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Mini-Percutaneous Nephrolithotomy versus Retrograde Intrarenal Surgery for Solitary 1-2 cm Renal Stones: A Quasi-Experimental Comparative Study

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ABSTRACT

Objective: To compare the efficacy and safety of Mini-Percutaneous Nephrolithotomy (Mini-PCNL) and Retrograde Intrarenal Surgery (RIRS) for solitary renal stones measuring 1-2 cm.

Study Design: Quasi-experimental study.

Place and Duration of Study: Armed Forces Institute of Urology, Rawalpindi, conducted from Oct 2025 to Jan 2026.

Methodology: A total of 100 patients were enrolled by non-probability consecutive sampling and allocated to Mini-PCNL (n=50) or RIRS (n=50). Eligible patients were adults aged 18-60 years with a solitary 1-2 cm renal stone. Stone-free rate at four weeks, operative time, hospital stay, postoperative pain, and complications were compared between groups.

Results: Mini-PCNL achieved a higher stone-free rate than RIRS (90.0% vs. 74.0%, p=0.037) and had a shorter operative time (68.4 ± 15.2 min vs. 85.7 ± 20.2 min, p<0.001). RIRS was associated with a shorter hospital stay (median 3.35 [IQR 3.00–3.88] days vs. 4.57 [4.01–4.97] days, p<0.001) and lower pain scores on postoperative days 1 and 2 (p<0.001). Overall complication rates were comparable (24.0% vs. 20.0%, p=0.629).

Conclusion: Mini-PCNL provided better stone clearance and shorter operative time, whereas RIRS offered less postoperative pain and shorter hospitalization. Procedure selection should be individualized according to clinical priorities and patient preference.

Keywords: Hospital Stay; Kidney Calculi; Nephrolithiasis; Percutaneous Nephrolithotomy; Postoperative Pain; Retrograde Intrarenal Surgery; Stone-Free Rate; Treatment Outcome; Ureteroscopy.

How to Cite This Article: *Jogezai AK, Zia Q, Kakar A, Tahir M, Tareen F, Ahmed N. Mini-Percutaneous Nephrolithotomy versus Retrograde Intrarenal Surgery for Solitary 1-2 cm Renal Stones: A Quasi-Experimental Comparative Study. Pak Armed Forces Med J 2026; 76(Suppl-8): S1388-S1392. DOI: https://doi.org/10.51253/pafmj.v76i2.14578*

INTRODUCTION

Renal stone disease is a common recurrent urological condition and remains an important cause of emergency visits, outpatient consultations, hospital admissions, and repeated surgical intervention. Its burden has increased with dietary changes, low fluid intake, obesity, sedentary lifestyle, metabolic disorders, and rising environmental temperatures. Global evidence shows a continuing increase in urolithiasis, with about 106 million incident cases reported in 2021.[1-3] The problem is also relevant in Asia and Pakistan, where populations in the stone belt are affected; local studies have linked stone disease with male gender, young to middle age, inadequate fluid intake, family history, higher body mass index, rural residence, and socioeconomic factors.[4,5]

Solitary renal stones measuring 1-2 cm are frequently encountered in clinical practice and fall into an intermediate treatment zone where more than one operative option may be suitable. International guidance recommends that treatment choice should consider stone size, location, renal anatomy, symptoms, patient factors, and available expertise.[6,7] Mini-Percutaneous Nephrolithotomy (Mini-PCNL) uses a smaller percutaneous tract to improve clearance while reducing tract-related morbidity, whereas Retrograde Intrarenal Surgery (RIRS) uses flexible ureteroscopy and laser lithotripsy through the natural urinary tract. Current evidence suggests that percutaneous techniques may achieve higher stone-free rates, while RIRS may offer less postoperative pain and shorter recovery.[8]

However, published results vary because studies differ in stone location, imaging used to define stone-free status, residual fragment thresholds, surgeon experience, and inclusion of solitary versus multiple stones. Local comparative evidence remains limited, especially in resource-sensitive centres where equipment availability, inpatient stay, cost, and patient affordability influence treatment choice. Therefore, this quantitative comparative study was conducted to compare Mini-PCNL and RIRS for

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Received: 18 Jun 2026; revision received: 08 Jul 2026; accepted: 09 Jul 2026

solitary 1-2 cm renal stones, using stone-free rate, operative time, hospital stay, postoperative pain, and complications as measurable outcomes to support evidence-based counselling in local practice.

