% (n=14) of the interventions. RIRS was carried out in 8% (n=4) of the cases, while PCNL was the chosen treatment for 6% (n=3) of the patients.

Discussion

Urolithiasis ranks among the most prevalent urological conditions, with its occurrence ranging between 1% and 20%, influenced by factors such as location, diet, genetics, and climate. It's notably frequent in dry, warm climates and traditionally more prevalent in males, though recent data shows gender incidence nearing parity (2,3) Today, urolithiasis is viewed as a systemic condition with connections to ailments like diabetes, obesity, high blood pressure, metabolic issues, heart disease, and chronic kidney disorders. Additionally, individuals with stone formation typically report a diminished quality of life compared to those without (2).

Kidney stones remain a significant health challenge, with the prevalence rising over the past few decades. Our study embarked on an journey to gauge the efficacy of ESWL in the management of kidney stones, particularly aiming to identify predictors of treatment success. While ESWL stands as a non-invasive choice, the underlying question was how many patients benefit from it and which parameters could indicate an expected outcome.

A stone-free rate of 62% was achieved in our study, which falls in line with various other studies that have demonstrated success rates ranging between 50% to 90% (14,15). This wide variance may be attributed to differences in stone size, location, equipment used, and patient selection criteria across studies.

Age, notably, emerged as a statistically significant parameter, with younger patients (39.4±12.1 years in Group 2) showing better outcomes than their older counterparts (43.6±13.5 years in Group 1). This observation parallels some existing literature suggesting better outcomes in younger patients, possibly because of their overall better health status, renal resilience, or differences in stone composition (14,15).

The gender and anatomical side of the stone did not show a significant difference between the groups. This suggests that these factors may not play a decisive role in ESWL outcomes, a viewpoint reinforced by many previous studies.

Interestingly, two factors stood out as critical independent predictors of ESWL success: stone size and stone density. Notably, stones with a lower average size (9.4±3.9 mm) and lower average density (784±318 HU) were associated with higher treatment success. This underscores the importance of stone characteristics in determining ESWL outcomes. It's worth noting that a cut-off value of 1025 HU for stone density had a good specificity (82%) but moderate sensitivity (50%) for predicting ESWL success. Clinicians may consider this cut-off value when contemplating ESWL as a treatment modality, keeping in mind that denser stones might require alternative interventions.

The substantial number of patients (38%) that did not respond to ESWL and required further treatment indicates that while ESWL is a valuable tool, it may not be universally effective. Among these, Ureterorenoscopy (URS) emerged as the most common subsequent intervention. This aligns with the procedure's reputation as a minimally invasive, effective tool in managing kidney stones.

In light of our findings, for patients presenting with kidney stones, especially those with larger and denser stones, a comprehensive evaluation and discussion about the pros and cons of ESWL and the likelihood of its success are imperative. This ensures informed decision-making and sets realistic expectations.

Some potential limitations of our study include its retrospective nature and the single-center setting, which may not make our findings universally applicable. Future multicentric, prospective studies with larger cohorts might provide a more in-depth understanding and validation of our observations.

Conclusions

ESWL remains a valuable, non-invasive modality for the management of kidney stones. Stone size and density stand out as key predictive parameters for its success. Recognizing these predictors can aid in tailoring individualized treatment plans, optimizing outcomes, and reducing healthcare costs.

Conflict of interest:

The authors report no conflict of interest.

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Ethical approval:

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Informed consent:

Written informed consent was obtained from all individual participants and/or their gaurdians.

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Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Contributions

Research concept and design: **SS, HS**
Data analysis and interpretation: **SS**
Collection and/or assembly of data: **SS**
Writing the article: **SS, HS**
Critical revision of the article: **SS, HS**
Final approval of the article: **SS, HS**

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