

# EXTRACORPOREAL SHOCK WAVE LITHOTRIPSY(ESWL) OUTCOME BASED ON CT SCAN AND PATIENT PARAMETERS USING ESWL SCORE IN A TERTIARY CARE HOSPITAL

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## Abstract

**Objective:** To assess the outcome of ESWL and to confirm the validity of the ESWL score in predicting stone-free status.

**Methods:** This prospective observational study was conducted at Jinnah Postgraduate Medical Centre (JPMC), Karachi from 1<sup>st</sup> October, 2025 to 6<sup>th</sup> March, 2026 and included 94 adult patients undergoing ESWL for renal calculi. Stone-free status was assessed at 4-week follow-up. ESWL score components (BMI <27 kg/m<sup>2</sup>, stone size <11 mm, and stone density <900 HU) were calculated, and the association between ESWL score and treatment outcome was analyzed using SPSS v27. Receiver operating characteristic (ROC) curve analysis was performed for prediction of the ESWL score.

**Results:** The median age was 41 years (IQR 32–46), and 60 patients (63.8%) were male. At 4 weeks, 68 patients (72.3%) achieved stone-free status. Smaller stone size (9.0 vs 10.2 mm,  $p=0.015$ ), lower stone density (803 vs 913 HU,  $p=0.022$ ), upper-pole location ( $p=0.039$ ), and treatment by experienced operators ( $p=0.017$ ) were significantly associated with stone-free outcome. All individual ESWL score components were significantly predictive of success ( $p<0.05$ ). Stone-free rates increased progressively with higher ESWL scores, from 16.7% for score 0 to 96.0% for score 3 ( $p<0.001$ ). An ESWL score cut-off of  $\geq 2$  demonstrated an area under the ROC curve of 0.74 (95% CI 0.63–0.84), with sensitivity of 79.4%, specificity of 50.0%, and overall diagnostic accuracy of 71.3%.

**Conclusion:** ESWL remains an effective treatment modality for appropriately selected patients with renal calculi.

**KEYWORDS:** Extracorporeal Shock Wave Lithotripsy, Stone-Free Status, Renal Calculi

## INTRODUCTION

Extracorporeal shock wave lithotripsy (ESWL) is a viable mode of treatment of small to medium renal stones despite the rising popularity of percutaneous nephrolithotomy (PCNL) and retrograde intrarenal surgery (RIRS)<sup>1</sup>. The recent guidelines suggest ESWL as an initial therapy for renal stones smaller than 10 mm in the lower pole and less than 20 mm in other renal sites<sup>2</sup>. However, the success of ESWL could be affected by several factors, such as the age of patients<sup>3</sup>, BMI<sup>4</sup>, the size, density, and location of the stones<sup>5</sup>, and the experience of the operator<sup>6</sup>. To maximize the selection of patients, various scoring systems have been developed. Tran et al. proposed the Triple D score, which uses skin-to-stone distance, stone volume, and stone density to predict stone-free rates (SFR)<sup>7</sup>. Quadruple D score introduces the location of stones as the fourth parameter, with a lower score given to lower pole stones<sup>8</sup>. These systems are predictively valid<sup>9</sup>, but due to the complex measurements used, they cannot be used routinely. The ESWL Score created by Bengio et al. in turn relies on three parameters that are simple to measure, i.e., BMI, stone size, and stone density, which makes it more practical in the outpatient practice<sup>10</sup>.

The rationale behind this study is that there is need to have evidence-based selection of patients to undergo ESWL in the treatment of renal stones. Thus, it is necessary to develop and test a practical tool that will assist in selecting the best candidates to work in ESWL. The proposed study will provide a prospective assessment of ESWL outcomes and prove the ESWL Score in order to contribute to evidence-based patient selection.