METHODOLOGY

This quasi-experimental study was conducted at the Armed Forces Institute of Urology (AFIU), Rawalpindi, from Oct 2025 to Jan 2026 after synopsis approval. Sample size was calculated using the WHO sample size calculator taking 95% confidence level, 5% margin of error, 80% test power, and expected proportions of 83.34% for Mini-PCNL and 26.66% for RIRS from a previous study. The estimated sample size came out to be 100 patients (50 in each group). Eligible patients were enrolled through non-probability consecutive sampling and were allocated non-randomly to either Mini-PCNL or RIRS. Ethical approval was obtained from the Ethical Review Board (Uro-Trg-1/IRB/2025/16) on 25 March 2025, and the study was initiated after synopsis approval by the College of Physicians and Surgeons Pakistan (CPSP). Written informed consent was obtained from all patients before enrolment.

Inclusion Criteria: Patients were included if they were 18-60 years of age, of either gender, had a solitary renal stone measuring 1-2 cm located in any intrarenal calyx or the renal pelvis, and were planned for treatment by either Mini-PCNL or RIRS.

Exclusion Criteria: Patients were excluded if they had multiple renal stones, bilateral renal stones, a stone burden outside the 1-2 cm range, anatomical abnormalities affecting the collecting system, chronic kidney disease, bleeding disorders, urinary tract infection, pregnancy, or significant medical comorbidities likely to confound perioperative outcomes.

The exposure variable was the operative technique, either Mini-PCNL or RIRS. The primary outcome was stone-free status at four weeks after surgery. Secondary outcomes included operative time, length of hospital stay, postoperative pain measured on a Visual Analog Scale (VAS) on the first and second postoperative days, and perioperative complications. Baseline variables included age, gender, comorbidities, stone size, and stone location (Figure).

Baseline data were obtained from patient history, physical examination, laboratory investigations, and imaging records. Stone size and location were recorded from preoperative imaging. Stone-free status at four weeks was assessed using non-contrast computed tomography or ultrasound kidney-ureter-bladder according to clinical availability. Pain scores were recorded using the VAS. Complications were documented from the perioperative and postoperative clinical record. The same outcome definitions were applied in both treatment groups.

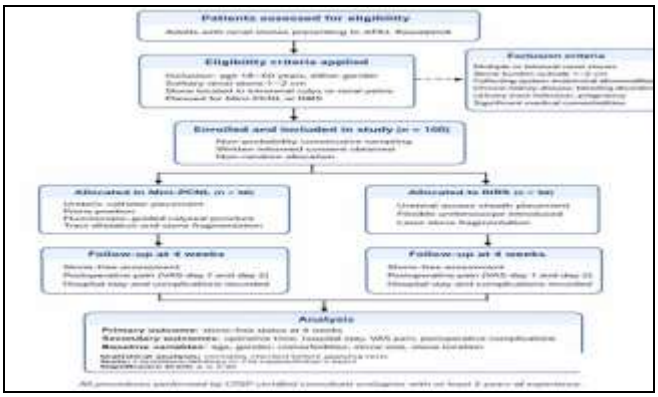

Figure: Patient Flow Diagram

All procedures were performed by CPSP-certified consultant urologists with at least five years of experience. In the Mini-PCNL group, ureteric catheter placement was followed by prone positioning, fluoroscopic-guided calyceal puncture, tract dilatation, and stone fragmentation. In the RIRS group, a ureteral access sheath was placed, a flexible ureteroscope was introduced, and the stone was fragmented using laser energy. Data were recorded systematically on a structured proforma.

