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Comparison of flexible ureterorenoscopy and mini-percutaneous nephrolithotomy in treatment of lower calyceal stones smaller than 2 cm.

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Abstract

Background: Flexible ureterorenoscopy (fURS) and mini-percutaneous nephrolithotomy (mini-PCNL) are treatment options for lower calyceal stones smaller than 2 cm. Their comparative value depends on stone clearance, procedural morbidity and postoperative recovery. Aim: To compare the efficacy and safety of fURS and mini-PCNL in patients with lower calyceal stones smaller than 2 cm. ***Materials and Methods***: A prospective randomised comparative study design was assumed, involving 80 patients allocated equally to fURS and mini-PCNL. The primary outcome was single-procedure stone-free status at three months, defined as no residual fragments on non-contrast computed tomography and no additional stone-clearing intervention. Secondary outcomes included operative time, haemoglobin reduction, postoperative pain, analgesic requirement, hospital stay, complications and auxiliary procedures. Between-group comparisons used Welch's independent-samples t test, Pearson's chi-square test or Fisher's exact test, as appropriate. ***Results***: Single-procedure clearance was higher with mini-PCNL than fURS (90.0% versus 70.0%; p=0.025), with a risk difference of −20.0 percentage points for fURS minus mini-PCNL (95% CI: −36.6 to −2.3). Final clearance after auxiliary treatment was 97.5% versus 92.5% (p=0.615). Operative time was shorter with mini-PCNL (52.48±12.84 versus 64.72±15.36 minutes; p<0.001). However, fURS produced less haemoglobin reduction (0.38±0.24 versus 0.94±0.52 g/dL), lower pain scores, lower rescue tramadol consumption and shorter hospitalisation (1.42±0.56 versus 2.18±0.74 days), all p<0.001. Overall complications occurred in 25.0% versus 30.0% (p=0.617), and auxiliary procedures were required in 22.5% versus 7.5% (p=0.060), respectively. ***Conclusion***: The results favoured mini-PCNL for single-procedure clearance and operative time, while fURS offered advantages in postoperative recovery. Differences in final clearance and complications remained uncertain.

Keywords: Flexible ureterorenoscopy; Mini-percutaneous nephrolithotomy; Lower calyceal calculi.

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INTRODUCTION

Lower calyceal stones present a particular challenge in endourological practice because their dependent position and calyceal anatomy can hinder access and clearance of stone fragments. Treatment aims to achieve complete stone clearance while minimising complications, hospitalisation and additional interventions. Flexible ureterorenoscopy (fURS), also described as retrograde intrarenal surgery, and mini-percutaneous nephrolithotomy (mini-PCNL) are established treatment options for small renal stones. However, their relative advantages require consideration of stone characteristics, anatomical factors and procedural morbidity. Kumar et al. (2015)[1], in a randomised study of 1–2 cm radiolucent lower calyceal stones, reported three-month stone-free rates of 86.1% following retrograde intrarenal surgery and 95.1% following miniperc, demonstrating the effectiveness of both endoscopic approaches.

Flexible ureterorenoscopy provides access to the collecting system through the natural urinary passage and allows laser fragmentation and basket extraction without a percutaneous renal tract. Mini-PCNL provides direct access to the affected calyx through a small tract, facilitating fragmentation and evacuation. Fayad et al. (2017)[2] reported stone-free rates of 92.72% with mini-PCNL and 84.31% with retrograde intrarenal surgery, without a statistically significant difference. Operative time was significantly longer with retrograde intrarenal surgery.

More recent studies have demonstrated variation in the balance between efficacy and morbidity. Darwish et al. (2024)[3], studying renal stones measuring ≤2 cm at different renal locations, found higher initial success with mini-PCNL than fURS,

but also more complications; final success was comparable. Zeinelabden et al. (2024)[4], in a study of hard lower-pole stones measuring ≤2 cm, reported comparable stone-free outcomes with fURS and mini-PCNL. These findings suggest that stone characteristics, operative techniques and outcome definitions influence the apparent advantages of each procedure.

Elmansy et al. (2025)[5] reported higher three-month stone-free rates following mini-PCNL than fURS for 1–2 cm lower-pole stones. Using a strict definition of no residual fragments, the rates were 72.2% and 37.1%, respectively; allowing fragments smaller than 4 mm increased both rates. This highlights the importance of consistent imaging and clearly defined endpoints. The present study was therefore undertaken to compare stone clearance, perioperative outcomes and complications following fURS and mini-PCNL for lower calyceal stones smaller than 2 cm.

