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ARTICLE

Flexible ureterorenoscopy vs. mini percutaneous nephrolithotomy for kidney stones in chronic kidney damage: a prospective study

Nazım Furkan Günay,* Mücahit Gelmiş, Çağlar Dizdaroğlu, Abdullah Esmeray, Ufuk Çağlar, Ömer Sarılar, Faruk Özgör

Department of Urology, University of Health Sciences Haseki Training and Research Hospital, Istanbul, 34260, Türkiye

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Objectives: *Chronic kidney disease (CKD) poses unique challenges in the management of renal stones, and high-quality evidence to guide treatment decisions is limited. This study aimed to compare the effects of flexible ureteroscopy (f-URS) and mini-percutaneous nephrolithotomy (m-PCNL) on perioperative outcomes and long-term renal function in patients with CKD and renal stones.*

Methods: *This prospective randomized study included 60 CKD patients with renal stones measuring 1–4 cm. Participants were randomized into f-URS ($n = 24$) and m-PCNL ($n = 36$) groups. Baseline demographics, stone characteristics, and perioperative parameters were recorded. Stone-free rate (SFR) was defined as the absence of any residual fragments on postoperative computed tomography (CT) at 1 month. Renal function was assessed by estimated glomerular filtration rate (eGFR), serum creatinine, and CKD stage at baseline and 6 months. A post hoc exploratory subgroup analysis was performed for patients with 10–20 mm stones.*

Results: *Stone-free rates were comparable between groups (79.2% vs. 86.1%, $p > 0.05$). f-URS was associated with shorter operative duration, reduced fluoroscopy time, lower hemoglobin drop, and shorter hospital stay (all $p < 0.01$). At 6 months, median renal function values were more favorable in the f-URS group, with higher median eGFR (44.0 vs. 51.5 mL/min, $p = 0.042$) and lower creatinine (1.6 vs. 1.4 mg/dL, $p = 0.031$), whereas the changes from baseline (ΔeGFR and Δcreatinine) did not show a statistically significant difference. In the exploratory 10–20 mm subgroup results were statistically in favor of f-URS, but these findings should not be generalized due to the small sample size and post hoc nature of the analysis.*

Conclusions: *Both f-URS and m-PCNL achieved similar stone clearance in CKD patients. f-URS may offer advantages regarding perioperative safety and renal function preservation, but these observations require confirmation in larger studies with long-term follow-up. Treatment decisions in this high-risk population should be individualized.*

Key Words: flexible ureteroscopy, chronic kidney disease, percutaneous nephrolithotomy, kidney stones

Introduction

Managing kidney stones involves several treatment modalities, including percutaneous nephrolithotomy (PCNL), flexible ureteroscopy (f-URS), and extracorporeal shock wave lithotripsy. Treatment selection is based on stone size, location, kidney anatomy,

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*Corresponding Author: Nazım Furkan Günay.
Email: nfurkangunay@gmail.com

and patient characteristics. PCNL is the gold standard for stones >2 cm, achieving stone-free rates of up to 96%.[1] For stones measuring 1–3 cm, f-URS demonstrates comparable outcomes despite requiring multiple sessions and routine postoperative ureteral stent placement.[2] While PCNL offers higher stone-free rates in a single session, it is more invasive.

Each treatment option poses a risk of kidney damage via various mechanisms. PCNL and f-URS require continuous saline irrigation, which increases intrarenal pressure beyond the normal range of 5–10 cmH_2O. Although some studies suggest a safe upper limit of 40 cmH_2O for intraoperative pressure, higher pressures elevate the risk of complications.[3]

Ureteral access sheaths (UASs) optimize irrigation by enhancing visualization while maintaining safe intrarenal pressures and fluid temperatures. UASs also contribute to shorter operative times and higher stone-free rates. However, they may increase complication risks through direct organ injury or ureteral ischemia.[4]

Pressures exceeding 40 cmH_2O are associated with postoperative complications such as bleeding, perirenal fluid collection, and sepsis.[5] Sepsis is often attributed to pyelovenous reflux, wherein bacteria are transported from the urinary collecting system into the bloodstream. A pig model study revealed significant saline backflow and renal parenchymal scarring at pressures exceeding 30 cmH_2O, while no scarring occurred at lower pressures.[3]

Additional PCNL-associated complications include renal bleeding, colonic or pleural injury, and postoperative pulmonary issues.[6,7] The procedure involves puncturing and dilating the renal parenchyma, which risks damage to adjacent structures such as the colon, lungs, or major vessels. Meticulous anesthetic and surgical management during PCNL are essential to minimize complications.

Chronic kidney disease (CKD) is a clinical syndrome characterized by irreversible kidney damage and progressive decline in kidney function. Patients with CKD undergoing surgery face an increased risk of 30-day mortality and complications such as stroke, myocardial infarction, pneumonia, septic shock, deep vein thrombosis, and postoperative bleeding.[8] Therefore, treating patients with CKD having kidney stones requires heightened caution. Hence, this study aimed to compare the effects of f-URS and mini percutaneous nephrolithotomy (m-PCNL) on long-term renal outcomes in patients with CKD who had kidney stones.