## METHODS

The research was carried out at the Urology and Transplantation Department, of Jinnah Postgraduate Medical Centre (JPMC), Karachi. It was conducted over a period of Five months from **1<sup>st</sup> October, 2025 to 6<sup>th</sup> March, 2026**. The study was a Prospective Observational study in nature. Ethical approval was obtained from the Institutional Review Board (IRB) of JPMC, ethical approval no: **F.2-81/2025-GENL/223/JPMC**; Dated: **1<sup>st</sup> March, 2025**. Adult patients aged 18 years and older were screened based on having solitary, radio-opaque renal stones. Included were only individuals whose stone size was less than 15 mm on NCCT, with normal renal function (serum creatinine less than 1.3 mg/dL), with negative urine culture, and no structural abnormality of the urinary tract. Morbidly obese patients (more than 130 kg without correction) and uncorrected coagulopathies, pregnant women, and those who were not willing to give informed consent were not allowed.

A sample size estimation was done to determine the discriminative power of the ESWL score in predicting the success of the treatment. An anticipated AUC of 0.85 and a minimally acceptable AUC of 0.70 gave a sample size of 78 to identify a difference between the two at 80% power at 5% level of significance. The target number of enrolled patients was raised to 94 to counteract the potential dropouts and missing follow-ups.

Baseline NCCT was done on all patients before ESWL. The structured proforma was used to record demographic characteristics, clinical data, stone sizes, stone location and stone density. Axial images were standardized, and the density of the stone in Hounsfield units (HU) was measured using a region of interest that contained the largest cross-section of stone. A radiologist who was not aware of all clinical outcomes carried out these measurements. The size of the stones and stone density were determined on the baseline non-contrast CT scan done before ESWL. Each participant was assigned one point each in the calculation of the ESWL score, which included: body mass index (BMI) under 27 kg/m<sup>2</sup>, stone size under 11 mm and stone density under 900 HU. These thresholds have been chosen on the basis of previous validation studies by Bengió RG et al., so the ESWL score is between 0 and 3 where a higher score corresponds to an incrementally higher likelihood of attaining a stone-free state. The most favorable group of patients for ESWL is those with a score of 3. Conversely, the scores 0-1 indicate low chances of success.

ESWL was performed on all patients using the same lithotripter found in the department. The procedures were done based on a departmental protocol that standardized the position of the patients, the coupling technique, imaging guidance, ramping, frequency of shocks, and the maximum amount of shocks to be administered in a session. Analgesia or sedation was done as required.

Follow-ups were done four weeks after the index ESWL session. Stone clearance was determined through X-ray KUB and NCCT KUB was only used in cases where the X-ray results were inconclusive. The main research outcome was the stone-free rate (SFR) which was defined as a full clearance or a residual fragment of a stone that is clinically insignificant and 4 mm or less in diameter. A radiologist who was not informed of the ESWL scores and procedural information of the patients interpreted all post-treatment imaging to reduce assessment bias. The experience of the operator was divided into experienced (consultant) and junior (resident/fellow) and any other procedure performed after ESWL was classified as auxiliary procedures.

Data analysis was done using IBM SPSS version 27. The Shapiro-Wilk test was used to test the normality of continuous variables and they were reported as median and interquartile range. The frequencies and percentages were used to summarize categorical variables. Chi-square tests or Fisher exact tests were used to compare SFR in categories of ESWL scores. While Mann Whitney U test was applied to test median differences in continuous predictors of stone-free versus non-stone-free groups. ESWL score predictive performance was assessed by receiver operating characteristic (ROC) analysis and the area under the curve (AUC) and its 95% confidence interval were determined. All analyses had a p-value of below 0.05 as statistically significant.

## RESULTS

A total of 94 patients undergoing ESWL were included in the analysis. The 4-week follow-up showed that 68 patients (72.3%) were stone-free and 26 (27.7%) still had residual stones. Stone-free patients were much younger than non-stone free patients (median 39 [IQR 31-45] vs 43 [IQR 37-50] years,  $p=0.034$ ). In the same manner, median BMI was also significantly less in stone-free patients than in non-stone-free patients (25 [IQR 23-28] kg/m<sup>2</sup> vs 28 [IQR 23-31] kg/m<sup>2</sup>,  $p = 0.047$ ). (Table 1)

The characteristics of stones were shown to have a strong effect on the results of ESWL. The median stone size of the stone-free group was lower in comparison with the not stone-free group (9.0 [IQR 7.8-10.6] vs 10.2 [IQR 8.7-12.1] mm,  $p= 0.015$ ). Likewise, the median density of the stones was much lower in stone-free patients than in non-stone-free patients (803.0 [IQR 576.5-933.8] vs 913.0 [IQR 785.2-1030.0] HU,  $p=0.022$ ). Stone position was also correlated with outcome significantly ( $p=0.039$ ). (Table 1)

