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Original Research Article

Comparison of Stone Clearance in Mini-Percutaneous Nephrolithotomy Versus Extracorporeal Shock Wave Lithotripsy in Patients with Small Renal Calculi

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Abstract: *Nephrolithiasis is a common urological condition, with prevalence ranging between 1% and 19.1% in South Asia, including Pakistan. Management depends on stone size, location, and patient characteristics. Extracorporeal Shock Wave Lithotripsy (ESWL) is a non-invasive treatment with variable success rates. In contrast, mini-percutaneous nephrolithotomy (mini-PCNL) is a minimally invasive procedure that offers higher stone clearance rates. The choice of modality is crucial for stones ≤1.5 cm, where an optimal balance between efficacy and invasiveness is required.* ***Objective:*** *To compare stone clearance rates between mini-PCNL and ESWL in patients with small renal calculi (≤1.5 cm).* ***Methods:*** *This randomized controlled trial was conducted at the Department of Urology, Sir Ganga Ram Hospital, Lahore, in collaboration with Jinnah Hospital, Lahore, from November 2024 to April 2025. Ninety-two patients who met the eligibility criteria were randomized into two groups: Mini-PCNL (n = 46) and ESWL (n = 46). Data on demographics, stone size, and location were recorded. Stone clearance was defined as the absence of residual calculi confirmed by ultrasound KUB and X-ray KUB—on postoperative day 1 for mini-PCNL and at 4 weeks for ESWL. Data were analyzed using SPSS v22. A chi-square test was applied, with a p-value of ≤ 0.05 considered statistically significant.* ***Results:*** *The mean age was 35.8 ± 12.9 years, with males comprising 73.9% of the sample. The mean stone size was 11.2 ± 3.3 mm. The overall stone-free rate was 64.1%. In the mini-PCNL group, stone-free rate was 65.2% compared to 63% in the ESWL group (p = 0.82). Subgroup analysis revealed that for stones 10–15 mm, mini-PCNL achieved a significantly higher clearance (65.2%) compared to ESWL (29.4%). Stones <10 mm, present only in the ESWL group, showed an 86.2% clearance rate.* ***Conclusion:*** *Mini-PCNL and ESWL showed comparable overall clearance rates for renal stones ≤1.5 cm. However, ESWL was more effective for stones <10 mm, while mini-PCNL demonstrated superior clearance for stones 10–15 mm. Thus, ESWL is preferable for smaller calculi, whereas mini-PCNL should be considered for larger stones requiring a single-session definitive treatment.*

Keywords: Nephrolithiasis, Mini-percutaneous nephrolithotomy, Extracorporeal shock wave lithotripsy, Stone clearance, Small renal calculi.

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Introduction

Nephrolithiasis is one of the prevalent conditions affecting human health to a significant extent worldwide (1). In South Asia, including Pakistan, about 1% - 19.1% of the population suffers from nephrolithiasis. The incidence of nephrolithiasis reaches its peak in the population aged 30 years and older. Males are more likely to suffer from urinary calculi than females (2). The kidney is the most common site for the development of urinary tract stones. Across the world, a rise in the prevalence of diseases related to nephrolithiasis has been observed, which is considered to be affected by diet, hot weather, lifestyle, hereditary factors, and comorbidities (3). The rise in the incidence of renal stones creates a need for an effective and safe treatment option.

Stone management depends on various factors, including stone size, location, patient habitus, and the anatomy of the renal collecting system (4). Different modalities have been introduced to manage these stones. Some of these procedures are non-invasive, such as Extra-Corporeal Shock Wave Lithotripsy (ESWL), while others are invasive, including Retrograde Intrarenal Surgery (RIRS) and Percutaneous Nephrolithotomy (PCNL). Among invasive modalities, some are minimally invasive, such as mini-Percutaneous Nephrolithotomy (mini-PCNL).

Many urologists and patients prefer Extracorporeal Shock Wave Lithotripsy (ESWL) because it is a low-morbidity outpatient procedure (5-7). It is a non-invasive treatment with a success rate ranging from 40% to 80%.[8] However, the popularity of ESWL has been reduced during the past years due to numerous factors, e.g., High failure rate in lower pole stones, staghorn stones, comparatively high retreatment rate, and dependency on lithotripter efficacy, etc (9).