Material and Methods

Study design and participants

Written informed consent was obtained from all participants, and ethical approval was granted by the Haseki Training and Research Hospital Ethics Committee (approval date/No.: 01.03.2023/88-2022). Patients with renal stones measuring between 1 and 4 cm in maximum diameter and a confirmed diagnosis of CKD were included in the study. All participants were required to be suitable candidates for surgery and able to provide written informed consent. Patients were recruited from the Urology Clinic of the University of Health Sciences, Haseki Training and Research Hospital, during the study period between January 2023 and June 2023. This relatively broad size range was selected to reflect real-world clinical practice in CKD patients, where stones of varying sizes within this range may require intervention. The decision also allowed sufficient recruitment in this high-risk patient group, in whom treatment options may be limited. Patients under 18 years of age, those with a history of kidney transplantation, renal or skeletal anomalies, or pregnancy were excluded.

The primary endpoint was the change in renal function at 6 months postoperatively, assessed by glomerular filtration rate (GFR), serum creatinine levels, and CKD stage progression. A sample-size calculation was performed using previously published data on renal functional outcomes after endourological interventions in patients with CKD, which reported between-group differences in postoperative estimated glomerular filtration rate (eGFR) in the range of 4–6 mL/min with standard deviations of approximately 6–7 mL/min.[9,10] Assuming a clinically relevant difference of 5 mL/min in eGFR at 6 months between groups, a standard deviation of 6–7 mL/min, a two-sided α of 0.05, and 80% power, we calculated that at least 50 evaluable patients were required. A total of 102 patients were initially considered, of whom 93 met the inclusion criteria. Thirteen patients declined randomization, resulting in 80 participants. Patients were randomized to the f-URS and m-PCNL groups, with 40 patients each using a sealed envelope system. Of the 80 randomized patients, sixteen in the f-URS group and four m-PCNL group were excluded due to noncompliance with follow-up protocols. The main reasons for loss to follow-up were patient preference to continue care at another institution, inability to attend scheduled visits due to comorbid conditions, and withdrawal of consent. Finally, the study was conducted as f-URS (n = 24)

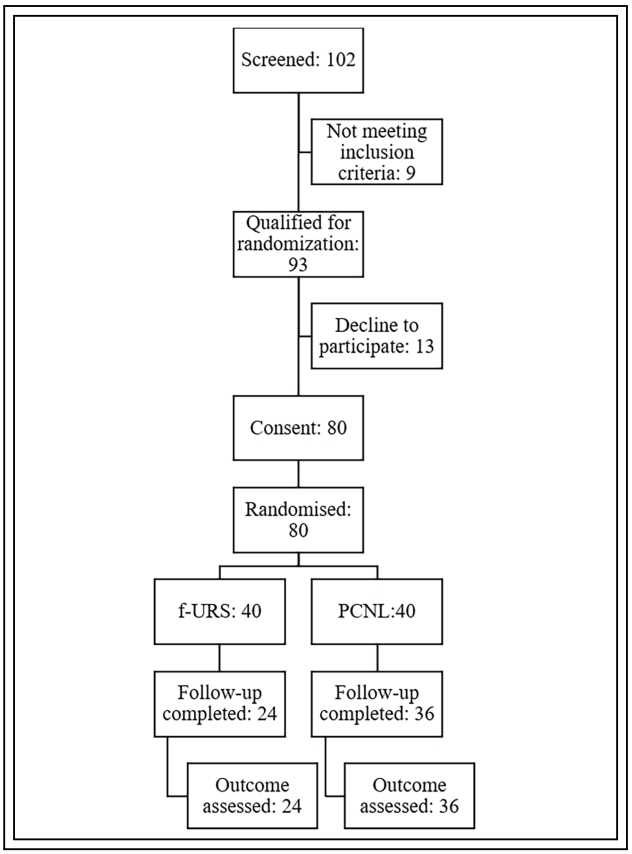

FIGURE 1. Study flow

and m-PCNL (n = 36) (Figure 1). Importantly, baseline characteristics of the initially randomized cohort (n = 80) were comparable to those of the final study population (n = 60), suggesting that attrition did not significantly alter group demographics.

CKD is diagnosed when a patient exhibits a GFR below 60 mL/min/1.73 m^2 for 3 months or longer or when structural kidney damage is evident despite a GFR above 60 mL/min/1.73 m^2.[11] CKD is classified into five stages based on GFR; Stage 1: Kidney damage with normal GFR (>90 mL/min), Stage 2: Mild reduction in GFR (60–89 mL/min), Stage 3a: Moderate reduction in GFR (45–59 mL/min), Stage 3b: Moderate reduction in GFR (30–44 mL/min), Stage 4: Severe reduction in GFR (15–29 mL/min), Stage 5: Renal failure (GFR < 15 mL/min).

Stone-free status (SFR) was defined as the absence of any residual stone fragments on non-contrast abdominopelvic computed tomography (CT) at 1 month postoperatively. In line with recent literature, including the systematic review by Çavdar et al. residual fragments of any size were considered clinically relevant in CKD patients due to their potential to promote infection, obstruction, and further renal function deterioration.[12] Therefore, the presence of any residual fragment, regardless of size, was classified as not stone-free. A 6-month follow-up period was deemed appropriate when reviewing studies on kidney stone patients with chronic kidney disease.[9]

The primary endpoint of the study was the change in renal function at 6 months postoperatively, assessed by serum creatinine levels, eGFR, and CKD stage progression.

