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Original Research Article

Is ESWL Score a Good Predictor of Stone Clearance? A Comparison in Patients Undergoing ESWL With Stones of Low, Medium, and High Density

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Abstract: *Extracorporeal shock wave lithotripsy (ESWL) remains a first-line, non-invasive treatment for renal stones. However, predicting treatment success remains a challenge. The ESWL Score was proposed as a simple predictive tool, yet its real-world validation in prospective settings remains limited.* ***Objective:*** *To assess the predictive capabilities of the ESWL Score in determining stone clearance following ESWL in a prospective clinical setting.* ***Methods:*** *A prospective observational study was conducted at The Kidney Centre, Karachi, from October 2024 to April 2025. All eligible patients undergoing ESWL for renal calculi were enrolled. Demographic data, including age, gender, height, and weight, were recorded, and body mass index (BMI) was calculated. Stone characteristics—size, location, number, and density—were assessed via non-contrast computed tomography (NCCT). The ESWL Score was calculated for each patient. Stone clearance was assessed one week post-procedure using plain X-ray KUB, with clearance defined as no visible fragments or residual fragments <4 mm. Statistical analysis was performed using IBM SPSS version 26. Logistic regression was used to evaluate the predictive value of the ESWL Score.* ***Results:*** *A total of 143 patients were included, with a median age of 43 years (IQR=20); 87 (60.8%) were male. Median stone size was 8.1 mm (IQR=3.9), ranging from 4.3 to 15.5 mm. Median stone density was 890 HU (IQR=366), and median BMI was 24.4 kg/m² (IQR=2.6). Most patients fell within normal or overweight BMI categories. Successful stone clearance was achieved in 112 (78.3%) patients. The most common ESWL Score was 2 (45.5%), followed by 3 (36.4%). Stone size significantly affected clearance outcomes (p<0.05), whereas BMI and stone density did not. Logistic regression analysis revealed that the ESWL Score was a significant predictor of stone clearance. Specifically, patients with an ESWL Score of 2 had 9.54 times higher odds of successful clearance (p<0.001).* ***Conclusion:*** *The ESWL Score is a practical and reliable tool for predicting treatment success in patients undergoing ESWL for renal stones. Its simplicity and predictive validity make it a valuable adjunct in pre-procedural planning.*

Keywords: Body Mass Index, Computed Tomography, Kidney Calculi, Lithotripsy, Prognosis, Renal Stone, Treatment Outcome

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Introduction

Renal stones are one of the most common presentations in urological practice. (1) Due to high prevalence and recurrence rate, they are an important health issue. (2,3) Multiple factors contribute to stone formation, such as diet, genetic predisposition, environment, and physical activity. (4) Pakistan is a country with one of the highest stone disease burdens. (5) Treatment modalities have evolved over the last few decades to tackle this problem and consist of various options, broadly categorized as invasive, minimally invasive, and non-invasive techniques.

Extracorporeal Shockwave Lithotripsy (ESWL) is a well-known non-invasive treatment modality that utilizes ultrasonic sound wave energy delivered from outside the body to clear renal calculi. Its success is based on several factors, including the size of the stone, the number of stones, body mass index (BMI), the stone's composition and density, and the anatomical location. (6) Generally, stone sizes larger than 2 cm, multiple or hard stones, or stones present in the lower calyx lead to less satisfactory results in terms of stone fragmentation and clearance.

Multiple imaging modalities are available for identifying renal stones. Non-contrast computed tomography (NCCT) remains the gold standard imaging modality for identifying renal stones as it provides a detailed image along with multiple properties of the stones, such as site, size, and density. Another advantage over ultrasound is that it is not an operator-dependent imaging modality. Hence, its results are considered more reliable than those of other imaging modalities.

Stone density is a factor that plays a substantial part in the outcome of stone clearance. It is expressed in Hounsfield units (HU), and its predictive value in ESWL success has been documented in literature as early as 2005. (7,8) However, the cutoff values predicting ESWL success are still under debate. Multiple values have been put forward, such as 970 HU (9), 750 HU (10), and 499 HU (11). Based on the current literature, this study will attempt to investigate the optimum range of HU with successful ESWL in stones of varying density.