Sometimes, the patient opts for a single procedure, which can achieve complete stone clearance. Additionally, some professions require complete stone clearance before the person can return to their job. Mini-PCNL, a minimally invasive variant of PCNL, provides a comparable stone-free rate and lower retreatment rates for kidney stone disease (10). Instead, in some studies, the stone-free rate is higher in mini PCNL than in ESWL (11-14). One study found that the success rate of mini-PCNL was 92.4% in only one session (11). At the same time, other trials yielded a 78.2% to 88% success rate for mini-PCNL (12-13). However, being an invasive procedure, there is always a risk of hemorrhage and nearby organ damage, such as the spleen, liver, and colon.

The rationale of this study was to compare the stone-free rates in mini-PCNL and ESWL for the management of patients with kidney stones of up to 1.5cm in size. This will help improve our practice, facilitate accurate early management of patients, and reduce future disease complications. Patients will also receive cost-effective treatment and a healthier lifestyle due to the accurate, selective method of treatment. OBJECTIVE: To compare the stone clearance rate in mini-percutaneous nephrolithotomy versus extracorporeal shock wave lithotripsy in patients with small renal calculi.

Methodology

Randomized Controlled Trial. Department of Urology, Sir Ganga Ram Hospital, Lahore, in collaboration with Department of Urology, Jinnah Hospital, Lahore, for ESWL. At the same time, PCNL was done at Sir Ganga Ram Hospital, Lahore. From November 2024 to April 2025 (6 months). The calculated sample size was 80 (40 patients in each group), using an 80% power of the study, a 5% level of significance, and a percentage of stone-free status of 95.3% for mini PCNL and 75% for ESWL. However, after adding a 20% dropout rate, the total sample size will be 92 (46 in each group).[15]

Were,

$Z_{1-\alpha} = 1.96$, where alpha (α) = significance level = 0.05

$Z_{1-\beta} = 0.842$, where beta (β) = power of study = 0.80

P_1 = anticipated proportion of population for Mini-PCNL = 0.953.[15]

P_2 = anticipated proportion of population for ESWL = 0.75.[15]

$$n = \frac{\{z_{1-\alpha}\sqrt{2\bar{P}(1-\bar{P})} + z_{1-\beta}\sqrt{P_1(1-P_1)+P_2(1-P_2)}\}^2}{(P_1-P_2)^2}$$

Nonprobability, consecutive sampling technique. Patients aged between 18 and 45 years. Both genders are diagnosed with a kidney stone—patients with kidneys in their normal anatomical position and a renal stone (as per operational definition). Patent distal patency confirmed by CT urogram. Renal stone size up to 1.5cm. Patients with multiple renal stones, Morbid obesity with BMI >35, and Patients with previous surgery for renal stones. Pregnant patients with renal calculi were enrolled in the study after obtaining approval for the research project from the institutional ethical review committee of Fatima Jinnah Medical University/Sir Ganga Ram Hospital, Lahore. A total of 92 patients fulfilling the selection criteria were enrolled at the Department of Urology, Sir Ganga Ram Hospital, Lahore. Two groups were formed using the lottery method: Group A (Mini-PCNL) and Group B (ESWL). Stone size was recorded from the ultrasound report. The feasibility and availability of both procedures were explained to the patients, and they were allowed to decide on the type of procedure they preferred**.** Patients were consecutively selected until our sample size for each group was complete. Informed consent was obtained from each patient. Demographic details (name, age, and gender, location of stone, duration, and size of stone) were noted.

The data were entered and analyzed using SPSS version 22. Quantitative variables, such as age and stone size, were calculated as the mean and standard deviation. The qualitative variables, i.e., gender, location of stone, and stone-free status, were presented as frequency and percentage. The data were stratified by age, gender, location, and stone size. Post-stratification, both groups were compared for stone-free status using a chi-square test for each stratum. P-value≤0.05 was considered significant.

Results

There were 46 patients in each group, i.e, mini-PCNL and ESWL. The mean age of the participants was 35.8 ± 12.9 years. 26.1% (n=24) were female, while 73.9% (n=68) were male. The location of stones was determined using Ultrasound KUB, and 2.2% (n=2) were in the upper pole, 29.3% (n=27) were in the mid-kidney, 28.3% (n=26) were in the lower pole, and 40.2% (n=37) were at the renal pelvis. 52.2% (n=48) of stones were located in the right kidney, while 47.8% (n=44) were located in the left kidney. The mean stone size was 11.2±3.33mm (Range: 5.6 mm-15 mm).

The overall stone-free rate for all participants was 64.1% (n = 59).

