

Original Article

Flexible ureteroscopy vs. percutaneous nephrolithotomy for upper ureteral calculi: efficacy and postoperative quality of life

Yuaning Zhang*, Chongjiong Cai*, Ling Zhou, Long Cai

*Department of Urology, Renhuai People's Hospital, Renhuai 564500, Guizhou, P. R. China. *Equal contributors and co-first authors.*

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Abstract: This study compared the clinical efficacy and postoperative quality of life of flexible ureteroscopy (fURS) versus percutaneous nephrolithotomy (PCNL) in patients with upper ureteral calculi (UUC). A total of 152 patients with UUC treated at Renhuai People's Hospital between January 2024 and January 2026 were enrolled and divided into two groups based on the surgical procedure received: a fURS group (n=75) and a PCNL group (n=77). Outcomes included clinical efficacy, stone-free rates at 1 week and 1 month post-surgery, surgical metrics (bleeding volume (BV), operative time (OT), hospital length of stay (HLOS)), postoperative pain (POP; Visual Analogue Scale (VAS)), inflammatory markers (interleukin (IL)-6, IL-8, high-sensitivity C-reactive protein (hs-CRP)), hemorheology (plasma viscosity (PV), low/high shear (LS/HS), hematokrit (HCT)), clinical safety outcomes, and quality of life (Generic Quality Of Life Inventory-74 (GQOLI-74)). The PCNL group had a significantly higher overall clinical efficacy rate than the fURS group, with comparable 1-week and 1-month stone-free rates between groups. Patients receiving fURS had less bleeding and shorter hospital stays than PCNL patients, while OTs were similar. The fURS group had lower VAS scores on postoperative days 1 and 3, as well as lower inflammatory and hemorheological marker levels on day 3, compared to the PCNL group. The clinical safety of the two procedures was equivalent. The postoperative GQOL-74 scores across domains were higher in the fURS group than in the PCNL cohort. PCNL offers a higher efficacy rate in UUC patients, with stone-free rates comparable to fURS at 1 week and 1 month post-surgery. However, fURS is clinically advantageous in terms of bleeding (less), recovery (faster), and short-term POP (milder). fURS also better suppressed postoperative inflammatory rises, had a milder effect on hemorheological parameters, and was associated with better postoperative quality of life.

Keywords: Flexible ureteroscopy, percutaneous nephrolithotomy, upper ureteral calculi, curative effect, quality of life

Introduction

Ureteral calculi (UC) are a common urological condition with an increasing incidence of occurrence [1]. The condition may present with renal colic, hematuria, hydronephrosis, and fever, and is characterized by a high recurrence rate and significant complication risk [2]. World-wide, UC is found in one-fifth of all urolithiasis cases, with 70% in the distal ureter and 30% in the upper ureter [3]. Delayed stone removal, especially for UUC, may cause persistent obstruction and subsequent hydronephrosis [4]. This is because UUC is located close to the renal hilum. Obstruction can elevate intrarenal pressure, promote bacterial translocation, and

trigger inflammation, thereby increasing the risk of acute hydronephrosis, renal dysfunction, and chronic kidney disease [5, 6]. Optimizing clinical management, particularly treatment selection, is essential to alleviate symptoms and improve quality of life (QoL) in UUC patients.

Percutaneous nephrolithotomy (PCNL) and flexible ureteroscopy (fURS) are effective minimally invasive procedures for UUC [7]. Although PCNL has a high stone-free rate, it requires establishing a percutaneous tract and carries risks of bleeding and injury to adjacent organs [8]. fURS, also known as retrograde intrarenal surgery (RIRS), uses a flexible endoscope that can effectively fragment intrarenal stones, as well

as displaced or migrated ureteral stones [9]. The procedure is easier to perform and does not require puncture or tract dilation [10]. A meta-analysis showed that fURS for lower pole stones may require more unplanned procedures and retreatments than PCNL [11]. A systematic review of 18 RCTs reported that PCNL offers higher efficacy than fURS for UUC, but is associated with longer hospital length of stay (HLOS), greater hemoglobin decline, more intense postoperative pain (POP), higher costs, and more complications [12].