As mentioned earlier, stone size, density, and BMI are some of the key factors influencing the outcome of ESWL. To aid clinicians in better predicting stone clearances, multiple models and tools have been proposed in recent literature using a variety of combinations and a range of values to predict ESWL success reliably. Clinicians generally prefer tools that are easy to use and provide reliable results, as this is clinically useful when offering various modes of intervention to their patients.

One such tool is the ESWL Score. Proposed by Bengió et al. (12), it uses three independent factors, namely stone size, body mass index (BMI), and stone density, to predict the outcome of lithotripsy. Each factor has a documented cut-off point, and values less than the cut-off point are documented as 1; otherwise, the value is documented as 0. Cut-off values for the three factors are stone size < 11 mm, stone density < 900 HU, and BMI < 27 kg/m2. An aggregate of these three factors produces an ESWL score value that is documented as 0 to 3 in the ascending order of favorability for stone clearance.

Despite being a recent tool, first proposed in 2016, its initial results and ease of use have led to a heightened general interest in it. However, not much literature is currently available on this tool. Rasheed et al. (13) tested it on 146 patients and reported good results, which emphasized its reliability in predicting stone clearance. However, more studies need to be performed before this score can be validated, which will be the primary aim of this study.

Methodology

All patients who fell within the study parameters at The Kidney Centre, Karachi, were included in the study. The duration of data collection was from October 2024 to April 2025. Ethical approval was received from The Kidney Centre Ethical Review Committee. Patient consent was not needed as there was no patient contact, and confidentiality of hospital records was ensured. Inclusion criteria were age above 18 years and less than 80 years, the presence of solitary, symptomatic, radio-opaque renal stone measuring < 20 mm with normal renal functions (serum creatinine < 1.3 mg/dl) without any anatomical urinary tract abnormality or distal obstruction, and negative urine cultures before ESWL. Patients with staghorn calculus or a history of any open, percutaneous, or endoscopic intervention(s) done before ESWL (including placement of DJ stent/ nephrostomy tube) were excluded.
A structured form was used to gather details regarding each patient, such as their age, gender, height, and weight, using standardized weighing scales and height charts. BMI for each patient was also calculated. Pre-procedure radiological evaluation was done with a non-contrast computed tomography (NCCT) scan performed within two weeks of the procedure. The stone's location within the kidney, including the number, density, and which kidney (right or left), as well as its size, was recorded. Patients were recorded and categorized into three density groups: low (<750 HU), medium (750–1000 HU), and high (>1000 HU). Data on stone size, density, and BMI were used to calculate each patient's ESWL Score. All patients underwent ESWL using the same lithotripter apparatus, as a daycare procedure. Four thousand shockwaves per session were delivered, with energy levels ranging from 60 to 90 shocks per minute. The frequency of shockwaves would range from 0.5 to 2 Hertz. The Storz Modulith® SLK lithotripter was used for all ESWL procedures, which were performed in a prone position. Follow-up was after one week to assess stone clearance rates based on plain X-ray KUB findings done on the same day. Stone clearance was defined as no visible fragments or less than 4mm in size, on plain x-ray KUB. Confidentiality was maintained by anonymizing data using patient ID numbers.
The data was entered, coded, cleaned, edited, and analyzed on IBM SPSS version 26. Frequency with percentage was calculated for categorical data, such as gender, location, density, and stone clearance. Continuous variables such as age, height, weight, BMI, size of stone, stone density, and ESWL score were reported in mean + SD/median IQR in case of non-normality. Normality of data was assessed using the Shapiro-Wilk test. Mann-Whitney test and Kruskal-Wallis tests were applied to perform the analysis. The ROC curve was constructed with the best cut-off value. Post-stratification ROC/AUC curves were constructed with the best cut-off value.

