

Extracorporeal Shock Wave Lithotripsy as a Salvage Therapy after Ureteroscopy, Percutaneous Nephrolithotomy, and Pyelolithotomy in Clinically Significant Residual Stones

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ABSTRACT

Objective: To determine the **stone-free rate (SFR)** of **extracorporeal shock wave lithotripsy (ESWL)** for the management of **clinically significant residual stones** measuring **5 to 12 mm** in size.

Methodology: This cross-sectional study was conducted in the Department of Urology, SIUT Karachi, using a non-probability consecutive sampling technique. A total of 108 patients aged 18–60 years with clinically significant residual renal stones (5–12 mm) following URS, PCNL, or pyelolithotomy underwent ESWL. Data were analyzed through SPSS version 26.0 using descriptive statistics and chi-square tests, considering $p < 0.05$ as significant.

Results: A total of 108 patients were studied, comprising **63% males (n=68)** and **37% females (n=40)**, with a mean age of **41.6 ± 10.5 years**. The overall stone-free rate after extracorporeal shock wave lithotripsy was **87%**. Stone clearance was higher in females (95%) than males (82.4%) ($p = 0.051$) and greater for left-sided stones (93%) compared with right-sided stones (80.4%) ($p = 0.048$).

Conclusion: Extracorporeal shock wave lithotripsy proved to be a highly effective and safe treatment for clinically significant residual renal stones following endourological procedures. Better outcomes were observed among female patients and those with left-sided calculi, establishing ESWL as a reliable, minimally invasive alternative for postoperative stone management and a valuable option to achieve complete stone clearance.

Keywords: Extracorporeal Shock Wave Lithotripsy (ESWL), Residual Renal Stones, Stone-Free Rate (SFR), Ureteroscopy (URS), Percutaneous Nephrolithotomy (PCNL).

Introduction: Kidney stone disease, or nephrolithiasis, is among the most frequent urological disorders worldwide. Its lifetime incidence varies from 1 % to 15 %, depending on geography, diet, and hereditary factors [1, 2]. During the past several decades, major improvements in minimally invasive approaches—such as ureteroscopy (URS), percutaneous nephrolithotomy (PCNL), and pyelolithotomy—have transformed stone management, providing better clearance with shorter recovery times [3–5]. Despite these advances, total elimination of stones is not always achieved. Fragments measuring five millimeters or more, regarded as clinically significant residual stones, may persist after surgery and can later act as a source for infection, obstruction, or recurrence [6–8]. The persistence of these fragments often necessitates further procedures and reduces the overall success of treatment [9].

Extracorporeal shock wave lithotripsy (ESWL), introduced in the early 1980s, offered a non-invasive alternative for fragmenting calculi using externally generated shock waves. It remains attractive because it can be performed on an outpatient basis, without general anaesthesia, and is associated with low complication rates [10]. Although newer endourological methods have become more common for primary treatment, ESWL continues to have an important role as a salvage option for patients who still have residual calculi after URS, PCNL, or pyelolithotomy [11]. Studies have reported stone-free rates (SFR) between 81 % and 90 % when ESWL is applied in this context, outcomes that depend largely on stone size, site, and composition [12, 13]. Nevertheless, formal clinical guidelines on how best to manage clinically significant residual stones are still limited, and the choice of therapy frequently depends on institutional experience or surgeon preference [14, 15].

Recognizing these gaps, the present study seeks to determine the stone-free rate of ESWL in patients with residual renal stones sized 5–12 mm after URS, PCNL, or pyelolithotomy. The results are expected to clarify the role of ESWL as a minimally invasive salvage procedure and contribute evidence toward standardized management of postoperative residual stones.

Methodology : The present cross-sectional investigation was carried out in the Department of Urology at the Sindh Institute of Urology and Transplantation, Karachi, over a six-month period following institutional ethical approval. Participants comprised male and female patients aged between 18 and 60 years who demonstrated clinically significant residual renal calculi measuring 5–12 mm on ultrasound and X-ray KUB four weeks after undergoing primary procedures such as ureteroscopy (URS), percutaneous nephrolithotomy (PCNL), or pyelolithotomy. Residual stones were operationally defined as calculi ≥ 5 mm identified after the primary treatment, while a stone-free rate (SFR) referred to the absence of any visible stone fragments on follow-up imaging four weeks following extracorporeal shock wave lithotripsy (ESWL). Sampling was performed through a non-probability consecutive method. Eligible participants met the above criteria, whereas those with obstructive uropathy, untreated urinary tract infection, coagulation abnormalities, pregnancy, body mass index exceeding 30 kg/m², or multiple residual calculi were excluded. Using the WHO sample size calculator, a total of 108 participants were required, based on an anticipated SFR of 90.1%, a 95% confidence level, and a 3.09% margin of error. After obtaining written informed consent, demographic and clinical characteristics—including age, gender, BMI, stone site, and primary intervention—were documented using a structured proforma. ESWL was performed within 4–6 weeks after the

