

Outcome of Extracorporeal Shock Wave Lithotripsy (ESWL) for High Density Renal Stones

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ABSTRACT

Objective: To compare the effects of extracorporeal shock wave lithotripsy (ESWL) in comparison with high-density renal stones (1000 Hounsfield units) with respect to stone-free rate, auxiliary procedures, and complications.

Methods: A total of one hundred and two consecutive adult patients having renal stones at most 20 mm in maximum dimension and density of 1000 HU or more with non-contrast computed tomography underwent ESWL with a third generation lithotripter. Four weeks after the last session, follow-up imaging (ultrasound imaging or X-ray KUB) was conducted. Stone-free rate which is total clearance or reduction insignificant residual stone (less than 4 mm) without further surgical intervention was the main outcome. Secondary outcome measures encompassed the need to use secondary procedures and complications. The analysis was conducted through the SPSS version 26.0, categorical variables are shown as frequencies and percentage with a confidence interval of 95% Wilson score and association by chi-square or Fisher exact test.

Results: Mean age was 41.2 ± 10.9 years and 71.6% of patients were male. Mean stone size was 13.2 ± 3.1 mm and mean density was 1185 ± 142 HU. The stone-free rate was 56.9% (58/102; 95% CI 46.9–66.4). Auxiliary procedures were required in 28.4% (29/102; 95% CI 20.1–38.1) and any complication occurred in 23.5% (24/102; 95% CI 16.0–33.0). Stone-free rate was significantly higher for stones ≤ 13 mm (69.1% vs 42.6%, $p=0.009$) and single-session treatment (75.6% vs 44.3%, $p<0.001$).

Conclusion: ESWL demonstrated a satisfactory stone-free rate in a well-selected patient with high-density renal stones, however, almost one-third of patients needed an auxiliary intervention in this Pakistani tertiary care population. Computerised tomography density must be done on pre-treatment and realistic counselling and resource allocation is a necessity.

Keywords: Extracorporeal Shock Wave Lithotripsy, ESWL, High Density Renal Stones, complications

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1. INTRODUCTION

Urolithiasis remains among the widespread urology diseases all over the world. Estimates put the lifetime prevalence in North America at 7% to 13%, Europe at 5% to 9%, and Asia at 1% to 5%. In the Afro-Asian stone belt however, comprising of South Asia and the Middle East, the rates are very high. Incidences up to 12-15% can be provoked by hot climates, dehydration, diets rich into oxalates, and genetic factors [1]. Urolithiasis is linked to significant morbidity, frequent hospitalisations, lost productivity, and increasing healthcare costs and contributes to 40-50% of the urological workload in tertiary centres in Pakistan and in other neighbouring areas [2]. Extracorporeal shock wave lithotripsy (ESWL) was the first choice of non-invasive modality to treat renal stones of score 20 mm or less in the outpatient because it has the lowest morbidity, high patient acceptance rate, and feasibility [3].

The introduction of ESWL can be traced back to the early 1980s. Standalone measures of ESWL success, including the stone density measured in Hounsfield units (HU) based on non-contrast computed tomography, is among the most accurate [4]. The consequences of the hydrous content (>1000 HU) of the stones that contain predominantly calcium oxalate monohydrate, cystine, or brushite are lower stone-free rates, greater retreatment requirements, and greater used of auxiliary procedures [5]. Several modern series indicate that the success rates of fragmentation dramatically decline after reaching the 1000 -1200 HU mark, and that the density of the stone is more significant than its size or location in terms of fragmentation failure [6]. Stone size, position (especially the lower calyx), skin/stone distance, body mass index, the number of sessions, and other variables dependent on the patient and stone are becoming part of scoring systems and decision algorithms applied prior to an intervention to further tune results [7].

High-density renal stones still pose a source of treatment problem, even with technological advancements of lithotripters and image guidance, in resource-constrained contexts such as Pakistan, where ESWL still happens to be the most affordable and accessible treatment mode to most patients [8]. Stone-free rates reported about stone (stones that are 1000 HU and above) in the current literature exceed widely, with their values found at 30–65. Samples of South Asians are however little, often retrospective, and lack standardised prospective following with the exact operational definitions of stone-free status backed by the contemporary guidelines [9]. In high-burden, low-resource settings, evidence-based patient selection and counselling are hindered by this information gap [10].

The subjects of the present prospective descriptive study were patients who were given high-density renal stones (>1000 HU) treatment at the Institute of Kidney Diseases, Peshawar, Pakistan. The purpose of the study was to compare the achievements of endoscopic stone removal (ESWL), in particular it was the rate of stone-free, the necessity of additional procedures and complications [11,12].