AIM

To compare the efficacy and safety of flexible ureterorenoscopy and mini-percutaneous nephrolithotomy in patients with lower calyceal stones smaller than 2 cm.

OBJECTIVES

1. To compare the single-procedure stone-free rate at three months following flexible ureterorenoscopy and mini-percutaneous nephrolithotomy.
2. To compare operative time, haemoglobin reduction, postoperative pain, analgesic requirement and duration of hospitalisation between the two groups.
3. To compare intraoperative and postoperative complications and the requirement for auxiliary or repeat procedures between the two groups.

MATERIALS AND METHODS

Source of data

Data were obtained from patients presenting to the Urology outpatient department or admitted to the Urology inpatient service with lower calyceal calculi smaller than 2 cm who required active surgical treatment. Information was collected from clinical interviews, physical examinations, laboratory investigations, imaging studies, operative records and scheduled postoperative assessments using a structured case-record form.

Study design

The study was designed as a prospective, parallel-group, randomised comparative study with a 1:1 allocation ratio. Eighty eligible patients were allocated to two groups: Group A underwent flexible ureterorenoscopy, and Group B underwent mini-percutaneous nephrolithotomy, with 40 patients in each group.

Study location

The study was conducted in the Department of Urology, VDGMC, Latur, with support from the Departments of Radiology, Anaesthesiology, Pathology and Microbiology.

Study duration

The study was conducted from 12 months. The recruitment period ended sufficiently early to permit three months of postoperative follow-up for the final enrolled participant.

Sample size

The target sample size was 80 patients, comprising 40 patients per group.

Inclusion criteria

Patients were included if they met all the following criteria:

1. Age ≥18 years, irrespective of sex.
2. A single unilateral lower calyceal stone with a maximum diameter <20 mm, confirmed by non-contrast computed tomography of the kidneys, ureters and bladder.
3. An indication for active treatment, such as persistent symptoms, documented stone growth, recurrent infection after adequate treatment, or informed patient preference.
4. Anatomical and clinical suitability for either fURS or mini-PCNL.
5. Fitness for anaesthesia and the planned intervention.
6. Written informed consent and willingness to attend follow-up.

Exclusion criteria

Patients were excluded if they had:

1. A stone measuring ≥20 mm, multiple renal stones, or associated ipsilateral ureteric stones requiring treatment.
2. Active untreated urinary tract infection, pyonephrosis or sepsis.
3. Uncorrected coagulopathy or an inability to interrupt antithrombotic treatment when required for safe intervention.
4. Pregnancy.
5. A solitary functioning kidney, a non-functioning study kidney, or advanced renal impairment that made either procedure unsuitable.
6. Congenital renal anomalies, calyceal diverticular stones, ureteric strictures or pelviureteric junction obstruction requiring additional treatment.
7. Severe comorbidity precluding anaesthesia or either study procedure.

Procedure and methodology

Preoperative evaluation: A detailed history was recorded, including flank pain, haematuria, urinary infection, previous stone episodes, previous urological procedures and comorbidities. Physical examination included vital signs, body mass index and relevant systemic assessment. Investigations included complete blood count, serum creatinine, electrolytes, coagulation profile, urinalysis and urine culture. Additional investigations were performed according to clinical and anaesthetic requirements.

Non-contrast CT was used to confirm stone location, laterality, maximum diameter, density in Hounsfield units and associated hydronephrosis. Lower calyceal anatomy was assessed where adequately visualised. Patients with positive urine cultures received culture-directed treatment, and elective surgery proceeded after appropriate control of infection. Perioperative antibiotic prophylaxis followed the institutional policy.

Randomisation and allocation concealment: Eligible consenting patients were assigned using a computer-generated random sequence prepared by a person independent of recruitment. Allocation was concealed using sequentially numbered, opaque, sealed envelopes opened after enrolment. The operating surgeon could not be blinded. Follow-up images were evaluated by a radiologist blinded to treatment allocation wherever feasible.

Group A—flexible ureterorenoscopy: The procedure was performed under general anaesthesia in the lithotomy position. Cystoscopy and guidewire placement were followed by ureteric access under appropriate imaging guidance. A ureteral access sheath was used when safe passage was possible. The flexible ureteroscope was advanced into the collecting system, and the lower calyceal stone was identified. Holmium:YAG laser lithotripsy was performed, and retrievable fragments were removed using a basket. Stone relocation to a more accessible calyx was undertaken when necessary and documented. Laser settings, access-sheath use and intraoperative difficulties were recorded.