At present, the comparative performance of PCNL versus fURS in UUC patients remains debated and needs further clarification. This study sets out to compare the clinical efficacy of PCNL and fURS in UUC-affected individuals, while also systematically evaluating 1-week and 1-month postoperative stone-free rates, surgical metrics, postoperative pain, inflammatory markers, hemorheology, clinical safety, and quality of life, to comprehensively clarify which treatment plan has a greater clinical advantage. The ultimate goal of this study is to inform treatment decisions and improve clinical practice for UUC.

Clinical data

Baseline information

This retrospective study enrolled 152 patients with UUC treated at Renhuai People's Hospital between January 2024 and January 2026. All consecutive patients meeting the eligibility criteria during the study period were included. Patients were divided into a fURS group (n=75) and a PCNL group (n=77) according to the procedure received. This study was approved by the ethics committee of Renhuai People's Hospital. The surgical approach was chosen by the surgeon based on individual patient factors, including stone diameter, CT attenuation values, impaction status, and hydronephrosis. Clinical data were independently extracted from the electronic medical record system by two researchers. Data analysis was performed by a third researcher blinded to group allocation.

Case selection criteria

Patients were included if they had a UUC diagnosis confirmed by urinary ultrasound and abdominal plain film [13]; unilateral single stone;

first-time treatment; planned fURS or PCNL without contraindications; normal cognitive and communication ability; and complete medical records.

Exclusion criteria were: ureteral or renal malformations, urinary tract infection or severe hydronephrosis, pregnancy or lactation, creatinine >451 $\mu\text{mol/L}$, ureteropelvic junction stenosis, renal tuberculosis, renal tumor or other malignancies, and serious organic diseases.

Treatment methods

All surgeries were performed by two senior attending physicians with over 5 years of experience. All patients fasted for 12 hours and were deprived of water for 4 hours before surgery.

Patients in the fURS group underwent flexible ureteroscopic lithotripsy. Under general anesthesia in the lithotomy position, an 8/9.8 F rigid ureteroscope was inserted for inspection. The affected ureter was dilated, and a 0.035-inch super-elastic nitinol guidewire was inserted, over which a ureteral access sheath (UAS) was placed. Under direct vision, a flexible ureteroscope was inserted through the lumen of the UAS. After localizing the stone, a 200- μm holmium laser fiber was passed through the working channel for lithotripsy. The laser power was set at 10-20 W and adjusted as needed until the stone was fragmented to <3 mm. Stone fragments were removed using a stone retrieval basket. A 5F double-J stent was placed postoperatively and removed within 3 months depending on recovery.

Patients in the PCNL group underwent PCNL. Under general anesthesia in the prone position, the stone was localized using B-ultrasound guidance. The appropriate renal calyx was selected for puncture. A 16-24F percutaneous renal access tract was then established via sequential dilation. A percutaneous nephroscope or ureteroscope was inserted through the tract, and pneumatic or ultrasonic lithotripsy was performed for stone fragmentation and removal. A nephrostomy tube and a 5F double-J stent were placed postoperatively and removed at 3 days and 3 weeks, respectively.

Postoperative patient-controlled intravenous analgesia (flurbiprofen axetil 50 mg in 100 mL normal saline) was provided, with a background

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rate of 2 mL/h, bolus of 1 mL, and lockout interval of 15 min.

Outcome measures

Efficacy. Complete remission was defined as complete resolution of flank pain and residual stone <4 mm on CT plain scan; Partial remission was defined as marked improvement in flank pain with residual stone <4 mm. Non-remission was defined as no significant pain relief or symptom worsening, with residual stone >4 mm. The overall remission rate was calculated as (complete + partial remissions)/total cases × 100%.

Stone-free rate. Abdominal CT was performed at 1 week and 1 month postoperatively to assess stone-free status. The criteria for clinical success were no residual stones, or stones with the longest diameter <3 mm.