Intervention and procedure

All patients received comprehensive preoperative information about the procedures, and informed consent was obtained before surgery. Each surgery was performed under general anesthesia by the same experienced endourologist team. In both procedures, irrigation was delivered by gravity only (saline bags elevated to 80–100 cm above the operating table), without any pressure bag systems.

Mini percutaneous nephrolithotomy (m-PCNL)

Patients were initially placed in the lithotomy position, where a guidewire and a 5-Fr ureteral catheter were inserted under fluoroscopic guidance, followed by the placement of a Foley catheter. The patients were then repositioned to the prone position for renal access. The renal puncture was performed using an 18-gauge needle, followed by serial dilation up to 21 Fr. Stones were fragmented using a 16-Fr Nephroscope (Hangzhou HAWK Optical Electronic Instuments, Hangzhou, China) holmium: yttrium-aluminum-garnet (Ho:YAG) laser lithotripter and subsequently removed. Ureteral and/or nephrostomy tubes were placed at the surgeon's direction. Foley catheters were typically removed the morning after the procedure.

Flexible ureterorenoscopy (f-URS)

A disposable digital 8.5-Fr f-URS (Zhuhai Pusen Medical Technology, Zhuhai, China) was used for the procedure. Patients were placed in the lithotomy position under general anesthesia. A 9.5-Fr rigid URS (AMNOTEC, Neuhausen ob Eck, International Medical GmbH, Germany) was used to guide the insertion of a guidewire (Boston Scientific Corporation, Natick, MA, USA) into the ureter. Passive dilation was performed after advancing the scope to the ureteropelvic junction (UPJ).

In all f-URS cases, an 11–13 Fr ureteral access sheath (UAS) was used (45 cm for males, 35 cm for females). The UAS was inserted under fluoroscopic guidance following passive ureteral dilation with a semi-rigid ureteroscope. No ureteral trauma or insertion failure occurred. UAS use allowed continuous

outflow, reduced intrarenal pressure, and improved visualization during lithotripsy. Stones were fragmented using a Ho:YAG laser with a 200-μm probe. After stone fragmentation, a 4.8-Fr, 26-cm ureteral stent was placed. Postoperative Foley catheters were removed 6 h after surgery. No patient required additional treatment sessions for residual stones.

Statistical analysis

Data analysis was performed using SPSS software version 26 (IBM Corp., Armonk, NY, USA). Continuous variables were compared using independent samples *t*-tests, while categorical variables were analyzed using chi-square tests. Descriptive statistics were expressed as median (IQR) for continuous variables and as frequency (%) for categorical variables. Statistical significance was set at $p < 0.05$. An analysis of covariance (ANCOVA) was performed to compare postoperative eGFR and creatinine values between groups, adjusting for their respective baseline values.

A post hoc subgroup analysis was also conducted for patients with stones measuring 10–20 mm to explore potential size-related differences; as this analysis was not pre-specified, its findings should be interpreted as exploratory. For the 10–20 mm subgroup, Bonferroni correction was applied to account for multiple comparisons, and adjusted *p*-values were reported.

All primary analyses were performed per protocol and included only patients with complete 6-month renal function data, because imputing missing eGFR or creatinine values was deemed unreliable in this relatively small cohort. Baseline characteristics of the randomized population (n = 80) and the final analytic sample (n = 60) were comparable, which reduces the potential impact of attrition bias. An intention-to-treat analysis was not performed because 6-month renal function values were missing for several participants, and imputing these data in a relatively small sample was considered unreliable; therefore, a per-protocol approach was adopted.

Results

Baseline patients and stone characteristics, including stone size, location, opacity, side, and history of prior surgeries, were comparable between the two groups ($p > 0.05$, Table 1). Most stones in both groups were located in the pelvis and were radiopaque (80.6% in m-PCNL vs. 70.8% in f-URS).

The f-URS group demonstrated significantly better outcomes in hemoglobin reduction, operative duration, fluoroscopy exposure, and hospital stay ($p = 0.002$, $p < 0.001$, $p < 0.001$, and $p < 0.001$, respectively). Stone-free and overall complication rates were similar between the groups (Table 2). In the m-PCNL group, postoperative fever was observed in six patients, with two requiring blood transfusions. Two patients required ureteral catheter repositioning due to stent migration. In the f-URS group, postoperative fever developed in two patients, while one patient experienced pulmonary edema, which resolved with diuretic therapy. Additionally, one patient's ureteral stent was replaced under anesthesia due to migration.