Bias was reduced by applying eligibility criteria before allocation, comparing baseline variables between groups, using experienced surgeons for both techniques, and applying identical postoperative outcome definitions.

Data were entered and analyzed using Statistical Package for the Social Sciences (SPSS) version 27.0. Normality of quantitative variables was assessed using the Shapiro-Wilk test and by visual inspection of histograms and Q-Q plots. Normally distributed quantitative variables (stone size, operative time, and day-1 VAS pain score) were summarized as mean ± standard deviation and compared using the independent-samples t-test, while non-normally distributed quantitative variables (age, hospital stay, and day-2 VAS pain score) were summarized as median with interquartile range and compared using the Mann-Whitney U test. Categorical variables, including gender, stone location, comorbidities, stone-

free status, and complications, were summarized as frequencies and percentages. Pearson Chi-square test was used when all expected cell counts were ≥5; Fisher's exact test was used when any expected cell count was <5. The *p*-value ≤0.05 was considered statistically significant.

RESULTS

A total of 100 patients with solitary renal stones measuring 1-2 cm were analyzed, with 50 patients in the Mini-PCNL group and 50 patients in the RIRS group. Baseline characteristics were statistically comparable between groups: age (median 47.5 [IQR 38.3–53.8] vs. 44.0 [34.3–53.8] years, *p*=0.475), gender distribution (male: 64.0% vs. 58.0%, *p*=0.539), stone size (1.52 ± 0.28 vs. 1.49 ± 0.26 cm, *p*=0.572), stone location (*p*=0.815), and comorbidities (22.0% vs. 26.0%, *p*=0.640).

Table-I: Baseline Demographic and Clinical Characteristics of the Study Patients (n=100)

Characteristic	Mini-PCNL Group (n=50)	RIRS Group (n=50)	*p*-value
Age (years), Median (IQR)	47.5 (38.3–53.8)	44.0 (34.3–53.8)	0.475
Gender, n (%)			0.539
Male	32 (64%)	29 (58%)	
Female	18 (36%)	21 (42%)	
Stone Size (cm), Mean ± SD	1.52 ± 0.28	1.49 ± 0.26	0.572^
Stone Location, n (%)			0.815
Renal Pelvis	15 (30%)	18 (36%)	
Lower Calyx	22 (44%)	20 (40%)	
Middle/Upper Calyx	13 (26%)	12 (24%)	
Comorbidities, n (%)	11 (22%)	13 (26%)	0.640^

**Mini-PCNL=Mini-Percutaneous Nephrolithotomy; RIRS=Retrograde Intrarenal Surgery; SD=standard deviation. p-values were calculated using independent-samples t-test for normally distributed quantitative variables and Mann-Whitney U test for age (non-normally distributed), and Chi-square/Fisher's exact test for categorical variables. ^The p-values of 0.572 for stone size and 0.640 for comorbidities are correct and reflect non-significant differences between groups at baseline.*

In outcome analysis, Mini-PCNL demonstrated a significantly higher stone-free rate than RIRS (45/50, 90.0% vs. 37/50, 74.0%; *p*=0.037) and a significantly shorter operative time (68.4 ± 15.2 vs. 85.7 ± 20.2 minutes; *p*<0.001). RIRS demonstrated a significantly shorter hospital stay than Mini-PCNL (median 3.35 [IQR 3.00–3.88] vs. 4.57 [4.01–4.97] days; *p*<0.001) and significantly lower postoperative VAS pain scores on day 1 (2.30 ± 0.58 vs. 5.24 ± 0.43; *p*<0.001) and day 2 (median 1.50 [IQR 1.10–1.80] vs. 3.90 [3.60–4.28]; *p*<0.001). Overall complications were statistically comparable between RIRS and Mini-PCNL (20.0% vs. 24.0%; *p*=0.629), as shown in Table-II.