When safe access could not be achieved, a double-J stent was inserted and definitive treatment was deferred. Such patients remained in their original group, and staged treatment was counted as an additional procedure. Postoperative stenting was undertaken according to ureteric trauma, oedema, residual fragments and drainage requirements.

Group B—mini-percutaneous nephrolithotomy: The procedure was performed under general anaesthesia. Following ureteric catheter placement, the patient was positioned for percutaneous access according to the standard institutional technique. The selected calyx was punctured under ultrasonographic and/or fluoroscopic guidance. The tract was dilated to **16–18 Fr**, and a mini-nephroscope was introduced. Stones were fragmented using holmium:YAG laser lithotripsy, and fragments were evacuated through the sheath using irrigation and extraction instruments.

The collecting system was inspected for residual fragments. A nephrostomy tube and/or double-J stent was placed according to bleeding, collecting-system injury, residual stone burden and drainage requirements. Tubeless completion was documented when undertaken. Tract size, number of punctures, drainage method and any conversion were recorded.

Postoperative care: Patients were monitored for haematuria, fever, pain, urine output and other complications. Haemoglobin and serum creatinine were reassessed approximately 24 hours after surgery or earlier when clinically indicated. Pain was assessed using a 0–10 visual analogue scale at 6 and 24 hours. A standardised analgesic regimen was used, and rescue medication was recorded by drug and dose.

Discharge was considered when patients were clinically stable, afebrile, tolerating oral intake and had satisfactory pain control and urinary drainage. Stent and nephrostomy removal dates were documented.

Follow-up and outcome assessment: Follow-up assessments were performed at approximately two weeks and three months. Symptoms, complications, readmissions and additional procedures were recorded. Low-dose non-contrast CT was performed at three months using the same assessment protocol in both groups.

The primary outcome was single-procedure stone-free status at three months, defined as no residual stone fragments on CT and no additional stone-clearing procedure after the index intervention. Patients requiring an additional stone-clearing procedure were classified as primary-outcome failures, even when subsequent treatment achieved complete clearance. Final stone-free status after all interventions was recorded separately.

Secondary outcomes included:

- Operative time, measured from the first endoscopic instrumentation to completion of drainage placement, including repositioning where required.
- Haemoglobin reduction, calculated as preoperative minus approximately 24-hour postoperative haemoglobin.
- Pain scores and rescue analgesic requirements.
- Hospital stay, measured from completion of surgery to discharge.
- Intraoperative injuries, transfusion, fever, urinary infection, sepsis, readmission and other complications.
- Auxiliary procedures, repeat interventions and time to final clearance.

Postoperative complications were graded using the modified Clavien–Dindo classification. Conversions and unsuccessful access attempts were retained in the assigned group for analysis.

Sample processing

Midstream urine specimens were collected in sterile containers and processed for microscopy, culture and antimicrobial susceptibility testing according to laboratory procedures. Blood was collected in appropriate tubes for haematological and biochemical investigations and analysed using standard laboratory methods.

Retrieved stone fragments were placed in labelled containers and submitted for compositional analysis, preferably using Fourier-transform infrared spectroscopy where available. The method used was documented. If sufficient material was not retrieved, stone composition was recorded as unavailable rather than inferred from imaging. Renal pelvic urine or stone cultures were obtained when clinically indicated and recorded separately from preoperative urine cultures.

Statistical methods

Data were entered into Microsoft Excel, checked for completeness and consistency, and analysed using IBM SPSS Statistics version 26.0. Continuous variables were summarised as mean ± standard deviation when approximately normally distributed and as median with interquartile range when skewed. Categorical variables were presented as frequencies and percentages.

Between-group continuous outcomes were compared using an independent-samples *t* test, with Welch's correction where appropriate, or the Mann–Whitney *U* test for markedly non-normal data. Categorical outcomes were compared using the chi-square test or Fisher's exact test when expected cell frequencies were small.

The primary stone-free outcome was reported as an absolute risk difference and relative risk with 95% confidence intervals. Continuous outcomes were accompanied by between-group estimates and 95% confidence intervals where appropriate. All tests were two-sided, and $p<0.05$ was considered statistically significant. Secondary-outcome analyses were interpreted as exploratory.

The primary analysis followed the intention-to-treat principle. Crossovers, conversions and staged procedures remained in the originally allocated group. Missing three-month imaging was reported explicitly and was not assumed to indicate successful clearance. A conservative analysis treating missing primary outcomes as failures was accompanied by an available-case sensitivity analysis. A non-significant difference was not interpreted as proof of equivalence.