Preoperative eGFR and creatinine values were comparable between the groups (median [IQR] of eGFR: 48.0 [32.3, 50.8] mL/min for m-PCNL vs. 50.5 [40.0, 56.3] mL/min for f-URS, $p = 0.158$; median [IQR] of creatinine: 1.5 [1.3, 2.3] mg/dL vs. 1.4 [1.3, 1.6] mg/dL, $p = 0.123$). At the 6-month follow-up, the f-URS group had significantly higher eGFR and lower creatinine values compared to the m-PCNL group, indicating better renal function at that time point (median [IQR] of eGFR: (44.0 [28.0–53.0] mL/min vs. 51.5 [40.8–57.0] mL/min, $p = 0.042$); median [IQR] of creatinine: 1.6 [1.3, 1.9] mg/dL vs. 1.4 [1.3, 1.5] mg/dL, $p = 0.031$).

However, when the absolute change in eGFR from baseline to 6 months (ΔeGFR, median [IQR]) was analyzed, no statistically significant difference was observed between the groups (m-PCNL: 2.0 [−8.8, 6.0] mL/min vs. f-URS: 1.0 [−3.0, 3.8] mL/min, $p = 0.516$). Similarly, Δcreatinine values (median [IQR]) did not differ significantly (−0.1 [−0.2, 0.3] mg/dL vs. 0.1 [−0.1, 0.1] mg/dL, $p = 0.189$) (Table 3).

CKD stage progression differed markedly between the groups. Two patients (5.5%) showed improvement, while 11 (30.5%) patients experienced stage progression and 23 (63.8%) remained stable in the m-PCNL group (Figure 2). In contrast, 9 (35.5%) patients in the f-URS group showed improvement, only 1 (4.1%) experienced progression, and 14 (58.3%) remained stable (Figure 3).

In a post hoc exploratory subgroup analysis of patients with 10–20 mm stones (m-PCNL n = 16; f-URS n = 14), SFRs were similar between the groups (100% vs. 92.8%, $p = 0.74$), but perioperative and functional outcomes were significantly better in the f-URS group. Operative time was shorter (median [IQR]: 72.00 [70.25, 73.75] min vs. 41.50 [39.25, 43.75] min, $p = 0.004$), hemoglobin drop was lower (median [IQR]: 1.20 [1.12, 1.30] g/dL vs. 0.60 [0.50, 0.67] g/dL, $p < 0.001$), and hospital stay was significantly reduced (median [IQR]: 61 [48, 69] h vs. 24 [21, 26] h, $p < 0.001$). In terms of renal function, f-URS led to a modest improvement (median [IQR] of ΔeGFR: 1.15 [0.83, 1.73] mL/min) compared to a decline in

TABLE 1. **Comparison of patients' demographics and stone characteristics between groups**

Characteristic	PCNL (n = 36)	f-URS (n = 24)	*p* value
Age (year), median (IQR)	62 (49.5, 66)	53.5 (47.5, 68)	0.786
Gender, n (%)			
Male	23 (63.9)	13 (54.2)	0.451
Female	13 (36.1)	11 (45.8)	
BMI (kg/m²), median (IQR)	25 (47.5, 68)	24 (21.3, 32.3)	0.838
Hypertension, n (%)	20 (55.6)	10 (41.7)	0.292
Diabetes mellitus, n (%)	11 (30.6)	12 (50)	0.129
Coronary artery disease, n (%)	6 (16.7)	2 (8.3)	0.352
Stone size (mm), median (IQR)	21 (20, 25)	19 (16, 24.8)	0.078
Stone location, n (%)			0.583
Upper calyx	5 (13.9)	5 (20.8)	
Mid calyx	4 (11.1)	4 (16.7)	
Pelvis	14 (38.9)	11 (45.8)	
Lower calyx	7 (19.4)	2 (8.3)	
Multiple	6 (16.7)	2 (8.3)	
Stone opacity, n (%)			0.383
Opaque	29 (80.6)	17 (70.8)	
Non-opaque	7 (19.4)	7 (29.2)	
Side, n (%)			0.460
Right	20 (55.6)	11 (45.8)	
Left	16 (44.4)	13 (54.2)	
Previous stone surgery, n (%)			0.665
Primary	13 (36.1)	10 (41.7)	
Secondary	23 (63.9)	14 (58.3)	

Note. IQR, interquartile range; PCNL, percutaneous nephrolithotomy; f-URS, flexible ureterorenoscopy; BMI, body mass ındex.

TABLE 2. **Comparison of operation and postoperative data between groups**

Clinical data	PCNL (n = 36)	f-URS (n = 24)	*p* value
Heamoglobin drop (g/dL), median (IQR)	1.1 (0.5, 1.9)	0.5 (0.2, 1.0)	0.002
Operation duration (min), median (IQR)	85.5 (71.0, 96.0)	62.0 (41.5, 83.8)	<0.001
Fluoroscopy time (min), mean ± SD	0.7 ± 0.3	0.2 ± 0.1	<0.001
Hospital stays (hour), median (IQR)	64.5 (43.3, 74.8)	36.5 (20.3, 63.0)	<0.001
Stone-free rate, n (%)	31 (86.1)	19 (79.2)	0.480
Complication, n (%)	8 (22.2)	4 (16.7)	0.746
Clavien-Dindo 1-2	6 (16.7)	3 (12.5)	
Clavien-Dindo 3-5	2 (5.5)	1 (4.2)	

Note. IQR, interquartile range; SD, standard deviation; PCNL, percutaneous nephrolithotomy; f-URS, flexible ureterorenoscopy.

the m-PCNL group (median [IQR]: −3.85 [−4.07, −3.52] mL/min, $p < 0.001$). CKD stage progression was observed in none of the patients in the f-URS group (0/14), whereas 4 of 16 patients (25%) in the m-PCNL group experienced worsening of CKD stage ($p = 0.041$) (Table 4). Adjusted *p*-values using Bonferroni correction for multiple comparisons are presented in Table 4.