Results

Of the patients who underwent ESWL during the study period, 143 met the inclusion criteria. The median age was 40 years (IQR=20), and 87 (60.8%) were male. Median stone size was 8.1 (IQR=3.9) mm with a range from 4.3 to 15.5 mm. The most common stone location was the middle calyx (38.5%), followed by the lower calyx (30.8%). Median stone density was 890 (IQR=366) HU. 59 (40.3%) patients had stones with densities that were between 750 and 1000 HU, i.e., medium density stones. Median BMI was 24.4 (IQR=2.6) kg/m2, with a majority either within a normal BMI range or in the overweight category. Values for the normal category were a BMI of 19.5-24.9 kg/m2, while overweight was a BMI of 25.0-29.9 kg/m2. A score of less than 19.5 was considered underweight, while a score of 30 or higher was classified as obese. In this study group, five individuals were documented in the underweight and obese categories, respectively. Eighty participants were in the normal category, while the remaining 53 were classified as overweight. (Table 1)

Table 1 Patient Demographics and Stone Characteristics

Variable		Overall (n = 241)	Clearance Status		P-value
			Free (n = 112)	Residual (n = 31)	
		Median (IQR)			
Age (years)		40 (20)	42 (22.3)	26.5 (14.5)	0.028
BMI (kg/m2)		24.4 (2.6)	24.8 (2.5)	23.3 (2.1)	0.883
Stone Size (mm)		8.1 (3.9)	7.7 (3.2)	10.8 (3.8)	0.000
Stone Density (Hounsfield Unit)		890 (366)	860 (398)	987 (201)	0.042
		Frequency (%)			
Gender	Male	87 (60.8)	61 (70.1)	26 (29.9)	0.003
	Female	56 (39.2)	51 (91.1)	5 (8.9)	
Stone Location	Upper Calyx	22 (15.4)	16 (72.7)	6 (27.3)	0.202
	Middle Calyx	55 (38.5)	48 (87.3)	7 (12.7)	
	Lower Calyx	44 (30.8)	31 (70.0)	13 (30.0)	
	Pelvis	22 (15.4)	17 77.3)	5 (22.7)	
Stone Density Category	Low (< 750 HU)	38 (26.6)	33 (89.8)	5 (13.2)	0.246
	Medium (750 - 1000 HU)	59 (41.3)	46 (78.0)	13 (22.0)	
	High (> 1000 HU)	46 (32.2)	33 (71.7)	13 (28.3)	

The chi-square test was used for categorical variables, including gender, stone location, and density categories, and the Mann-Whitney U test for all other variables in this table.

112 (78.3%) patients had successful stone clearance as per study protocols after their ESWL procedure. The most common ESWL score value was 2 (45.5%), followed by 3 (36.4%), in this study population. In univariate analysis for impact on stone clearance, only stone size had a significant impact (p=0.00) while stone density and BMI had no significant impact. No significant differences were found between stone location and stone density categories concerning clearance. A review of stone clearance distribution for each ESWL score showed that excluding the score 0, the percentage of patients with stone clearance post-ESWL increased with an increasing score: 45.0% for ESWL score 1, 75.4% for ESWL score 2, and 94.2% for ESWL score 3. 83.3% of participants who had score 0 showed complete clearance while representing 4.2% of the total study population. Overall, the difference between these scores was statistically significant (p=0.000). (Table 2)

Table 2: Stone Clearance according to ESWL Score

		Clearance Status		**P-value**
		Free (n = 112)	**Residual (n = 31)**	
ESWL score	0	5 (83.3)	1 (17)	0.000
	1	9 (45.0)	11 (55)	
	2	49 (75.4)	16 (25)	
	3	49 (94.2)	3 (6)	
(Result calculated using Chi-square test using significant value as p < 0.05)				

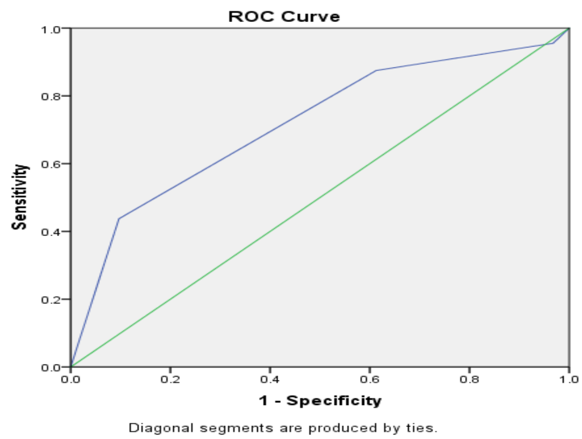

Figure 1 ROC for ESWL score (Blue line – ESWL Score, Green line – Reference)