Data collection

A structured case-record form captured demographic characteristics, symptoms, comorbidities, previous stone treatment, baseline laboratory findings, stone diameter and density, laterality, hydronephrosis and relevant anatomical findings. Operative details included allocation, procedure received, operative duration, equipment, access difficulties, laser use, stenting, nephrostomy placement and complications. Postoperative records included haemoglobin change, pain scores, analgesic use, hospital stay and readmissions. Follow-up records included CT findings, residual fragment size, repeat procedures and final clearance status.

RESULTS

Table 1: Baseline demographic and clinical characteristics relevant to the comparison of efficacy and safety

Characteristic	fURS (n=40)	Mini-PCNL (n=40)	Between-group difference (95% CI)	Test statistic	p value
Age, years, mean (SD)	42.68 (11.24)	43.92 (10.86)	−1.24 (−6.16 to 3.68)	t=−0.502	0.617
Male sex, n (%)	25 (62.5)	27 (67.5)	−5.0 pp (−24.8 to 15.4)	χ^2=0.220	0.639
Body mass index, kg/m², mean (SD)	25.36 (3.42)	25.81 (3.67)	−0.45 (−2.03 to 1.13)	t=−0.567	0.572
Right-sided stone, n (%)	18 (45.0)	21 (52.5)	−7.5 pp (−27.9 to 13.8)	χ^2=0.450	0.502
Maximum stone diameter, mm, mean (SD)	14.62 (2.81)	14.94 (2.73)	−0.32 (−1.55 to 0.91)	t=−0.517	0.607
Stone density, HU, mean (SD)	986.40 (218.60)	1012.70 (226.30)	−26.30 (−125.34 to 72.74)	t=−0.529	0.598

Preoperative haemoglobin, g/dL, mean (SD)	13.12 (1.24)	13.26 (1.18)	−0.14 (−0.68 to 0.40)	t=−0.517	0.606
Diabetes mellitus, n (%)	7 (17.5)	8 (20.0)	−2.5 pp (−19.7 to 14.8)	χ^2=0.082	0.775

Table 1 presents the baseline characteristics of the 80 patients, with 40 patients in each treatment group. The mean age was 42.68±11.24 years in the fURS group and 43.92±10.86 years in the mini-PCNL group, without a statistically significant difference (p=0.617). Males constituted 62.5% and 67.5% of the groups, respectively (p=0.639). Mean body mass index was 25.36±3.42 versus 25.81±3.67 kg/m² (p=0.572), while right-sided stones were present in 45.0% versus 52.5% of patients (p=0.502). Mean maximum stone diameter was 14.62±2.81 mm in the fURS group and 14.94±2.73 mm in the mini-PCNL group, with a mean difference of −0.32 mm (95% CI: −1.55 to 0.91; p=0.607). Stone density was also similar numerically, at 986.40±218.60 versus 1012.70±226.30 HU (p=0.598). Preoperative haemoglobin was 13.12±1.24 versus 13.26±1.18 g/dL (p=0.606), and diabetes mellitus was present in 17.5% versus 20.0% of patients (p=0.775).

Table 2: Comparison of single-procedure stone-free status at three months

Outcome	fURS (n=40), n (%)	Mini-PCNL (n=40), n (%)	Risk difference, pp (95% CI)	Test statistic	p value
Single-procedure stone-free status at three months—primary outcome	**28 (70.0)**	**36 (90.0)**	**−20.0 (−36.6 to −2.3)**	**χ^2=5.000**	**0.025**
Failure to achieve single-procedure stone-free status	12 (30.0)	4 (10.0)	—	—	—
Final stone-free status at three months, including auxiliary procedures	37 (92.5)	39 (97.5)	−5.0 (−17.5 to 6.5)	Fisher's exact	0.615
Residual fragments at three months after all treatment	3 (7.5)	1 (2.5)	—	—	—

Table 2 shows that single-procedure stone-free status at three months was achieved in 28 patients (70.0%) following fURS and 36 patients (90.0%) following mini-PCNL. This difference was statistically significant (χ^2=5.000; p=0.025), with an absolute risk difference of −20.0 percentage points (95% CI: −36.6 to −2.3), favouring mini-PCNL. Failure to achieve single-procedure clearance occurred in 12 patients (30.0%) in the fURS group and four patients (10.0%) in the mini-PCNL group. After including auxiliary procedures, final stone-free status increased to 37 patients (92.5%) and 39 patients (97.5%), respectively. The difference in final clearance was not statistically significant (risk difference: −5.0 percentage points; 95% CI: −17.5 to 6.5; Fisher's exact p=0.615). Residual fragments remained in three patients (7.5%) following fURS and one patient (2.5%) following mini-PCNL.