TABLE 3. **Comparison of creatinine and glomerular filtration rate values in the preoperative and postoperative periods**

Clinical data	PCNL (n = 36)	f-URS (n = 24)	*p* value
Preoperative creatinine (mg/dL), median (IQR)	1.5 (1.3, 2.3)	1.4 (1.3, 1.6)	0.123
Preoperative eGFR (mL/min/1.73 m²), median (IQR)	48.0 (32.3, 50.8)	50.5 (40.0, 56.3)	0.158
Postoperative 1. month creatinine (mg/dL), median (IQR)	1.5 (1.4, 2.1)	1.6 (1.3, 1.6)	0.149
Postoperative 1. month eGFR (mL/min/1.73 m²), median (IQR)	45.0 (29.3, 53.0)	47.0 (37.8, 52.0)	0.410
Postoperative 6. month creatinine (mg/dL), median (IQR)	1.6 (1.3, 1.9)	1.4 (1.3, 1.5)	0.031
Postoperative 6. month eGFR (mL/min/1.73 m²), median (IQR)	44.0 (28.0, 53.0)	51.5 (40.8, 57)	0.042
ΔeGFR (mL/min), median (IQR)	2.0 (−8.8, 6.0)	1.0 (−3.0, 3.8)	0.516
Δcreatinine (mg/dL), median (IQR)	0.1 (−0.2, 0.3)	−0.1 (−0.1, 0.1)	0.189

Note. IQR, interquartile range; eGFR, estimated glomerular filtration rate; PCNL, percutaneous nephrolithotomy; f-URS, flexible ureterorenoscopy; ΔeGFR, Absolute change in eGFR from baseline to 6 months; Δcreatinine, Absolute change in creatinine from baseline to 6 months.

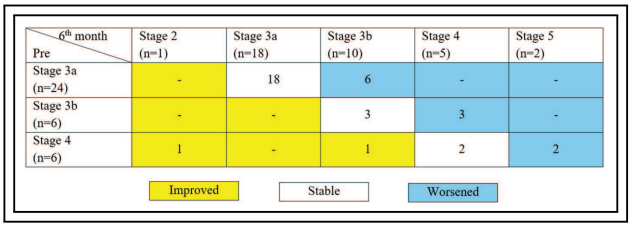

FIGURE 2. Change in preoperative and postoperative 6th month renal failure stages in patients who underwent percutaneous nephrolithotomy

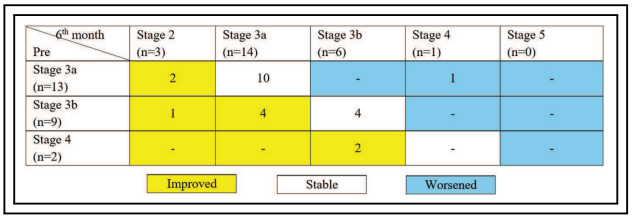

FIGURE 3. Change in preoperative and postoperative 6th month renal failure stages in patients who underwent flexible ureterorenoscopy

Discussion

Advancements in endourology have increased the efficacy of m-PCNL and f-URS in achieving high stone-free rates. A retrospective study by Ergin et al. involving 90 patients reported a mean stone size of 13.9 ± 2.9 mm and found no significant difference in SFR between m-PCNL and f-URS groups ($p > 0.05$).[13] In a meta-analysis, PCNL achieved higher stone-free rates than f-URS, particularly in subgroup analyses of stones ≥2 cm.[14] In our study, the stone-free rates were 86.1% for m-PCNL and 79.2% for f-URS. Although literature reports favor m-PCNL for stones >2 cm, our findings did not reveal a statistically significant difference. The definition of SFR in our study was intentionally strict, considering any residual fragment as treatment failure. This approach was based on recent evidence highlighting the clinical significance of even small residual fragments in CKD patients, who may be more susceptible to infection, obstruction, and progressive renal impairment. Çavdar et al. emphasized that residual fragments, regardless of size, should not be underestimated in high-risk populations.[12] In our cohort, 5 patients in the m-PCNL group and 5 patients in the f-URS group had small residual fragments (<4 mm), all of whom were classified as not stone-free and were managed with surveillance, or medical therapy.