Surgical metrics. For both patient groups, the intraoperative bleeding volume (BV), operative time (OT), and HLOS were recorded. Intraoperative blood loss was estimated using the weighing method. The formula was: intraoperative blood loss = hemoglobin concentration (g/L) of intraoperative samples × total flushing fluid volume (mL)/preoperative hemoglobin concentration (g/L).

POP [14]. The POP assessment was made with the 10-point Visual Analogue Scale (VAS), with the score positively correlated with the pain degree.

Inflammatory markers. Fasting venous blood samples (5 mL) were collected in the morning before and 3 days after surgery. Serum was separated by centrifugation, and IL-6, IL-8, and high-sensitivity C-reactive protein (hs-CRP) were measured using ELISA.

Hemorheology. Plasma viscosity (PV), low/high shear (LS/HS), and hematocrit (HCT) were measured using a hemorheology analyzer before and 3 days after surgery.

Clinical safety. Adverse events including hyperpyrexia, hematuria, infection, and renal colic were recorded.

QoL [15]. QoL was assessed in four domains (physical, psychological, social, and material life) using the Generic Quality Of Life Inventory-74 (GQOL-74). All dimensions were scored with a percentage system, with higher scores denoting better QoL.

Statistical methods

The Shapiro-Wilk test was used to assess normality of continuous variables. Normally distributed data were expressed as mean ± SD. Between-group and within-group comparisons were made using independent-sample and paired t-tests, respectively. Non-normally distributed data were presented as median (IQR) and compared using the Mann-Whitney U test. Categorical data were expressed as n (%) and compared using the chi-square test. Statistical analyses were performed using SPSS 22.0. A *P*-value <0.05 was considered statistically significant.

Results

General patient information

Table 1 summarizes the baseline characteristics. There were no significant differences between groups in sex, age, BMI, disease duration, stone diameter, stone location, or hydronephrosis (all *P*>0.05).

Efficacy comparison

Table 2 shows that 61 patients in the fURS group achieved remission (36 complete, 25 partial). In the PCNL group, 71 patients achieved remission (45 complete, 26 partial). The overall remission rate was significantly higher in the PCNL group (*P*=0.047).

Stone-free rates of the two groups

As shown in **Table 3**, the 1-week stone-free rate was 94.67% in the fURS group and 97.40% in the PCNL group. Both groups achieved 100% stone-free status at 1 month. The stone-free rates of the two groups at 1 week and 1 month after surgery, as tested by Fisher's exact test, showed no significant differences (*P*>0.05).

Surgical metrics

As shown in **Table 4**, the fURS group had significantly less bleeding and shorter HLOS than the PCNL group (both *P*<0.001), while OTs were similar (*P*>0.05).

POP

According to **Table 5**, preoperative VAS scores were similar between groups (*P*>0.05). Both groups showed significant pain reduction on days 1 and 3 postoperatively, with the fURS

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Table 1. General patient information

Indicators	fURS group (n=75)	PCNL group (n=77)	χ^2/t	P
Sex			0.110	0.741
Male	40 (53.33)	39 (50.65)		
Female	35 (46.67)	38 (49.35)		
Age (years)	48.53±5.49	47.16±7.57	1.274	0.205
BMI (kg/m ²)	23.42±2.72	23.78±2.56	0.840	0.402
Disease duration (months)	8.12±2.26	8.53±2.14	1.149	0.253
Stone diameter (mm)	13.80±3.10	14.58±3.70	1.407	0.162
Stone location			0.229	0.632
Left	38 (50.67)	42 (54.55)		
Right	37 (49.33)	35 (45.45)		
Hydronephrosis			0.445	0.505
No	32 (42.67)	37 (48.05)		
Yes	43 (57.33)	40 (51.95)		

Note: fURS, flexible ureteroscopy; PCNL, percutaneous nephrolithotomy; BMI, body mass index.

Table 2. Efficacy comparison

Indicators	fURS group (n=75)	PCNL group (n=77)	χ^2	P
Complete remission	36 (48.00)	45 (58.44)		
Partial remission	25 (33.33)	26 (33.77)		
Non-remission	14 (18.67)	6 (7.79)		
Overall remission	61 (81.33)	71 (92.21)	3.932	0.047

Note: fURS, flexible ureteroscopy; PCNL, percutaneous nephrolithotomy.