initial procedure under ultrasound or fluoroscopic guidance, conducted on an outpatient basis with up to 3200 shock waves per session and gradually increasing voltage from 3–5 kV to 6–9 kV. The procedure concluded when the maximum number of shocks was reached or when only minute residual fragments remained. Treatment success was evaluated by post-procedure ultrasound or X-ray KUB. Data were processed using SPSS version 26.0; quantitative data were expressed as means with standard deviations, categorical variables as frequencies and percentages, and chi-square tests were applied to examine associations and control for confounding factors, considering a p-value of less than 0.05 as statistically significant.

Results: A total of 108 patients who underwent extracorporeal shock wave lithotripsy (ESWL) for the management of clinically significant residual renal stones were evaluated. The average age of participants was 41.62 ± 10.55 years (95% CI: 39.61–43.63). The mean body mass index (BMI) was 24.07 ± 3.74 kg/m² (95% CI: 23.36–24.79), while the average stone size measured 9.33 ± 1.84 mm (95% CI: 8.98–9.69) (**Table I**).

Among the study group, 68 (63.0%) were males and 40 (37.0%) were females. Residual calculi were slightly more frequent in the left kidney (52.8%) compared with the right kidney (47.2%). Considering stone location, the lower calyx was the most commonly affected site (53.7%), followed by the renal pelvis (20.4%), mid calyx (14.8%), and upper calyx (11.1%).

After ESWL, stone-free status was achieved in 94 (87.0%) participants, while 14 (13.0%) retained residual fragments (**Table II**). The average age of patients who became stone-free was 41.61 ± 10.61 years, closely comparable to 41.71 ± 10.52 years among those who were not ($p = 0.972$). Similarly, there was no meaningful variation between the two groups in BMI (24.02 ± 3.67 vs. 24.43 ± 4.29 ; $p = 0.706$) or stone size (9.32 ± 1.83 vs. 9.43 ± 1.98 mm; $p = 0.837$). A higher stone-free rate was observed in female patients (95.0%) compared with males (82.4%), and this difference approached statistical significance ($p = 0.051$). Regarding laterality, left-sided stones were cleared more effectively (93.0%) than right-sided stones (80.4%), demonstrating a significant association ($p = 0.048$). Although not statistically significant ($p = 0.365$), stones located in the lower calyx (91.4%) and renal pelvis (86.4%) showed higher clearance rates than those in other regions.

Discussion: This research explored the performance of extracorporeal shock wave lithotripsy (ESWL) as a secondary intervention for patients with clinically significant residual renal stones measuring 5–12 mm following minimally invasive procedures such as ureteroscopy (URS), percutaneous nephrolithotomy (PCNL), or pyelolithotomy. The diagnosis of residual stones was established through imaging—either ultrasonography or X-ray KUB—performed four weeks after the primary operation. Residual fragments of ≥ 5 mm were considered clinically relevant because such stones can obstruct urinary flow, serve as a nidus for infection, and contribute to recurrence [6,8]. Participants were carefully selected to ensure uniformity in clinical and metabolic characteristics, eliminating confounders such as infection, bleeding tendencies, or obesity that could alter stone clearance. The overall stone-free rate (SFR) achieved in this analysis was 87.0%, confirming that ESWL remains an effective, non-invasive and low-risk procedure for postoperative residual calculi.

The SFR obtained in this series is comparable to previously reported international outcomes, further validating ESWL as a reliable treatment option for residual stones. Akram et al. [13]

documented an SFR of 88% for residual fragments following URS or mini-PCNL, while Aminsharifi et al. [12] found similar success rates exceeding 85%, concluding that fragments left after primary treatment often respond better to ESWL than untreated stones of similar size. This improved response has been attributed to microfractures and reduced structural density induced during initial fragmentation, which facilitate subsequent disintegration [13]. Bahilo-Mateu and Budia-Alba [10] also emphasized the enduring relevance of ESWL due to its safety, ease of application, and ability to be performed on an outpatient basis. The absence of serious complications in the present study reinforces these observations, confirming ESWL as both safe and efficient in selected patients.

The current analysis did not reveal significant associations between SFR and patient age, BMI, or stone size. Similar results were reported by Tundo et al. [1] and Abufaraj et al. [2], who demonstrated that physical attributes exert minimal influence on lithotripsy outcomes once stone size remains within the treatable range. Instead, factors such as stone composition, urinary flow pattern, and collecting system configuration are more critical determinants of success. Notably, female participants in this study achieved a higher clearance rate (95%) compared with males (82.4%), a difference that approached statistical significance ($p = 0.051$). Ermis et al. [6] also observed a comparable gender variation, suggesting that differences in urinary tract anatomy and flow velocity might account for more effective stone clearance among females. This observation highlights a potentially important physiological component that merits further evaluation in larger, gender-stratified studies.