The patient positioning and kidney access required for PCNL typically result in longer operation times than f-URS.[14] Fluoroscopy is employed during f-URS to position access sheaths and identify non-visible stones, while PCNL utilizes fluoroscopy at various stages, including kidney access and stone evaluation. Aligning with these findings, our results indicated that f-URS was advantageous regarding operation and fluoroscopy times ($p < 0.001$). This

TABLE 4. **Subgroup analysis of patients with 10–20 mm renal stones**

Subgroup	m-PCNL (n = 16)	f-URS (n = 14)	*p*-value	Adjusted *p*-value
Stone-free rate (%), (n/N)	100% (16/16)	92.8% (13/14)	0.74	>0.99
Operative time (min), median (IQR)	72.00 (70.25, 73.75)	41.50 (39.25, 43.75)	0.004	0.024
Hemoglobin drop (g/dL), median (IQR)	1.20 (1.12, 1.30)	0.60 (0.50, 0.67)	<0.001	0.006
Hospital stay (hours), median (IQR)	61 (48, 69)	24 (21, 26)	<0.001	0.006
CKD stage progression (%), (n/N)	25.0% (4/16)	0.0% (0/14)	0.041	0.246
ΔeGFR (mL/min), median (IQR)	−3.85 (−4.07, −3.52)	1.15 (0.83, 1.73)	<0.001	0.006

Note. IQR, interquartile range; eGFR, estimated glomerular filtration rate; PCNL, percutaneous nephrolithotomy; f-URS, flexible ureterorenoscopy; CKD, chronic kidney disease; ΔeGFR, absolute change in eGFR from baseline to 6 months.

discrepancy may be partially attributed to the limited use of ultrasonography during percutaneous access in our clinic.

Percutaneous nephrolithotomy is inherently associated with a higher risk of bleeding. A retrospective study by Akbulut et al., which included 94 patients, demonstrated a significantly lower postoperative hemoglobin drop in the f-URS group than in the m-PCNL group (0.39 g/dL vs. 1.15 g/dL, $p < 0.001$).[15] Similarly, our study revealed a greater hemoglobin decrease in the PCNL group ($p = 0.002$), contributing to longer postoperative hospital stays ($p < 0.001$). Acute blood loss adversely affects renal function, potentially explaining the observed deterioration in eGFR and creatinine levels 6 months postoperatively.[16]

Regarding postoperative complications, Wan et al. reported no significant differences between f-URS and m-PCNL groups.[17] Consistent with this, our study found no statistically significant variation in complication rates between the two groups ($p = 0.746$).

Several previous studies have demonstrated perioperative advantages of f-URS over m-PCNL for stones around 2 cm; however, most excluded patients with impaired renal function, limiting their applicability to CKD populations. In contrast, CKD-specific evidence is largely derived from retrospective cohorts. Consistent findings have been reported across other retrospective series; however, interpretation remains limited by selection bias, heterogeneity in surgical techniques, and incomplete biochemical follow-up[9,10,18] By providing prospective randomized data with standardized follow-up, the present study strengths existing evidence by directly comparing functional outcomes between f-URS and m-PCNL in CKD patients. Nevertheless, potential cofounders such as stone composition, baseline hydronephrosis, and chronic parenchymal changes may also influence postoperative renal function and were not fully captured in prior studies nor in the current analysis.[19,20] These factors should be considered when interpreting renal functional outcomes and warrant further investigation in larger, CKD-specific trials.

In parallel with the existing literature on PCNL in patients with compromised renal function, our findings also indicate that postoperative renal functional trajectories vary within this population. In the study by Patel et al., among 60 patients with chronic kidney damage who underwent percutaneous nephrolithotomy, 6-month follow-up revealed improvement in GFR values in 45 patients (75%) and deterioration in 15 patients (25%). Seven of these patients showed improvement in their CKD stages, while 53 were stable.[9] In our cohort of 36 PCNL patients, only two patients' CKD stages had improved, while 23 remained stable and 11 experienced a decline. This is concorded with an overall improvement in renal function, as seen in the reported literature.[18,21]

Conversely, f-URS has demonstrated more favorable outcomes in renal function. A study investigating f-URS surgery in 163 patients reported significant deterioration in kidney function in 4.9% of cases and significant improvement in 14.1%.[22] Similarly, our findings showed kidney function improvement in 35.5% (n = 9) of patients, stability in 58.3% (n = 14), and decline in only 4.1% (n = 1). These results

align with existing literature, highlighting the renal preservation advantage of f-URS.

At the 6-month follow-up, absolute eGFR values were higher in the f-URS group ($p = 0.042$), while the m-PCNL group showed a slight decrease. However, this difference was not statistically significant when the ΔeGFR from baseline was analyzed. The apparent discrepancy may be explained by the categorical nature of CKD staging, where even small fluctuations in eGFR can cross threshold values and result in apparent stage progression or improvement. This limitation should be considered when interpreting CKD stage outcomes, as stage shifts may overestimate the true clinical impact of renal function changes.[23] When viewed in this context, the lower CKD stage progression observed in the f-URS group may indicate a potential advantage, but this should be interpreted cautiously given the absence of significant differences in functional change from baseline. These observations are consistent with those of Reeves et al., who demonstrated the safety of f-URS in CKD patients, particularly regarding renal function preservation[10] Importantly, our study adds value by focusing specifically on CKD patients, where even small differences in renal preservation may be clinically meaningful.