DISCUSSION

The principal finding of this study was that Mini-PCNL achieved a higher stone-free rate than RIRS for solitary 1-2 cm renal stones (90.0% vs. 74.0%, *p*=0.037). This finding is in line with Jain et al., who also reported better clearance after minimally invasive PCNL than after RIRS for solitary 1-2 cm renal stones.[9] Mahmood *et al.* reported similarly strong clearance with mini-PCNL in an economically challenged setting, supporting the value of a percutaneous approach when complete stone removal is the main treatment goal.[10] Grisard *et al.*, in patients with lower pole stones, also found that miniaturized PCNL may offer a clearance advantage, especially when anatomy makes fragment passage after RIRS less predictable.[11]

Table-II: Comparison of Primary and Secondary Outcomes between Mini-Percutaneous Nephrolithotomy (Mini-PCNL) and Retrograde Intrarenal Surgery (RIRS) Groups (n=100)

Outcome Measure	Mini-PCNL Group (n=50)	RIRS Group (n=50)	*p*-value
Stone-Free Rate (SFR), n (%)	45 (90.0%)	37 (74.0%)	0.037*
Operative Time (min), Mean ± SD	68.4 ± 15.2	85.7 ± 20.2	<0.001*
Hospital Stay (days), Median (IQR)	4.57 (4.01–4.97)	3.35 (3.00–3.88)	<0.001*†
Postoperative Pain (VAS), Mean ± SD			
Day 1	5.24 ± 0.43	2.30 ± 0.58	<0.001*
Day 2, Median (IQR)	3.90 (3.60–4.28)	1.50 (1.10–1.80)	<0.001*†
Complications, n (%)			
Overall	12 (24.0%)	10 (20.0%)	0.629
Postoperative Fever	7 (14.0%)	8 (16.0%)	0.779
Hematuria (requiring intervention)	5 (10.0%)	1 (2.0%)	0.204†
Others (e.g., UTI, steinstrasse)	2 (4.0%)	3 (6.0%)	1.000†

**Statistically significant (p≤0.05). p-values were calculated using independent-samples t-test for normally distributed quantitative variables and Chi-square/Fisher's exact test for categorical variables. Mini-PCNL=Mini-Percutaneous Nephrolithotomy; RIRS=Retrograde Intrarenal Surgery; SD=standard deviation; VAS=Visual Analog Scale; UTI=urinary tract infection. †Mann-Whitney U test used for hospital stay and day-2 VAS pain score, which were non-normally distributed on Shapiro-Wilk testing. † p-value calculated using Fisher's exact test due to expected cell count <5; all other categorical p-values calculated using Pearson Chi-square test.*

Operative time in the present study also favoured Mini-PCNL, with a mean duration of 68.4 ± 15.2 minutes compared with 85.7 ± 20.2 minutes for RIRS (*p*<0.001). This agrees with Shukla et al., who reported efficient operative performance with mini-PCNL in solitary 1-2 cm renal stones.[12] Similar findings were noted by Koushik *et al*. in a randomized study of juxta uretero-pelvic junction upper ureteric calculi, where miniperc PCNL required shorter surgery duration and less lasing time.[13] However, this finding should be interpreted with care, as percutaneous surgery can take longer when access is difficult or when more than one calyceal tract is required. In our setting, the shorter Mini-PCNL time may reflect surgeon familiarity, direct access to the stone-bearing calyx, and less dependence on prolonged laser dusting.

The recovery profile favoured RIRS. Patients treated with RIRS had a significantly shorter hospital stay (median 3.35 [IQR 3.00–3.88] days) than those treated with Mini-PCNL (median 4.57 [IQR 4.01–4.97] days; *p*<0.001), and their VAS pain scores were lower on both postoperative days. These findings are consistent with the randomized comparison by Chavannavar *et al.*, in which RIRS offered a less invasive recovery pathway for renal stones between 8

and 15 mm.[14] Shah *et al*. also reported shorter hospitalization after RIRS for lower calyceal stones of ≤2 cm, despite the higher clearance tendency observed with mini-PCNL.[15] In everyday counselling, this trade-off is important: Mini-PCNL may clear more stones in one sitting, but RIRS is often easier for patients during the early postoperative period.