The ROC curve analysis showed that the ESWL Score was a good predictor of stone clearance (AUC = 0.71, p = 0.000). It also showed that an ESWL Score of ≥2 was the optimal threshold for predicting stone clearance, with a sensitivity of 87.5% and a specificity of 61.3%. Binary logistic regression showed that ESWL Score was a significant predictor of stone clearance (p = 0.005). Patients with an ESWL Score of 2 had 9.54 times higher odds of successful stone clearance (p = 0.008). Stone size also significantly influenced clearance (p = 0.002, OR = 1.471). BMI and stone density did not significantly impact stone clearance (p > 0.05). (Figure 1)
The overall complication rate was 9.8% (n=14) patients. 10 patients had post-procedural flank pain, of which 4 required intravenous analgesia. 4 patients developed post-procedural hematuria. However, it remained mild and was managed conservatively with increased hydration. No patient required admission for management of their complication. No cases of urinary tract infections or urosepsis were documented. 15 patients required further procedures to achieve stone clearance (10 patients underwent ureterorenoscopy (URS) while five had their stone burden cleared with retrograde intrarenal surgery (RIRS)

Discussion

ESWL remains one of the first-line treatment modalities for renal stones along with percutaneous nephrolithotomy (PCNL), ureterorenoscopy (URS), and retrograde intrarenal surgery (RIRS). It has a significant advantage over other procedures in that it requires no anesthesia in the adult population and is performed as a daycare procedure. This makes it one of the most cost-effective procedures as well. It is, however, limited by some patient characteristics, such as BMI, and stone characteristics, including size and density.
The success rate of stone clearance after ESWL has a wide range, from 46% to 91% in scientific literature. (14) This can be attributed to multiple factors, such as the type of lithotripter used, the number of sessions undergone by a patient, the body habitus of the patient, and the number, size, location, and composition of the stones being produced.(15) The anatomy of the kidney plays an important role in stone clearance, as well as the hydration status of the patient post-procedure and their ambulatory status. A systematic review performed in 2018 identified skin-to-stone distance (SSD) and stone density as independent predictors of stone clearance using ESWL. (16)
To help doctors decide on whether to offer ESWL as a treatment modality and better to counsel their patients, multiple tools and models have been proposed. They usually explore common variables such as patient and stone characteristics. Still, many like the 'Quadruple-D' system incorporating 'D'istance (SSD), 'D'ensity, 'D'imension (stone volume),, and 'D'istribution (stone location) (19), or S3 HoCK score using initials of variables (size, SSD, sex, HU, colic and kidney or ureter) appear too complex for an office setting, requiring specialized software to calculate. (20)
The ESWL score is one such score that can be calculated with ease and helps patients in making informed decisions regarding their stone treatment. It was first proposed by Bengió et al., who retrospectively analyzed 114 patients who underwent ESWL. (12) This score was further explored prospectively by Rasheed et al. in 146 patients. (13) In this study, the overall stone clearance rate was 78.3% which was comparable to that found in scientific literature. It was also considerably higher when compared with Bengió et al. (51%) and Rasheed et al. (67.8%). When comparing ESWL scores, there was higher success for ESWL scores 0 (83.3%), 1 (45%), and 2 (75.4%), and 3 (94.2%) compared to Rasheed et al. 0 (50%), 1 (55.6%), and 2 (66.1%), and 3 (85.7%) respectively. The mean stone size (8.59 ± 2.46 mm) and age (40.64 ± 13.95 years) of participants in this study were comparable to those of Rasheed et al. (8.90 ± 3.09 mm) and (40.89 ± 14.13 years), respectively.
The median BMI was lower in this study compared to Rasheed et al., 24.4 kg/m2 vs 27 kg/m2, respectively, while the median stone density was only slightly higher, 890HU vs 774HU. (13) Pareek et al. reported significantly

lower mean BMI (26.9 ± 0.5 kg/m2) in patients with stone clearance when compared to those with residual stones (30.8 ± 0.9 kg/m2). (19) Therefore, a lower BMI in this study could correspond to better targeting and delivery of acoustic energy for stone fragmentation, which would explain the better clearance rates when compared with those of Rasheed et al.