Our subgroup analysis of 10–20 mm stones further refine this perspective. This size range—often regarded as a therapeutic grey zone—poses a clinical decision-making challenge, as both f-URS and m-PCNL are considered viable.[24,25] In this subset, f-URS demonstrated superior functional preservation and perioperative safety, lending support to a more conservative, kidney-sparing strategy for appropriately selected CKD patients. Given the small sample size (n = 30) and the post hoc nature of this group analysis, these findings should be interpreted cautiously and regarded as hypothesis-generating rather than conclusive, as the statistically significant differences may partly reflect and increased risk of type 1 error.[26] Taken together, these findings highlight the need for individualized treatment plans and underscore the importance of larger, stratified studies to confirm the optimal approach for CKD patients with urolithiasis.

The main strength of our study lies in its prospective randomized design. However, the relatively small sample size may have limited the statistical power and reduced the ability to perform robust subgroup or multivariate analyses. Although baseline characteristics did not differ significantly between groups, numerical trends in comorbidities such as diabetes and hypertension could still have influenced the outcomes. The inclusion of stones measuring 1–4 cm was intentional to reflect real-world clinical practice in CKD patients and to ensure adequate recruitment, but it inevitably introduced heterogeneity in stone burden and procedural complexity. The dropout rate differed between the groups, with a greater proportion of exclusions occurring in the f-URS arm. Although the baseline characteristics of the initially randomized 80 patients were comparable to those of the 60 patients who completed the study, suggesting no major demographic imbalance, this differential attrition may still have introduced bias. The subgroup analysis of patients with 10–20 mm stones was performed post hoc and included a limited number of patients, so its results should be interpreted as exploratory. Additionally, no multivariable adjustments were applied to control for potential confounders. Future studies with larger cohorts should include stratified analyses and multivariable models to further validate these findings.

Conclusions

In this prospective randomized study of CKD patients with 1–4 cm renal stones, f-URS and m-PCNL achieved comparable SFRs. At 6 months, absolute eGFR and creatinine values favored f-URS, although ΔeGFR and Δcreatinine did not differ significantly between groups. CKD stage progression was more frequent after m-PCNL, whereas improvement or stability was more common with f-URS. Taken together, these results suggest that f-URS may provide advantages in perioperative safety and renal function preservation, but larger cohorts and long-term follow-up are needed to confirm these findings. Given the high-risk nature of this population, treatment selection should be individualized, balancing stone burden, comorbidities, and procedural risks.

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Author Contributions

Nazım Furkan Guünay: Conceptualization (lead); writing—original draft (lead); formal analysis (lead); writing—review and editing (equal). Mücahit

Gelmiş, Çağlar Dizdaroğlu: Software (lead); writing—review and editing (equal). Ufuk Çağlar, Abdullah Esmeray: Methodology (lead); writing—review and editing (equal). Faruk Özgör, Ömer Sarılar: Conceptualization (supporting); writing—original draft (supporting); writing—review and editing (equal). All authors reviewed the results and approved the final version of the manuscript.

Availability of Data and Materials

Data are available from the corresponding author upon reasonable request.

Ethics Approval

This study was approved by the Haseki Training and Research Hospital Ethics Committee (date/No: 01.03.2023/88-2022) and was performed in accordance with the Declaration of Helsinki.

Informed Consent

Written informed consent was obtained from all individual participants prior to enrollment.

Conflicts of Interest

The authors declare no conflicts of interest to report regarding the present study.