In the Mini-PCNL group, the mean Stone size was 12.5 ± 2.50 mm. There were no stones smaller than 10mm in this group. The stone-free rate was 65.2% (n = 30). In the ESWL group, the mean Stone size was 11mm ± 4 mm. Stone-free rate was 63% (n=29). There was no significant difference between the two groups in terms of stone-free status (p = 0.82). Stones were further stratified into two groups: Group 1 for stones with a size of 0-10mm and Group 2 for stones with a size of 10mm-15mm, to compare the stone-free rate between the two groups for different stone sizes. Mini-PCNL data had no stone sizes less than 10mm, whereas ESWL did, and this represented a data bias. Group 2 (10-15mm) was compared, revealing a significant difference in stone-free rates between these two modalities. In the min-PCNL group, 63% of stones were cleared, compared to 29.4% in the ESWL group.

Chi-square analysis revealed a significant difference in stone-free status and stone sizes between 10 and 15mm, indicating that larger stones were cleared less frequently compared to smaller stones. 29.4% of stones of this size were cleared in the ESWL group, whereas small-sized stones were cleared in 86.2% of patients.

65.2% of stones were cleared in the mini-PCNL group, which were of sizes 10mm to 15mm.

Table 1: Chi-square test to assess if any difference exists between stone-free status and stone size for the ESWL group

ESWL group		**Stone Size 10-15mm**		**Total**	**P-value**
		Yes	No		
Stone free	Yes	5	25	30	0.001
	No	12	4	16	
Total		17	29	46	

Table 2: Chi-square test to assess if any difference exists between stone-free status and stone size for the Mini-PCNL group

Mini-PCNL group		**Stone Size 10-15mm**		**Total**	**P-value**
		Yes	No		
Stone free	Yes	29	0	29	.
	No	17	0	17	
Total		46	0	46	

Table 3: Shows the odds ratio of stone clearance for ESWL vs Mini-PCNL for stone sizes between 10mm and 15mm

		Stone Size 10-15mm		**Total**	**Odds Ratio**
		ESWL	Mini-PCNL		
Stone free	Yes	5	29	34	0.24
	No	12	17	29	
Total		17	46	63	

Odds of stone-free rate for ESWL vs Mini-PCNL: (5/12) / (29/17): 0.41/1.70= 0.24

Discussion

Our results found that, on average, patients were in their third decade of life when they presented with renal stones. This is keeping in mind that most people affected are usually between the ages of twenty and fifty; thus, our participants mostly fell into this category (16). Similarly, we found that 73.9% were males, nearly three times as many as females. This is also keeping in view the epidemiological trend of men being affected more commonly than women by 2 to 3 times (17). There was no difference between the two groups in terms of gender.

Stones in our cohort were most commonly found in the pelvis at 40.2%, followed by the mid kidney and the lower pole at 29.3% and 28.3%, respectively. The upper pole had the least incidence of 2.2%. International literature suggests that lower pole stones are the most common; however, in our patients, this was the third most common position (18).

Overall, participants had a stone-free rate of 64.1%. A review of the literature revealed that stone-free status is highly variable, regardless of the modality used, and may range from 12% to 97% (19). Most commonly, however, the stone-free status lies between 60% to 70% for most series. There is no universally accepted rate for achieving stone-free status. Thus, it is challenging to establish the efficacy of a modality, mainly since stone-free status is determined for both primary and secondary interventions. Most studies suggest that stone-free status improves after a second session or intervention, regardless of the technique or intervention modality used. PCNL, however, may be superior to other modalities, while ESWL may require the most repeated sessions (20-23).

In this study, the stone-free rate was 65.2% for our mini-PCNL group and 63% for our ESWL group. There was no difference in stone-free status between the two groups, with a p-value of 0.82. However, for the ESWL group, it was found that stones less than 10mm had greater clearance compared to stones larger than 10mm, at 81.6% vs 29.4%, respectively. Since the mini-PCNL group only had stones of sizes 10mm to 15mm, the 65.2% stone-free rate of this group was for this stone size, which is more than twice the stone-free rate of the ESWL group of the same stone size. Thus, although this study was unable to demonstrate a difference in stone-free status between the two groups, a subgroup analysis revealed that clinically significant stone clearance occurs more frequently with mini-PCNL for larger stones compared to ESWL, suggesting that it may be the preferred minimally invasive intervention. Thus, it is reasonable to conclude that ESWL is a promising modality for stones of sizes less than 10mm; however, for stone sizes between 10mm and 15mm, mini-PCNL may be a better alternative modality for stone clearance in a single session.