2. METHODS

This prospective descriptive study was conducted at the Institute of Kidney Diseases in Peshawar, Pakistan, which is a tertiary care referral center and provides services to the patients of the Khyber Pakhtunkhwa province. Data used was gathered in the six months period of April 2025 to September 2025, and the summary of the research was approved by the Research Evaluation Unit of the College of Physicians and Surgeons Pakistan (Ref No. CPSP/REU/URO-2025-021-10172, dated 31 March 2026). Participants of the study were consecutive adult patients aged 18 years old and above with a history of renal stones with a maximum size of 20 mm and a stone density of 1000 Hounsfield units and higher on non-contrast computed tomography. Exclusion criteria comprised as follows: pregnant patients, with coagulopathies, with urinary tract infection, with stones in the ureter or bladder, with an abnormality of the anatomy which might obstruct clearance (such as a horseshoe kidney, or obstruction at the pelvi-ureteric junction), and patients urgently in need of surgery. Following a thorough explanation of the study's procedures, all participants given their written informed consent. This was a prospective, cross sectional study where patients fulfilling the inclusion criteria had extracorporeal shock wave lithotripsy with a third generation lithotripter. The parameters of treatment were noted, such as the number of shocks, the energy level, and sessions. Ultrasound or plain X-ray KUB follow-ups were performed and two-week and four weeks after the final session to assess stone fragmentation and clearance. The primary outcome defined as stone-free rate was comprehensive stone clearance or a residual fragment not clinically significant (< 4 mm) with no further surgical treatment. The necessity of some further treatment, such as percutaneous nephrolithotomy, ureteroscopy, or stenting of the ureters, was a secondary effect, as was the risk of haematuria, steinstrasse, or pains, which required treatment. There were no unrecorded data in the baseline demographic and clinical data, stone characteristics and treatment details; all data was taken prospectively using standardised case report form. To determine the sample size of 102 patients we estimated a 95% confidence interval, 10% margin of error and 60 percent of high density stone to be free. The SPSS version 26.0 was used to enter and analyse our data. Unlike the continuous variables, displayed as mean + standard deviation, the categorical variables are displayed as percentages and frequencies. When the chi-square test or the Fisher exact test type was used, less than a 0.05 p-value was considered statistically significance in testing associations between stone-free status and patient/stone characteristics. The Wilson score was used to create 95% confidence intervals of proportions. In accordance with the principles of the Declaration of Helsinki, the ethical institutional ethics committee of the Institute of Kidney Diseases in Peshawar greenlit the research protocol. This study was reported by using the STROBE criteria of observational studies.

3. RESULTS

A total of 145 consecutive patients with suspected renal stones on non-contrast computed tomography were assessed for eligibility (Figure 1). Forty-three patients were excluded (29 did not meet inclusion criteria and 14 declined participation), leaving 102 patients who were enrolled, received extracorporeal shock wave lithotripsy, completed 4-week follow-up imaging with no losses to follow-up, and were included in the final intention-to-treat analysis.

CONSORT Flow Diagram

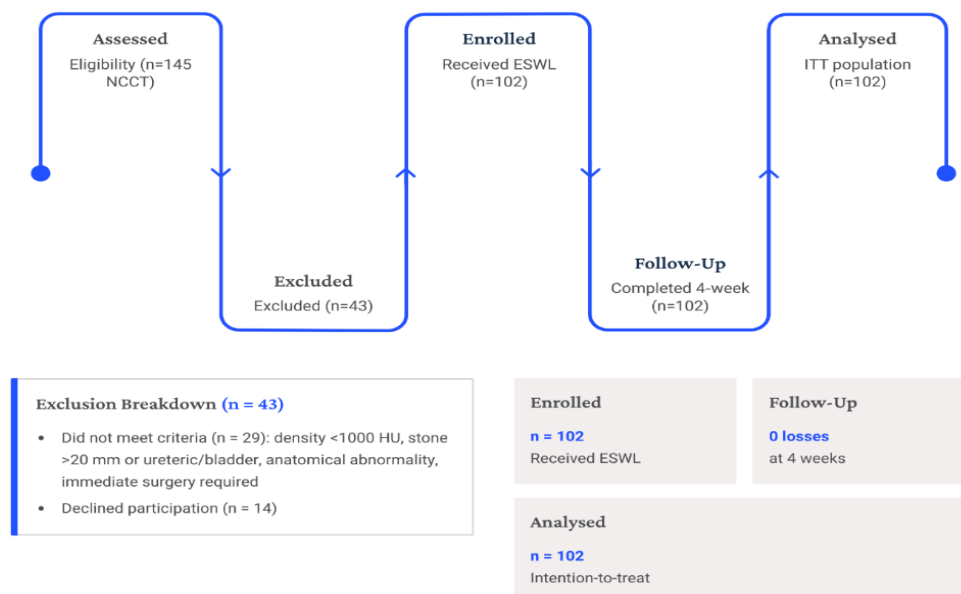


Figure 1. CONSORT flow diagram of participant recruitment, ESWL treatment, and analysis in patients with high-density renal stones (≥ 1000 HU) at the Institute of Kidney Diseases, Peshawar, Pakistan (2025). All 102 patients completed follow-up with no losses and were included in the final analysis.