References

1. Ghani KR, Andonian S, Bultitude M et al. Percutaneous nephrolithotomy: update, trends, and future directions. *Eur Urol* 2016;70(2):382–396. doi:10.1016/j.eururo.2016.01.047. Epub 2016 Feb 11.
2. Yanaral F, Ozgor F, Kucuktopcu O et al. Comparison of flexible ureterorenoscopy and mini percutaneous nephrolithotomy in the management of multiple renal calculi in 10–30 mm size. *Urol J* 2019;16(4):326–330. doi:10.22037/uj.v0i0.3310.
3. Sener TE, Cloutier J, Villa L et al. Can we provide low intrarenal pressures with good irrigation flow by decreasing the size of ureteral access sheaths? *J Endourol* 2016;30(1):49–55. doi:10.1089/end.2015.0387.
4. Asutay MK, Lattarulo M, Liourdi D et al. Does ureteral access sheath have an impact on ureteral injury? *Urol Ann* 2022;14(1):1–7. doi:10.4103/UA.UA_163_20.
5. Schwalb DM, Eshghi M, David Ian M, Franco I. Morphological and physiological changes in the urinary tract associated with ureteral dilation and ureteropyeloscopy: an experimental study. *J Urol* 1993;149(6):1576–1585. doi:10.1016/s0022-5347(17)36456-x.
6. Escobar Monroy R, Proietti S, De Leonardis F et al. Complications in percutaneous nephrolithotomy. *Complications* 2025;2(1):5. doi:10.3390/complications2010005.
7. Yu J, Choi JM, Lee J et al. Risk factors for pulmonary complications after percutaneous nephrolithotomy: a retrospective observational analysis. *Medicine* 2016;95(35):e4513. doi:10.1097/MD.0000000000004513.
8. Cloyd JM, Ma Y, Morton JM, Kurella Tamura M, Poultsides GA, Visser BC. Does chronic kidney disease affect outcomes after major abdominal surgery? Results from the national surgical quality improvement program. *J Gastrointest Surg* 2014;18(3):605–612. doi:10.1007/s11605-013-2390-3.
9. Patel R, Agarwal S, Sankhwar SN, Goel A, Singh BP, Kumar M. A prospective study assessing feasibility of performing percutaneous nephrolithotomy in chronic kidney disease patients—What factors affect the outcome? *Int Braz J Urol* 2019;45(4):765–774. doi:10.1590/S1677-5538.IBJU.2018.0816.
10. Reeves T, Pietropaolo A, Somani BK. Ureteroscopy and laser stone fragmentation is safe and tends to improve renal function in patients with chronic kidney disease: prospective outcomes with a minimum follow-up of 6 months. *J Endourol* 2020;34(4):423–428. doi:10.1089/end.2019.0784.
11. Goodbred Andrew J, Langan Robert C. Chronic kidney disease: prevention, diagnosis, and treatment. *Am Fam Physician* 2023;108(6):554–561.
12. Çavdar OF, Aydin A, Tokas T et al. Residual stone fragments: systematic review of definitions, diagnostic standards. *World J Urol Vol* 2025;43(1):194. doi:10.1007/s00345-025-05572-x.
13. Ergin G, Kirac M, Kopru B, Ebiloglu T, Biri H. Flexible ureterorenoscopy versus mini-percutaneous nephrolithotomy for the treatment of renal stones. *Urol J* 2018;15(6):313–317. doi:10.22037/uj.v0i0.4208. Published 2018 Nov 17.
14. Chung DY, Kang DH, Cho KS et al. Comparison of stone-free rates following shock wave lithotripsy, percutaneous nephrolithotomy, and retrograde intrarenal surgery for treatment of renal stones: a systematic review and network meta-analysis. *PLoS One* 2019;14(2):e0211316. doi:10.1371/journal.pone.0211316.
15. Akbulut F, Kucuktopcu O, Kandemir E et al. Comparison of flexible ureterorenoscopy and mini-percutaneous nephrolithotomy in treatment of lower calyceal stones smaller than 2 cm. *Ren Fail* 2016;38(1):163–167. doi:10.3109/0886022X.2015.1128792.
16. Buse S, Mager R, Mazzone E, Mottrie A, Frees S, Haferkamp A. Impact of blood loss on renal function and interaction with ischemia duration after nephron-sparing surgery. *Curr Oncol* 2022;29(12):9760–9766. doi:10.3390/curroncol29120767. Published 2022 Dec 10.
17. Wan C, Wang D, Xiang J et al. Comparison of postoperative outcomes of mini percutaneous nephrolithotomy and standard percutaneous nephrolithotomy: a meta-analysis. *Urolithiasis* 2022;50(5):523–533. doi:10.1007/s00240-022-01349-8.
18. Kurien A, Baishya R, Mishra S et al. The impact of percutaneous nephrolithotomy in patients with chronic kidney disease. *J Endourol* 2009;23(9):1403–1407. doi:10.1089/end.2009.0339.

19. Nassir A, Saada H, Alnajjar T et al. The impact of stone composition on renal function. *Urol Ann* 2018;10(2):215–218. doi:10.4103/UA.UA_85_17.
20. Hsiao CY, Chen TH, Lee YC et al. Ureteral stone with hydronephrosis and urolithiasis alone are risk factors for acute kidney injury in patients with urinary tract infection. *Sci Rep Vol* 2021;11(1):23333. doi:10.1038/s41598-021-02647-8.
21. Bilen CY, Inci K, Kocak B, Tan B, Sarikaya S, Sahin A. Impact of percutaneous nephrolithotomy on estimated glomerular filtration rate in patients with chronic kidney disease. *J Endourol* 2008;22(5):895–900. doi:10.1089/end.2007.0435.
22. Hoarau N, Martin F, Lebdai S et al. Impact of retrograde flexible ureteroscopy and intracorporeal lithotripsy on kidney functional outcomes. *Int Braz J Urol* 2015;41(5):920–926. doi:10.1590/S1677-5538.IBJU.2014.0402.
23. Kovesdy CP. Epidemiology of chronic kidney disease: an update 2022. *Kidney Int Suppl* 2022;12(1):7–11. doi:10.1016/j.kisu.2021.11.003.
24. Elmansy H, Fathy M, Hodhod A et al. Mini-percutaneous nephrolithotomy vs. flexible ureteroscopy for 1–2 cm lower pole renal stones: a randomised controlled trial. *BJU Int* 2025;135(3):437–445. doi:10.1111/bju.16567.
25. Tonyali S, Haberal HB, Esperto F et al. The prime time for flexible ureteroscopy for large renal stones is coming: is percutaneous nephrolithotomy no longer needed? *Urol Res Pract* 2023;49(5):280–284. doi:10.5152/tud.2023.23142.
26. Kim HY. Statistical notes for clinical researchers: post-hoc multiple comparisons. *Restor Dent Endod* 2015;40(2):172–176. doi:10.5395/rde.2015.40.2.172.