The ESWL score component analysis showed that BMI <27kg/m<sup>2</sup>, stone size<11mm, and stone density<900HU were all significantly correlated with stone free outcome ( $p=0.036$ ,  $p=0.002$ , and  $p=0.027$  respectively). There was a significant stepwise correlation between the overall score on ESWL and success of treatment ( $p < 0.001$ ). (Table 2)

Complications occurring within 4 weeks of ESWL were classified using the Clavien–Dindo system. Minor complications (Grade I–II) included transient hematuria and urinary tract infection requiring oral antibiotics, while Major complications (Grade III) consisted of procedures such as JJ stenting, ureteroscopic removal of fragments, or PCNL performed due to obstruction or residual calculi. No Grade IV–V complications were observed. Overall, 77 patients (81.9%) reported no complications. Mild complications (Clavien–Dindo I–II) occurred in 11 patients (11.7%), while moderate complications (Clavien–Dindo III) occurred in 6 patients (6.4%). No severe

complications (Clavien–Dindo IV–V) were observed. When stratified by treatment outcome, the distribution of complications between stone-free and non–stone-free groups were not statistically significant ( $p = 0.092$ ). Mild complications occurred in 5 (45.5%) stone-free and 6 (54.5%) non–stone-free patients, while moderate complications occurred in 4 (66.7%) stone-free and 2 (33.3%) non–stone-free patients. (Table 3). Eight patients were also in need of auxiliary procedures. Of these 8 patients, ureteroscopy was performed in 2 (25.0%) and percutaneous nephrolithotomy in 6 (75.0%) patients. While none of the patients who needed auxiliary procedures were stone-free, thus achieving a significant correlation between auxiliary intervention and treatment failure ( $p < 0.001$ ).

Table 4 provides a summary of the diagnostic performance of the ESWL score in predicting the outcome of being stone-free. With the cut-off value of ESWL score  $\geq 2$ , the area underneath the receiver operating characteristic curve was 0.74 (95% CI 0.63–0.84). (Figure 1) The sensitivity at this threshold was 79.41%, the specificity was 50.00%, the positive predictive value was 80.60%, the negative predictive value was 48.15% and the overall diagnostic accuracy was 71.28%.

## DISCUSSION

The renal stone disease has a significant clinical burden in Pakistan<sup>11–13</sup>. Considering the high rate of occurrence and the high economic implications of renal stones<sup>14</sup>, it is important to select the right modalities of treatment with care. ESWL is a very popular and affordable procedure as it needs less anesthesia and fewer auxiliary procedures like stenting<sup>15</sup>; but it usually has lower stone-free rates than PCNL and RIRS<sup>16</sup>. The current prospective study shows that ESWL is an effective, safe, and minimally invasive intervention in the treatment of selected patients with renal calculi, with a SFR of 72.3% at 4 week follow up. Moreover, this analysis validates that the ESWL score is a useful predictive instrument, showing that the rates of stone-free status increase with the score and that it has medium predictive power (AUC = 0.74). These results justify the use of ESWL scoring systems in patient selection and counseling before treatment, as has been previously validated in other studies<sup>17,18</sup>.

The general SFR of the present study is similar to the success rates reported in the past between about 60 and 80 percent in prospective and retrospective cohorts. Rasheed et al.<sup>17</sup> had a SFR of 68% in their prospective analysis of the ESWL score and Oliveira et al.<sup>18</sup> had a fragmentation success rate of more than 80 percent with lower rates of complete clearance when auxiliary procedures were factored in. The small increased clearance rate in the current study could be explained by a relative small median stone size, selection of patients, and administration of therapy in a high-volume tertiary care unit<sup>19</sup>.

In our setting, the link between treatment success and the need for further procedures was quite straightforward. Patients who cleared their stones after ESWL naturally did not require anything else, while those who still had residual fragments needed additional help. Because of this, every URS or PCNL in our study took place in the non–stone-free group. This pattern fits well with routine urological practice, where secondary interventions are reserved for cases in which ESWL alone does not achieve full clearance. The strong statistical association we found simply reflects this usual clinical pathway rather than indicating any unexpected trend. In other words, the finding supports the way ESWL is typically used: as a first-line option, with auxiliary procedures offered only when necessary.