Also, the most common locations for stones in this study were the middle and lower calyces, whereas the most common location in Rasheed et al. was the pelvis, followed jointly by the middle and lower calyces. This study showed that ESWL can be offered to patients for stones in the lower calyces with an approximately 70% success rate. This is comparable to the literature, where the average stone clearance for stones in the lower calyxes was 61.1%. However, if the infundibulopelvic angle was ≥ 70 degrees, the stone-free rates went up to 81.4%. (20)

In this study, ESWL scores 2 and 3 achieved a stone clearance rate of 75.4% and 94.2% respectively. Having a score of 2 or more increased the ratio of successful stone clearance by nearly 10 times. This finding is comparable to the results published by Bengió et al. (12).. This information can be communicated to patients who often present queries on procedural success. It can aid them in making informed decisions on their healthcare.

No patient in this study underwent DJ stenting before the ESWL procedure. This contrasted with 17.5% who had a prior stent in Bengió et al. Prior stenting is generally recommended for large stone sizes (≥ 15mm), which was not seen in this study. (21) Furthermore, some studies suggest that it may reduce the effectiveness of ESWL by causing hindrance to the delivery of shockwave energy to the stones. (22)

Multiple articles have documented the importance of stone density on ESWL success. (9-11) However, no cut-off value could be universally agreed upon. EUA guidelines suggested a value of 1000 HU. (23) A systematic review compared 28 studies and suggested an optimum range of 750-1000 HU for successful stone clearance using ESWL. (24) Furthermore, there is much heterogeneity in the definition of terms such as high-density and low-density stones. One study focusing on ESWL success in high-density stones labelled all stones having a minimum of 760 HU as high density. (25) Based on this literature, the study attempted to group its sample population into three categories: low, medium, and high density stones. The results, however, showed that although there seemed to be a decrease in stone clearance as patients were moved to a higher category, the difference was not statistically significant. Hence, this should be further explored using a larger sample size.

There are a few limitations of this study, namely that it was a single-center study with a small sample size. The anatomical position of the stones was observed on the NCCT, but the anatomy of the pelvicalyceal system was not considered. The infundibulo-pelvic angle and the infundibular length were not documented, and any ureteropelvic junction obstruction was not ruled out using contrast studies. Plain x-rays KUB are inferior to NCCT for post-ESWL review of stone clearance. They are, however, cost-effective and involve considerably lower doses of radiation. Hence, they were decided as the imaging modality when designing the study. Lastly, to the best of the authors' knowledge, the ESWL Score has not been assessed for ureteral stones, and therefore any conclusions drawn from this data cannot be used for them.

Conclusion

ESWL remains one of the first-line treatment modalities for renal stones. Debate continues regarding optimal stone selection for this modality. This study shows that the ESWL Score is an easy-to-use tool that can reliably predict the success of ESWL. The results suggest that having a score of 2 or more shows a nearly 10 times greater chance of successful stone clearance. Furthermore, this score should be explored in a multicenter prospective trial to validate its predictive capabilities further.

Declarations

Data Availability statement

All data generated or analysed during the study are included in the manuscript.

Ethics approval and consent to participate

Approved by the department concerned. (IRBEC--24)

Consent for publication

Approved

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Conflict of interest

The authors declared the absence of a conflict of interest.

Author Contribution

MARK (Post Graduate Trainee)
Manuscript drafting, Study Design,
SM (Associate Professor)
Review of Literature, Data entry, Data analysis, and drafting articles.
WF (Senior Registrar)
Conception of Study, Development of Research Methodology Design,

All authors reviewed the results and approved the final version of the manuscript. They are also accountable for the integrity of the study.

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