Table 3. The stone-free rate of the two groups

Indicators	fURS group (n=75)	PCNL group (n=77)	P
1 week postoperative	71 (94.67)	75 (97.40)	0.439
1 month postoperative	75 (100.00)	77 (100.00)	>0.999

Note: fURS, flexible ureteroscopy; PCNL, percutaneous nephrolithotomy.

Table 4. Surgical metrics

Indicators	fURS group (n=75)	PCNL group (n=77)	t	P
BV (mL)	5.00±2.00	11.90±4.15	13.002	<0.001
OT (min)	53.55±12.11	56.47±13.72	1.390	0.167
HLOS (d)	6.13±2.22	10.94±3.03	11.140	<0.001

Note: fURS, flexible ureteroscopy; PCNL, percutaneous nephrolithotomy; BV, Bleeding volume; OT, Operative time; HLOS, hospital length of stay.

group reporting lower VAS scores than the PCNL group ($P<0.001$).

Inflammatory factors in two groups

Figure 1 shows the changes in inflammatory markers in both groups. IL-6, IL-8, and hs-CRP

levels were similar in both groups at baseline (all $P>0.05$). On postoperative day 3, all inflammatory markers increased significantly in both groups ($P<0.01$), but levels were significantly lower in the fURS group than in the PCNL group ($P<0.01$).

Hemorheology across groups

Baseline hemorheological parameters (PV, LS, HS and HCT) were similar between groups ($P>0.05$; **Figure 2**). On postoperative day 3, all parameters increased in both groups (all $P<0.05$), but the fURS group had significantly lower values than the PCNL group (all $P<0.05$).

Clinical safety analysis

As shown in **Table 6**, adverse events included hyperpyrexia (4 vs. 3), hematuria (1 vs. 5), infection (2 vs. 4), and renal colic (3 vs. 0) in the fURS and PCNL groups, respectively. There were no significant differences between groups in individual adverse events or total complication rates ($P>0.05$).

QoL

As shown in **Figure 3**, pre-operative GQOL-74 scores in all four domains were comparable between groups ($P>0.05$). Postoperative GQOL-74 scores improved significantly in both groups ($P<0.01$), with greater improvements observed in the fURS group ($P<0.01$).

Discussion

In this study, PCNL demonstrated a higher overall efficacy rate than fURS for UUC patients. This difference may be explained by the larger working channel (16-24F) of PCNL, which allows active stone aspiration during pneumat-

Table 5. Postoperative pain

Indicators	fURS group (n=75)	PCNL group (n=77)	Z	P
Pre-operation	6.00 (5.00, 7.00)	6.00 (4.00, 7.00)	-1.255	0.209
1 day postoperative	3.00 (2.00, 4.00)	4.00 (3.00, 5.00)	-5.150	<0.001
3 days postoperative	2.00 (1.00, 3.00)	3.00 (2.00, 4.00)	-3.850	<0.001

Note: fURS, flexible ureteroscopy; PCNL, percutaneous nephrolithotomy.