Table 3: Comparison of operative and postoperative recovery outcomes

Outcome, mean (SD)	fURS (n=40)	Mini-PCNL (n=40)	Mean difference (95% CI)	Welch's t statistic	p value
Operative time, minutes	64.72 (15.36)	52.48 (12.84)	12.24 (5.94 to 18.54)	3.867	<0.001
Haemoglobin reduction at 24 hours, g/dL	0.38 (0.24)	0.94 (0.52)	−0.56 (−0.74 to −0.38)	−6.184	<0.001
Pain score at 6 hours, VAS 0–10	3.18 (1.12)	4.26 (1.34)	−1.08 (−1.63 to −0.53)	−3.911	<0.001
Pain score at 24 hours, VAS 0–10	1.86 (0.82)	2.72 (1.06)	−0.86 (−1.28 to −0.44)	−4.059	<0.001
Cumulative rescue tramadol during first 24 hours, mg	62.50 (32.40)	91.25 (38.60)	−28.75 (−44.62 to −12.88)	−3.608	<0.001
Postoperative hospital stay, days	1.42 (0.56)	2.18 (0.74)	−0.76 (−1.05 to −0.47)	−5.180	<0.001

Table 3 demonstrates statistically significant differences in all reported operative and recovery outcomes. Mean operative time was longer with fURS than mini-PCNL, at 64.72±15.36 versus 52.48±12.84 minutes, with a mean difference of 12.24 minutes (95% CI: 5.94–18.54; t=3.867; p<0.001). However, the mean haemoglobin reduction at 24 hours was smaller following fURS, at 0.38±0.24 versus 0.94±0.52 g/dL (mean difference: −0.56 g/dL; 95% CI: −0.74 to −0.38; t=−6.184; p<0.001). Pain scores were lower in the fURS group at six hours (3.18±1.12 versus 4.26±1.34; mean difference: −1.08; 95% CI: −1.63 to −0.53; p<0.001) and 24 hours (1.86±0.82 versus 2.72±1.06; mean difference: −0.86; 95% CI: −1.28 to −0.44; p<0.001). Mean rescue tramadol consumption during the first 24 hours was also lower following fURS, at 62.50±32.40 versus 91.25±38.60 mg (mean difference: −28.75 mg; 95% CI: −44.62 to −12.88; p<0.001). Postoperative hospital stay was shorter in the fURS group, at 1.42±0.56 versus 2.18±0.74 days (mean difference: −0.76 days; 95% CI: −1.05 to −0.47; p<0.001).

Table 4: Comparison of complications and auxiliary or repeat procedures

Outcome	fURS (n=40), n (%)	Mini-PCNL (n=40), n (%)	Risk difference, pp (95% CI)	Test statistic/method	p value
At least one intraoperative or postoperative complication	**10 (25.0)**	**12 (30.0)**	**−5.0 (−23.8 to 14.3)**	**χ^2=0.251**	**0.617**
Significant bleeding requiring additional management	1 (2.5)	5 (12.5)	−10.0 (−23.8 to 2.5)	Fisher's exact	0.201
Blood transfusion	0 (0.0)	2 (5.0)	−5.0 (−16.5 to 4.5)	Fisher's exact	0.494
Ureteric or collecting-system injury	1 (2.5)	1 (2.5)	0.0 (−10.6 to 10.6)	Fisher's exact	1.000
Postoperative fever ≥38°C	5 (12.5)	6 (15.0)	−2.5 (−18.2 to 13.3)	χ^2=0.105	0.745
Symptomatic, culture-confirmed urinary tract infection	3 (7.5)	4 (10.0)	−2.5 (−16.4 to 11.3)	Fisher's exact	1.000
Sepsis	1 (2.5)	1 (2.5)	0.0 (−10.6 to 10.6)	Fisher's exact	1.000
Unplanned readmission within 30 days	2 (5.0)	3 (7.5)	−2.5 (−15.4 to 10.0)	Fisher's exact	1.000
Any auxiliary or repeat stone-clearing procedure by three months	**9 (22.5)**	**3 (7.5)**	**15.0 (−1.0 to 30.8)**	**χ^2=3.529**	**0.060**
Additional flexible ureterorenoscopy	7 (17.5)	2 (5.0)	12.5 (−2.0 to 27.4)	Fisher's exact	0.154
Auxiliary shock-wave lithotripsy	2 (5.0)	1 (2.5)	2.5 (−8.5 to 14.2)	Fisher's exact	1.000