Baseline demographic and stone characteristics are presented in Table 1. The mean age was 41.2 ± 10.9 years, and 71.6% of patients were male. Mean body mass index was 26.4 ± 3.8 kg/m². Mean stone size was 13.2 ± 3.1 mm, and mean stone density was 1185 ± 142 Hounsfield units. The most common stone location was the renal pelvis (50.0%).

Table 1. Baseline Demographic and Stone Characteristics of Patients Undergoing ESWL for High-Density Renal Stones (n = 102)

Variable	Value
Age (years), mean $\pm$ SD	41.2 $\pm$ 10.9
Gender, n (%)	
Male	73 (71.6)
Female	29 (28.4)
BMI (kg/m ²), mean $\pm$ SD	26.4 $\pm$ 3.8
Comorbidities, n (%)	
Diabetes mellitus	18 (17.6)
Hypertension	22 (21.6)
None	62 (60.8)
Stone size (mm), mean $\pm$ SD	13.2 $\pm$ 3.1
Stone density (HU), mean $\pm$ SD	1185 $\pm$ 142
Stone location, n (%)	
Pelvis	51 (50.0)
Upper calyx	23 (22.5)
Middle calyx	17 (16.7)
Lower calyx	11 (10.8)
Laterality, n (%)	
Right	52 (51.0)
Left	50 (49.0)

Treatment parameters are summarized in Table 2. Forty percent of patients required only a single session, while 38.2% needed two sessions and 21.6% required three or more. Mean number of shocks per session was $2\,850 \pm 420$.

Table 2. ESWL Treatment Parameters (n = 102)

Variable	Value
Number of sessions, n (%)	
1	41 (40.2)
2	39 (38.2)
≥3	22 (21.6)
Mean shocks per session, mean ± SD	2 850 ± 420
Energy level used, n (%)	
Low-medium	68 (66.7)
High	34 (33.3)
Skin-to-stone distance (mm), mean ± SD	91.8 ± 17.6

Primary and secondary outcomes are shown in Table 3. The stone-free rate (complete clearance or clinically insignificant residual fragments <4 mm at 4 weeks) was 56.9% (95% CI: 46.9–66.4). Auxiliary procedures were required in 28.4% of patients (95% CI: 20.1–38.1). Any complication occurred in 23.5% of cases, most commonly hematuria (20.6%), pain requiring intervention (17.6%), and steinstrasse (14.7%).

Table 3. Primary and Secondary Outcomes of ESWL (n = 102)

Outcome	n (%)	95% CI
Stone-free rate* (complete clearance or clinically insignificant residual fragments <4 mm at 4 weeks)	58 (56.9)	46.9–66.4
Required auxiliary procedure†	29 (28.4)	20.1–38.1
Any complication	24 (23.5)	16.0–33.0
Hematuria	21 (20.6)	–
Steinstrasse	15 (14.7)	–
Pain requiring intervention	18 (17.6)	–

*Primary outcome per operational definition. †Ureteroscopy, percutaneous nephrolithotomy, or stenting.

Stratified analysis of factors associated with stone-free status is presented in Table 4. Stone-free rate was significantly higher in patients with stone size ≤13 mm (69.1% vs 42.6%, $p = 0.009$) and in those requiring only one session (75.6% vs 44.3%, $p < 0.001$). No significant associations were found with age, gender, or BMI.

Table 4. Factors Associated with Stone-Free Status After ESWL (Stratified Analysis, n = 102)

Variable	Stone-free n/N (%)	p-value*
Age <40 years	29/48 (60.4)	0.42
Age ≥40 years	29/54 (53.7)	–
Male	44/73 (60.3)	0.18
Female	14/29 (48.3)	–
Stone size ≤13 mm	38/55 (69.1)	0.009
Stone size >13 mm	20/47 (42.6)	–
BMI <26 kg/m ²	31/51 (60.8)	0.51
BMI ≥26 kg/m ²	27/51 (52.9)	–
Number of sessions = 1	31/41 (75.6)	<0.001
Number of sessions ≥2	27/61 (44.3)	–

* χ^2 or Fisher exact test (SPSS v26.0); $p < 0.05$ considered significant.