There was a significant correlation between age and BMI and treatment outcome in this cohort with younger patients and patients with lower BMI having higher SFR. The results are in agreement with previous reports that show a decrease in the transmission of effective shock waves to the stone in obese patients<sup>20,21</sup>. Nonetheless, there are recent studies comparing Quadruple D and machine learning models that failed to find BMI as an independent predictor when controlling by the stone density and volume. This difference could be attributed to population peculiarities, since the distribution of BMI and body habitus could differ in different regions, and the effect of BMI could be exaggerated in those places where stones are smaller and lithotripter focal areas are smaller<sup>18,22</sup>.

The most predictive variables of ESWL outcome in the current analysis were stone related variables. The stone size and the stone density were also much lower in stone free patients which can be in line with the literature evidence that demonstrated a decreased fragmentation efficacy in stones greater than 1011mm or greater than the measurements of the Hounsfield unit<sup>23,24</sup>. NCCT based predictors meta analyses have repeatedly shown stone density to be one of the strongest predictors of ESWL success, which is why it should be included in simplified predictive models like the ESWL and Triple D scores<sup>25</sup>.

The location of the stone was also found to be a significant outcome determinant with upper pole stones showing the highest SFR. This finding is in agreement with a number of reports that indicate worse clearance rates of lower pole calculi, in part because of poor infundibulopelvic anatomy and poor gravitational fragment clearance. Though other authors have found better lower pole results with altered positioning, or with more recent lithotripters, these anatomical issues probably still apply to the normal clinical practice, especially at short term follow up<sup>19</sup>.

There are several limitations of this study. To begin with, the sample size was quite small, despite the study being prospective, which might have compromised the ability to find the associations with complication rates. Second, the composition of stone was not examined, because chemical analysis of recovered pieces was not regularly available; since it is known that stone composition has an effect on ESWL fragmentation, this can be a confounding variable that is not measured. Third, stone-free status was measured at 4 weeks, and this could underestimate the slow clearance of fragments, especially in lower-pole stones. Lastly, operator experience was considered, but other technical aspects, shock wave frequency, energy ramping protocols, and patient positioning were not standardized or quantitatively measured, which could have affected the treatment outcomes.

Despite these shortcomings, this research has several strengths. The prospective design minimizes recall and selection bias in contrast to retrospective analyses and facilitates a systematic collection of data. NCCT in the evaluation of the stone properties improves the accuracy of measurements and indicates the modern clinical practice. Moreover, the study population is a high-burden area of urolithiasis, and thus the data is of great value since it is based on a population that is often under-represented in the extant literature.

Future research ought to consider the validation of ESWL score in bigger, multicenter cohorts to increase the external validity and enable subgroup analyses according to stone position, size, and patient features. Adding stone composition information and longer follow up would further explain the sustainability of ESWL results and late fragment clearance. Comparative analyses of the ESWL score and more recent predictive models, including Quadruple D scores, radiomics based, or machine learning algorithms, would assist in establishing the best tradeoff between simplicity and predictive accuracy.

## CONCLUSION

ESWL remains an effective treatment modality for appropriately selected patients with renal calculi. The ESWL score is a simple and reliable tool with moderate discriminative ability for predicting stone-free outcome.