Table 4 shows that at least one intraoperative or postoperative complication occurred in 10 patients (25.0%) following fURS and 12 patients (30.0%) following mini-PCNL, without a statistically significant difference (χ^2=0.251; p=0.617; risk difference: −5.0 percentage points; 95% CI: −23.8 to 14.3). Significant bleeding occurred in one patient (2.5%) versus five patients (12.5%) (p=0.201), while blood transfusion was required in no patients versus two patients (5.0%) (p=0.494). Ureteric or collecting-system injury occurred in one patient (2.5%) in each group (p=1.000). Postoperative fever occurred in 12.5% versus 15.0% (p=0.745), symptomatic culture-confirmed urinary tract infection in 7.5% versus 10.0% (p=1.000), and sepsis in 2.5% of each group (p=1.000). Unplanned readmission occurred in 5.0% versus 7.5% (p=1.000). Auxiliary or repeat stone-clearing procedures were required in nine patients (22.5%) following fURS and three patients (7.5%) following mini-PCNL; this difference did not reach statistical significance (χ^2=3.529; p=0.060; risk difference: 15.0 percentage points; 95% CI: −1.0 to 30.8). Additional fURS was performed in seven patients (17.5%) versus two patients (5.0%) (p=0.154), while auxiliary shock-wave lithotripsy was performed in two patients (5.0%) versus one patient (2.5%) (p=1.000).

DISCUSSION

Table 1. Baseline demographic and clinical characteristics

The supplied comparison included 80 patients, with 40 patients in each treatment group. Mean age was 42.68±11.24 years in the fURS group and 43.92±10.86 years in the mini-PCNL group (p=0.617), while males represented 62.5% and 67.5%, respectively (p=0.639). This demographic pattern resembled that reported by Rehman et al. (2023)[1], whose randomised study of 150 patients with lower-pole stones documented mean ages of 43.27±13.86 years in the mini-PCNL group and 45.32±14.14 years in the RIRS group, with an overall male predominance of 68%. Similarly, Mhaske et al. (2018)[2], in an 80-patient prospective comparison, reported predominantly male participants and mean ages of 40.12 and 38.20 years in the mini-perc and RIRS groups, respectively. These similarities support the demographic relevance of the selected comparison studies, although differences in eligibility criteria limit direct generalisation.

Stone characteristics were numerically close between the supplied groups. Mean maximum stone diameter was 14.62±2.81 mm following allocation to fURS and 14.94±2.73 mm following allocation to mini-PCNL, with a difference of −0.32 mm (95% CI: −1.55 to 0.91; p=0.607). Zeng et al. (2018)[3] reported comparable stone diameters of 1.43±0.34 cm in the RIRS group and 1.50±0.29 cm in the super-mini-PCNL group (p=0.214), closely resembling the stone burden in the supplied tables. Their multicentre trial therefore provides a relevant comparison, although super-mini-PCNL is technically distinct from conventional mini-PCNL.

Mean stone density was 986.40±218.60 versus 1012.70±226.30 HU (p=0.598), indicating that the groups included relatively dense stones on average. Zeinelabden et al. (2024)[4] specifically investigated hard lower-pole stones with density exceeding 950 HU and found that fURS and mini-PCNL achieved comparable clearance outcomes. However, an average density near 1,000 HU does not mean that every patient in the supplied groups met that study's density threshold. Body

mass index, stone laterality, preoperative haemoglobin and diabetes prevalence also showed no statistically significant differences in the supplied comparison. These findings provide no clear evidence of imbalance in the measured variables, but non-significant baseline tests do not establish equivalence or exclude differences in unreported factors such as lower calyceal anatomy, preoperative stenting and infection history.

Table 2. Single-procedure stone-free status at three months

Single-procedure stone-free status was achieved in 70.0% of the fURS group and 90.0% of the mini-PCNL group. The absolute difference was −20.0 percentage points (95% CI: −36.6 to −2.3; χ^2=5.000; p=0.025), favouring mini-PCNL. This direction agrees with Kumar et al. (2015)[5], who reported three-month stone-free rates of 86.1% after RIRS and 95.1% after miniperc for 1–2 cm radiolucent lower calyceal stones. Fayad et al. (2017)[6] also reported numerically higher clearance with mini-PCNL than RIRS, at 92.72% versus 84.31%, although their between-group difference was not statistically significant. Their definition permitted residual fragments ≤2 mm, whereas the supplied primary endpoint required complete clearance without an additional procedure. Consequently, the percentages should not be treated as directly interchangeable.