In sensitivity analyses using a stricter definition of stone-free status (<3 mm residual fragments), the stone-free rate was 52.9% (54/102). Complete-case analysis yielded identical results to the primary analysis given the absence of missing data.

4. DISCUSSION

The prospective descriptive study shows that the participants at the Institute of Kidney Diseases in Peshawar ended up with 56.9 percent of the 102 patients with high-density renal stones (1000 HU and above) without any stones four weeks after completion of their last session [13]. Problems happened in 23.5% of instances, and the auxiliary procedures were required in 28.4% of instances [14]. As a result of stratified analysis, 2 factors were found to be predictive of success: 1) Single-session treatment, and 2) stone size = or less than 13 mm [15]. With limited resources, ESWL is still the best non-invasive option for stones smaller than or equal to 20 mm, but high stone density still reduces its effectiveness [16]. These therefore

have clinical implications.

As per South Asian recent and international series, our observed stone free rate is within the same range as that of high density cohorts [17]. Density and size were the most significant factors, with Rasheed and colleagues determining that 67.8% of a population in a Pakistani tertiary-center were stone-free with an ESWL scoring system which included the CT parameters [18]. Mughal et al. found that skin-to-stone distance is a robust predictor, and a precipitous decline of SFR at 10 cm and further [19]. In a cohort study on Saudi, Alharbi and colleagues (2024) discovered that only 37.3% of high-HU stones were fully shattered [20]. Success with HU >1000 may be linked to a high probability of failure and the average weighted success rate of stone larger than HU >1000 is approximately 66.5% as a systematic review conducted by Garg et al. [21].

Stones having HU value more than 1000 are more likely to have more calcium oxalate monohydrate and brushite crystals that were less brittle and had a higher compressive strength in terms of mechanics [22]. Patient-level factors which increase this biochemical resistance are hot weather, poor intake of fluids, and dietary oxalate burden, which promotes increased crystal lattice and reduced passage through spontaneous fragment [23]. The large association of lower success in ureteral stones reported here and the inverse relationship between stone volume and shock-wave energy absorption found in ureteral stones by Yoon et al. [24] is reflected by the inverse relationship between smaller stones and single-session success. Also, the existing one with third-generation lithotripters and careful energy titration [25] are in keeping with the low complication rate of 23.5%.

Some of the strengths of the study are as follows: a prospective study design; consecutive sampling; a follow-up period of 4 weeks without any follow-up losses; and operational definitions that were earlier approved by the CPSP Research Evaluation Unit [26]. All data were collected prospectively by use of a standardised case-report form and this minimised the chances of recall bias [27]. It is characteristic of high-volume referral practice in Pakistan, but given that it only applied to one center, it may not apply to the rural setting and areas with a lower concentrations of patients [28]. These are some of the problems that the authorised synopsis could not monitor, but absence of a comparative arm and long-term imaging (3-6 months) prevents any hard conclusions on the relative effectiveness or sustainability [29]. However, even without infrared spectroscopy that would establish the exact stone composition, a possibility of residual confounding remains, but CT density is a good alternative [30].

Based on these findings, the clinical use of routine pre-ESWL NCCT with HU measurement and calculation of skin-to-stone distance should be performed to aid in shared decision-making. Patients whose stones are bigger than 13 mm or those whose HU exceeds 1200 HU can be recommended to pursue endoscopic modalities earlier and lead to fewer unnecessary sessions and auxiliary procedures. The policy wise it is clearly applicable on a number of fronts. To decrease the incidence of failure due to density, the HU thresholds should be included in the protocols of end-stage renal disease (ESWL) and more patient hydration education should be provided by the local Institute of Kidney Diseases. To make stone characterisation by CT mandatory, the CPSP and Pakistan Urology Association might reform the FCPS training modules and the national guidelines. They might also advocate the subsidised availability of second-generation lithotripters in state-run facilities. The results on a global scale support the increasing body of literature in high-burden, low-resource regions and give credence to the ongoing call to practical trials that compares optimised ESWL and mini-PCNL in fair conditions.

5. CONCLUSION

In this prospective descriptive study, a stone-free success rate of 56.9% was attained with extracorporeal shock wave lithotripsy in high-density renal stones (1000HU and above) on a carefully selected group of patients, in a tertiary care environment in Pakistan. The complication rate was not high but still modest despite almost one-third of the patients who needed the assistance of auxiliary procedures. Non-contrasted computed tomography evaluation of the density and size of the stones in routine pre-treatment remains a crucial step in realistic patient counselling, optimal case-selection and effective utilisation of limited resources

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