**Table 1: Baseline demographic, clinical, and stone-related characteristics of patients undergoing ESWL**

Variables	Overall (n = 94)	Stone-free (n = 68)	Not stone-free (n = 26)	p-value
Age, years [median (IQR)]	41 (32-46)	39 (31-45)	43 (37-50)	0.034 <sup>a*</sup>
Gender, n (%)				
Male	60 (63.8)	44 (73.3)	16 (26.7)	0.775 <sup>b</sup>
Female	34 (36.2)	24 (70.6)	10 (29.4)	
BMI, kg/m <sup>2</sup> [median (IQR)]	26 (23-29)	25 (23-28)	28 (23-31)	0.047 <sup>a*</sup>
Stone size, mm [median (IQR)]	9.4 (8.1-10.8)	9.0 (7.8-10.6)	10.2 (8.7-12.1)	0.015 <sup>a*</sup>
Stone density, HU [median (IQR)]	845.5 (648.7-945.5)	803.0 (576.5-933.8)	913.0 (785.2-1030.0)	0.022 <sup>a*</sup>
Stone location, n (%)				
Upper pole	36 (38.3)	32 (88.9)	4 (11.1)	0.039 <sup>b*</sup>
Mid pole	19 (20.2)	11 (57.9)	8 (42.1)	
Lower pole	18 (19.1)	12 (66.7)	6 (33.3)	
Renal pelvis	21 (22.3)	13 (61.9)	8 (38.1)	
Operator experience, n (%)				
Experienced	58 (61.7)	47 (81.0)	11 (19.0)	0.017 <sup>b*</sup>
Junior	36 (38.3)	21 (58.3)	15 (41.7)	
Number of ESWL sessions, n (%)				
1 session	79 (84.0)	58 (73.4)	21 (26.6)	0.592 <sup>b</sup>
2 sessions	15 (16.0)	10 (66.7)	5 (33.3)	
Number of shocks delivered [median (IQR)]	2634.0 (1828.5-3001.8)	2466.0 (1581.5-2973.8)	2845.0 (2537.0-3099.0)	0.005 <sup>a*</sup>
Maximum energy level [median (IQR)]	4 (4-5)	4.0 (3.0-5.0)	4.0 (4.0-5.0)	0.276 <sup>a</sup>
Imaging used for targeting, n (%)				
x-ray	22 (23.4)	16 (72.7)	6 (27.3)	0.963 <sup>b</sup>
US	72 (76.6)	52 (72.2)	20 (27.8)	

<sup>a</sup>Mann-Whitney U test applied, <sup>b</sup>Chi-Square/Fisher Exact test applied

\*p-value <0.05

**Table 3: ESWL treatment outcomes at 4-week follow-up**

Outcome	Overall (n = 94)	Stone-free (n = 68)	Not stone-free (n = 26)	p-value
Complications, n (%)				
Mild	11	5 (45.5)	6 (54.5)	0.092
Major	6	4 (66.7)	2 (33.3)	

None	77	59 (76.6)	18 (23.4)	
<b>Auxiliary procedures, n (%)</b>				
None	86	68 (79.1)	18 (20.9)	<0.001*
URS	2	0 (0)	2 (100)	
PCNL	6	0 (0)	6 (100)	

PCNL: Percutaneous Nephrolithotomy, URS: Ureteroscopy

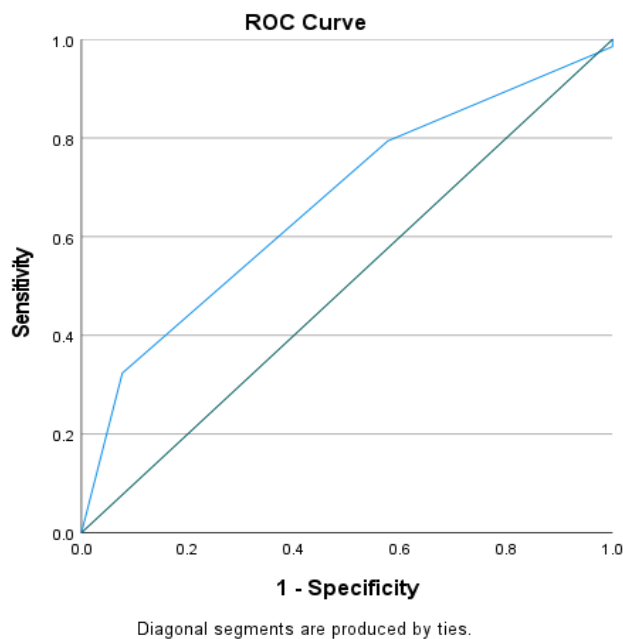
All data presented as number (%)

Chi-Square/Fisher-Exact test applied

p-value <0.05

**Table 4: Diagnostic performance of ESWL Score in predicting stone-free outcome**

Metric	Value
ROC curve	ESWL Score



**Figure 1: ROC curve for ESWL Score**

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