More recent trials reinforce the importance of the clearance definition. Elmansy et al. (2025)[7] reported three-month stone-free rates of 72.2% after mini-PCNL and 37.1% after fURS when no residual fragments were permitted (p=0.003). When fragments smaller than 4 mm were allowed, the corresponding rates increased to 86.1% and 65.7%. Dutta et al. (2023)[8] found clearance rates of 76% after mini-PCNL and 46% after flexible ureteroscopy using a 2-mm cutoff (p=0.0023), assessed by CT within 1–30 days. These studies support a potential clearance advantage for the percutaneous approach, but differing imaging schedules, residual-fragment thresholds and stone locations explain some of the variation in absolute success rates.

After auxiliary procedures, final clearance in the supplied tables increased to 92.5% with fURS and 97.5% with mini-PCNL. The difference was no longer statistically significant (−5.0 percentage points; 95% CI: −17.5 to 6.5; p=0.615). This pattern resembles Darwish et al. (2024)[9], who reported higher initial success with mini-PCNL than fURS—93% versus 70%—but comparable final success after follow-up and additional management. Similarly, Jain et al. (2021)[10] reported three-month clearance rates of 92.5% with mini-PCNL and 87.5% with RIRS, without a statistically significant overall difference.

Table 3. Operative and postoperative recovery outcomes

Mean operative time was significantly longer with fURS than mini-PCNL, at 64.72±15.36 versus 52.48±12.84 minutes, a difference of 12.24 minutes (95% CI: 5.94–18.54; p<0.001). Jain et al. (2021)[10] reported a similar pattern, with operative times of 69.75 minutes for RIRS and 51.58 minutes for mini-PCNL (p=0.003). Fayad et al. (2017)[6] likewise observed longer operating times with RIRS, at 109.66±20.75 versus 71.66±10.36 minutes. However, Lee et al. (2015)[11] found no significant operative-time difference (p=0.148). These contrasting findings indicate that operating time depends on access, fragmentation and extraction techniques, equipment and procedural definitions, rather than the treatment label alone.

The haemoglobin reduction was smaller with fURS, at 0.38±0.24 versus 0.94±0.52 g/dL, with a mean difference of −0.56 g/dL (95% CI: −0.74 to −0.38; p<0.001). This agrees with Mhaske et al. (2018)[2], who reported greater haemoglobin reduction following mini-perc, and with Zeng et al. (2018)[3], who found less haemoglobin loss following RIRS. Coskun et al. (2021)[12] similarly reported a greater decrease in haematocrit following mini-PCNL. Avoidance of a renal access tract is a plausible explanation for lower blood loss with fURS, although the supplied table does not establish the mechanism or show that the mean difference translated into a statistically significant transfusion difference.

Postoperative pain was lower following fURS at both six hours and 24 hours. The respective mean differences were −1.08 points (95% CI: −1.63 to −0.53) and −0.86 points (95% CI: −1.28 to −0.44), with p<0.001 for both comparisons. Rescue tramadol consumption was also lower, at 62.50±32.40 versus 91.25±38.60 mg (mean difference: −28.75 mg; 95% CI: −44.62 to −12.88; p<0.001). Zeng et al. (2018)[3] reported less postoperative pain with RIRS, supporting this direction. Nevertheless, Lee et al. (2015)[11] found greater immediate postoperative pain and analgesic requirements following RIRS, while Coskun et al. (2021)[12] found no significant differences in pain scores or analgesic requirements. Pain outcomes therefore require interpretation alongside assessment timing, stent and nephrostomy use, and the analgesic protocol.

Hospital stay was shorter following fURS, at 1.42±0.56 versus 2.18±0.74 days (mean difference: −0.76 days; 95% CI: −1.05 to −0.47; p<0.001). Rehman et al. (2023)[1] reported a similar difference, with stays of 1.1±0.09 days following RIRS and 2.3±0.64 days following mini-PCNL. Kandemir et al. (2017)[13] also found longer hospitalisation after micropercutaneous nephrolithotomy than RIRS, although microperc differs from the mini-PCNL procedure considered here. Higazy et al. (2025)[14] reported shorter operating time but greater pain, additional analgesic use and hospital stay following flexible mini-PCNL. Their study involved stones measuring 1.5–3 cm and a modified percutaneous technique, so it provides supporting rather than directly equivalent evidence. Collectively, these comparisons suggest that improved procedural efficiency with percutaneous treatment may coexist with a greater postoperative recovery burden.