Overall complication rates were comparable in the present study (24.0% in Mini-PCNL vs. 20.0% in RIRS, p=0.629). Hematuria requiring intervention was numerically higher after Mini-PCNL, whereas postoperative fever was numerically higher after RIRS, although neither difference reached statistical significance. This pattern is clinically plausible and is consistent with the general understanding that percutaneous access may increase bleeding-related events, while ureteroscopic procedures may be associated with fever or infection-related events, particularly when intrarenal pressure rises during lithotripsy.[8,10,15] In pediatric data, Wang et al. also reported broadly comparable safety profiles between micro-PCNL and RIRS for 1-2 cm solitary renal stones, although procedural requirements differed between approaches.[16]

When the present results are viewed alongside broader evidence, they support the view that the best procedure for a 1-2 cm renal stone is not decided by stone size alone. Systematic review evidence has generally shown better stone clearance with percutaneous techniques, while RIRS tends to have a gentler perioperative recovery profile.[8,17] Therefore, the difference in stone-free rate seen in the present study should be discussed with patients together with the expected differences in pain, hospital stay, and the possibility of secondary treatment.

Stone size thresholds also deserve attention. Although this study was restricted to 1-2 cm stones, Zafar *et al*. reported that RIRS clearance varies above and below 1.5 cm, suggesting that stone burden may affect success even within this narrow size range.[18] The baseline stone sizes in our two groups were similar (1.52 ± 0.28 cm in Mini-PCNL vs. 1.49 ± 0.26 cm in RIRS, p=0.572), which strengthens the internal comparison. Still, stone composition, density, lower pole anatomy, and infundibulopelvic angle were not analyzed in detail, and these factors may partly explain why RIRS achieved a lower stone-free rate despite favourable recovery outcomes.

From a local service-delivery perspective, these findings are relevant because both procedures compete for operating room time, endoscopic equipment, consumables, inpatient beds, and trained personnel. A higher clearance rate with Mini-PCNL may reduce repeat procedures in selected patients, whereas shorter admission and lower early pain after RIRS may improve bed turnover and patient satisfaction. The results therefore support balanced counselling rather than a single-procedure preference. Patients should understand that the treatment offering the highest chance of complete clearance may not be the same as the treatment associated with the easiest immediate recovery. This distinction is especially important for working-age adults, patients travelling from distant areas, and those for whom prolonged admission creates financial or family burden.

This study has limitations. The quasi-experimental design and non-random allocation carry a risk of selection bias. Although baseline demographic and stone characteristics were comparable, unmeasured factors such as stone density, infundibulopelvic angle, degree of hydronephrosis, previous stenting, and surgeon-level variation were not fully analyzed. The sample size was modest, and follow-up was limited to four weeks; therefore, delayed complications, retreatment, and longer-term recurrence were not assessed. Because the study was conducted at a specialized urology institute, the findings are most applicable to adults aged 18-60 years with solitary renal stones measuring 1-2 cm and may not be generalizable to patients with multiple stones, complex anatomy, chronic kidney disease, active infection, pregnancy, or major comorbid illness.

Future studies from local and regional settings should use randomized allocation, standardized imaging for residual fragments, longer follow-up, and cost-effectiveness analysis. This would help clarify which patients benefit most from Mini-PCNL and which are better served by RIRS when both procedures are available.

CONCLUSION

Mini-PCNL provided a significantly higher stone-free rate and shorter operative time than RIRS for solitary renal stones measuring 1-2 cm. RIRS, however, offered a shorter hospital stay and significantly less postoperative pain. The choice of procedure should therefore be individualized by balancing the need for complete stone clearance against the benefits of a less invasive postoperative recovery.

Conflict of Interest: None.

Funding Source: None.

Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

AKJ & QZ: Data acquisition, data analysis, critical review, approval of the final version to be published.

AK & MT: Study design, data interpretation, drafting the manuscript, critical review, approval of the final version to be published.

FT & NA: Conception, data acquisition, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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