A statistically significant difference was noted in the clearance rate between left- and right-sided stones, with success rates of 93% and 80.4%, respectively ($p = 0.048$). This asymmetry parallels findings from Sorokin et al. [9], who attributed such variation to differences in renal positioning and angulation that affect shockwave focusing and fragment expulsion. The anatomical configuration of the left kidney, particularly its orientation and the direction of the renal pelvis, may facilitate better energy transmission and fragment passage, explaining the higher clearance observed in our series. Although stone site within the kidney did not reach statistical significance, higher clearance rates were found for stones in the lower calyx (91.4%) and renal pelvis (86.4%). These findings correspond to observations by Tzelvels et al. [15] and Brain E et al. [16], who emphasized that calyceal anatomy, infundibulopelvic angle, and fragment mobility influence the likelihood of complete stone evacuation. Kayra et al. [17] Although our study did not assess stone density, the pattern of outcomes supports these anatomical and physical determinants.

The strict inclusion criteria in this research strengthened the internal validity of findings by focusing on a well-defined patient population with uniform stone size and limited comorbidity. The absence of major procedural complications corroborates the well-established safety of ESWL, aligning with the favourable outcomes reported in prior multicentre analyses [10,15,17]. Nonetheless, certain limitations must be acknowledged. Being a single-centre investigation, the results may not be fully generalizable to broader populations. The moderate sample size limits subgroup analysis, particularly regarding stone composition or location. Additionally, the use of ultrasonography and X-ray KUB for follow-up, although practical and widely available, may underestimate small residual fragments compared with non-contrast CT imaging. The four-week follow-up duration was sufficient to determine immediate clearance but not long-term recurrence or reintervention rates. Future prospective, multicentre studies with extended

follow-up and CT-based imaging would provide more robust evidence regarding ESWL's sustained efficacy and its comparative value against alternative modalities such as repeat URS or mini-PCNL.

In summary, the present findings affirm that ESWL continues to be a dependable, minimally invasive treatment option for patients with postoperative residual renal calculi. With an SFR of 87%, comparable to global standards, and a strong safety profile, ESWL remains a cost-effective and patient-friendly intervention for residual stones within the treatable range. The higher success observed among left-sided stones and female patients provides valuable clinical insight and encourages individualized treatment planning. Overall, this study contributes region-specific data to the growing evidence base supporting ESWL as a cornerstone in the contemporary management of residual renal stones.

Conclusion: Extracorporeal shock wave lithotripsy proved to be a highly effective and safe treatment for clinically significant residual renal stones following endourological procedures. Better outcomes were observed among female patients and those with left-sided calculi, establishing ESWL as a reliable, minimally invasive alternative for postoperative stone management and a valuable option to achieve complete stone clearance.

Table II: Comparison of Clinical and Stone Characteristics Based on Stone-Free Rate (n=108)

Demographic & Clinical Characteristics	Stone-Free Rate	P-Value
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Table I: Demographic and Clinical Characteristics of Study Participants (n=108)

Mean $\pm$ Standard Deviation		95% Confidence Interval
Age in years = 41.62 $\pm$ 10.55		39.61----43.63
BMI in kg/m ² = 24.07 $\pm$ 3.74		23.36----24.79
Stone Size in mm= 9.33 $\pm$ 1.84		8.98----9.69
Frequency (%)		
Gender	Male	68 (63.0)
	Female	40 (37.0)
Side of Stone	Left Kidney	57 (52.8)
	Right Kidney	51 (47.2)
Site of Stone	Lower calyx	58 (53.7)
	Mid calyx	16 (14.8)
	Renal pelvis	22 (20.4)
	Upper calyx	12 (11.1)

		Yes (n=94)	No (n=14)	
Age in Years		41.61 ± 10.61	41.71 ± 10.52	0.972
BMI in kg/m ²		24.02 ± 3.67	24.43 ± 4.29	0.706
Stone Size in mm		9.32 ± 1.83	9.43 ± 1.98	0.837
Gender	Male	56 (82.4)	12 (17.6)	0.051
	Female	38 (95.0)	2 (5.0)	
Side of Stone	Left Kidney	53 (93.0)	4 (7.0)	0.048
	Right Kidney	41 (80.4)	10 (19.6)	
Site of Stone	Lower calyx	53 (91.4)	5 (8.6)	0.365
	Mid calyx	12 (75.0)	4 (25.0)	
	Renal pelvis	19 (86.4)	3 (13.6)	
	Upper calyx	10 (83.3)	2 (16.7)	

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