Table 4. Complications and auxiliary or repeat procedures

At least one complication occurred in 25.0% of the fURS group and 30.0% of the mini-PCNL group (risk difference: −5.0 percentage points; 95% CI: −23.8 to 14.3; p=0.617). Dutta et al. (2023)[8] similarly found no significant difference in postoperative complications, whereas Darwish et al. (2024)[9] reported more complications with mini-PCNL than fURS, at 44.1% versus 18.6%. Coskun et al. (2021)[12] also found higher complication rates following mini-PCNL. The differing findings may reflect variation in complication definitions, tract sizes, patient selection and follow-up. In the supplied tables, the confidence interval remains compatible with clinically meaningful differences in either direction; consequently, the non-significant result should not be interpreted as equal safety.

Significant bleeding occurred in 2.5% of fURS patients and 12.5% of mini-PCNL patients (p=0.201), while transfusion was required in 0% and 5.0%, respectively (p=0.494). Although these differences were not statistically significant, their direction was consistent with the greater mean haemoglobin reduction after mini-PCNL in Table 3. Infectious complications were also statistically inconclusive: fever occurred in 12.5% versus 15.0%, urinary tract infection in 7.5% versus 10.0%, and sepsis in 2.5% of each group. Blackmur et al. (2016)[15], in a prospective ureteroscopy cohort, identified positive preoperative urine culture as an independent predictor of postoperative urosepsis despite preoperative antibiotic treatment (adjusted OR 4.88; 95% CI: 2.11–11.31). Their findings indicate that an infection comparison should account for preoperative microbiology and infection history, which are not presented in the supplied baseline table. Auxiliary or repeat stone-clearing treatment was required in 22.5% of fURS patients and 7.5% of mini-PCNL patients, an absolute difference of 15.0 percentage points (95% CI: −1.0 to 30.8; p=0.060). This was numerically consistent with Zeng et al. (2018)[3], who reported fewer auxiliary procedures following super-mini-PCNL. However, the supplied estimate remained imprecise and did not reach the prespecified significance threshold. Additional fURS accounted for most repeat interventions, occurring in 17.5% versus 5.0% of patients. Caglar et al. (2024)[16] specifically studied failed ureteral access-sheath placement, comparing staged fURS after stenting with same-session mini-PCNL. Residual fragments remained in three fURS patients and one mini-PCNL patient at three months. Their longer-term significance cannot be determined from this follow-up alone. Chew et al. (2016)[17], studying patients with residual fragments after ureteroscopy, found that fragments larger than 4 mm were associated with greater stone growth, complications and reintervention. Olvera-Posada et al. (2016)[18] similarly identified residual fragments larger than 4 mm and struvite or apatite composition as predictors of subsequent intervention following PCNL. These were selected residual-fragment cohorts, so their event rates should not be applied directly to all patients undergoing either procedure. Nevertheless, they support recording residual-fragment size and composition and extending follow-up beyond three months when assessing durable treatment success.

CONCLUSION

Mini-percutaneous nephrolithotomy achieved a higher single-procedure stone-free rate at three months than flexible ureterorenoscopy for lower calyceal stones smaller than 2 cm (90.0% versus 70.0%; p=0.025) and required less operative time. Flexible ureterorenoscopy was associated with a smaller haemoglobin reduction, lower postoperative pain scores, reduced rescue analgesic consumption and shorter hospitalisation. After auxiliary procedures, final stone-free rates were 97.5% and 92.5%, respectively, without a statistically significant difference. Overall complications and additional intervention rates also did not differ significantly; however, the small sample and wide confidence intervals precluded conclusions of equivalent safety or efficacy.

LIMITATIONS OF THE STUDY

The sample size of 80 patients, comprising 40 patients per group, limited the precision of outcome estimates, particularly for uncommon complications such as transfusion, sepsis and collecting-system injury. The study was not designed to establish equivalence or non-inferiority; therefore, non-significant differences in final stone clearance and complications could not be interpreted as equivalent outcomes. The assumed single-centre design restricted generalisability to institutions with different equipment, surgical expertise and perioperative practices. Three months of follow-up was insufficient to assess stone recurrence, delayed ureteric stricture, long-term renal function or subsequent events related to residual fragments.

Surgeons and patients could not be blinded to the procedure, potentially influencing subjective outcomes such as pain and decisions regarding discharge or additional treatment. Although measured baseline characteristics were numerically similar, detailed lower calyceal anatomy, stone composition, preoperative stenting and surgeon-specific experience were not presented in the supplied results. Variation in access-sheath use, stone relocation, drainage methods and laser settings could also have influenced outcomes. Multiple secondary comparisons increased the possibility of chance findings and required exploratory interpretation. Finally, treatment costs, stent-related symptoms, quality of life and return to normal activities were not assessed.

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