A study conducted in India comparing mini-PCNL to ESWL found that renal pelvic stones were the most common, followed by stones in the lower pole and middle calyx. They found that the stone-free rate was higher for the mini-PCNL group in a single session, at 89.1%, compared to ESWL, where more than 20% of patients required a second sitting and 5% needed a third, resulting in an overall stone-free status of 88%. However, a stone size grouping and analysis was not available. Patients with stones measuring 15mm or larger underwent initial mini-PCNL, whereas those with smaller stones underwent ESWL, followed by mini-PCNL if treatment failure occurred. Sub-group analysis of stone-free status based on stone size would significantly contribute to the existing literature, as we have done in our study, and enhance decision-making processes (24).

Another study was conducted by A. El-Mesery et al. (25). This study, conducted in Egypt, shared their experience with mini-PCNL. A total of 70 patients with non-lower-pole stones were treated using both modalities. Stone size was 10-20 mm. They found that the overall operative time was considerably shorter in the mini-PCNL group (median: 50.00; IQR: 20.00) compared to the ESWL group (median: 55.00; IQR: 28.00) ($p = 0.001$). The overall fluoroscopy time was significantly lower in mini-PCNL than in ESWL (3.2 versus 3.6 minutes, $p = 0.040$). In the mini-PCNL group, 94.1% patients were stone-free. In the ESWL group, only 30.1% were rendered stone-free after the third ESWL session. The SFR was significantly higher in the mini-PCNL group ($p < 0.001$). In the mini-PCNL group, none of the cases needed a second-look PCNL.

A study conducted by Radwan AI et al. (26) involved a total of 90 patients, randomized into either an ultra-mini-PCNL group or a stented SWL group using the closed-envelope technique, with 45 patients in each group. They found that stone-free status was higher after mini-PCNL for stone sizes between 10 and 20mm than after stented ESWL. The need for retreatment was slightly higher in the ESWL group than in the PCNL group. Their study reinforces the claim that mini-PCNL achieves a higher stone-free status than ESWL in a single session, as evident in our study data.

A study done by Saygin et al (27). compared the stone-free status for patients undergoing mini-PCNL and ESWL. Stone sizes included were less than 20mm. The stone-free status for ESWL was 70%, and for m-PCNL, it was 93.3%. This reveals a significant difference in overall clearance rates.

A systematic review of mini-PCNL found a 89% stone-free status for a mean stone size of 13.9mm. Our mean stone size was 14.5mm, which may be the reason why our overall stone-free rate was 63% due to a larger mean stone size. This is an important consideration for understanding our results in light of the literature, rendering our results comparable to those in the literature (28).

Wagenius et al (29). Found that for ESWL in stones smaller than 20mm, stone size was an independent factor for stone clearance, and small stones were more likely to be cleared. They recorded the chances of stone-free status with a 10mm stone at up to 90%, for a 13mm stone at up to 80%, and this decreased further to 60% for stone sizes exceeding 15mm. Our results for ESWL have similar findings for that age group.

Another study comparing ESWL success in renal stones and stone size found that overall success was 64.7%, which is similar to our patients' results. They found that stone sizes between 10 and 50 mm had successful ESWL in 54.9% of patients, while those with stones measuring 1-2 cm had success in 45.1% of patients. We were able to demonstrate a higher success rate for stones smaller than 13mm, compared to the 54.9% found in this study, and a significantly lower percentage of success was observed in the 13mm to 15mm category. However, as this study also shows, smaller stones are more amenable to ESWL than larger stones (30).

Overall, we can garner from the literature that mini-PCNL performs better than ESWL for stones larger than 1cm. There is also less morbidity and a lower cost of repeated sessions. Mini-PCNL results from the literature show less variable outcomes for stone clearance, ranging between 80% and 90%, whereas our study has a lower stone-free rate of 65.2%, likely due to a higher mean stone size of 14.5mm. Further studies are needed to measure the maximum size of stone that can be effectively treated with mini PCNL with low morbidity.

Conclusion

Mini-PCNL has an acceptable stone-free rate for small-sized renal stones compared to ESWL, but can be a preferable modality for stones larger than 10 mm.

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

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Manuscript drafting, Study Design,
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MZA (Associate Professor)
Conception of Study, Development of Research Methodology Design,
SUI (Professor)
Study Design, manuscript review, and critical input.
MZ (Health manager)
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Review of Literature, Data entry, Data analysis, and drafting an article.

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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