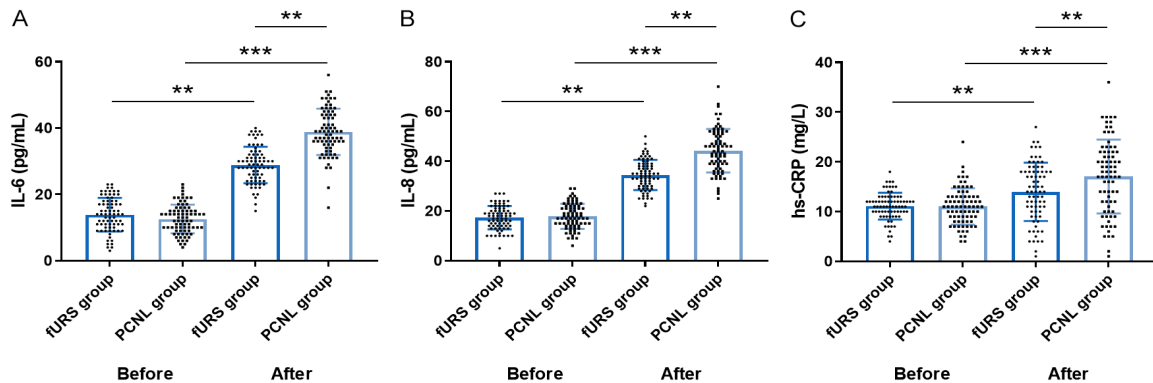


Figure 1. Inflammatory markers in two groups. A. Pre- and post-operative interleukin (IL)-6 levels in fURS (n=75) and PCNL (n=77) groups. B. IL-8 levels before and after surgery in fURS (n=75) and PCNL (n=77) groups. C. Pre- and post-operative high-sensitivity C-reactive protein (hs-CRP) levels in fURS (n=75) and PCNL (n=77) groups. Note: fURS, flexible ureteroscopy; PCNL, percutaneous nephrolithotomy. **P<0.01; ***P<0.001.

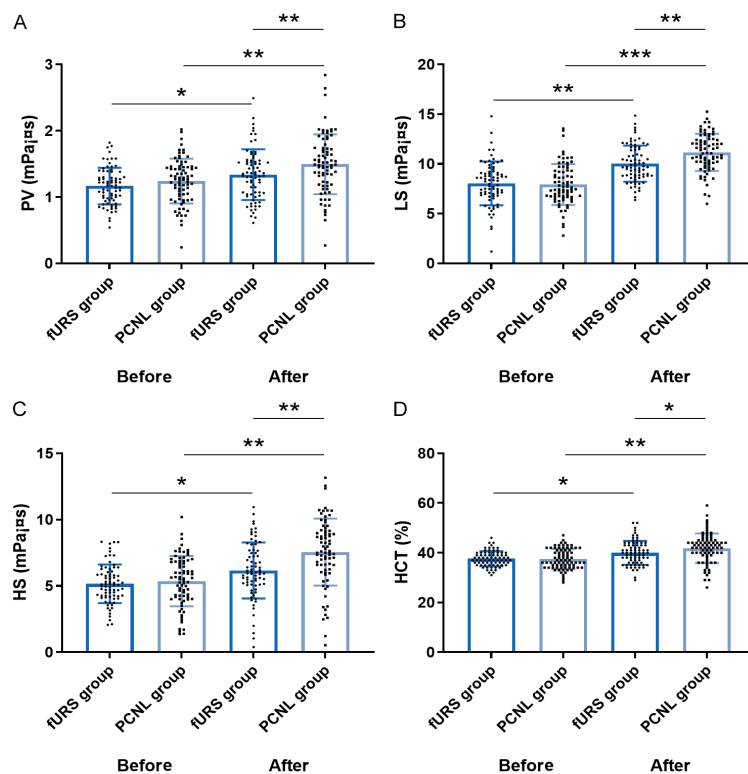


Figure 2. Hemorheology of the two groups. A. Pre- and post-operative plasma viscosity (PV) levels in fURS (n=75) and PCNL (n=77) groups. B. Pre- and post-operative low shear (LS) levels in fURS (n=75) and PCNL (n=77) groups. C. High shear (HS) levels before and after the operation in fURS (n=75) and

PCNL (n=77) groups. D. Pre- and post-operative hematocrit (HCT) levels in fURS (n=75) and PCNL (n=77) groups. Note: fURS, flexible ureteroscopy; PCNL, percutaneous nephrolithotomy. *P<0.05, **P<0.01, ***P<0.001.

ic or ultrasonic lithotripsy. In contrast, fURS relies on passive fragment removal after laser fragmentation [16]. Concerning stone-free rates, PCNL and fURS showed equivalent stone clearance efficiency at one week and one month post-operative. This may be attributed to the use of stone retrieval baskets during fURS, which reduces stone displacement and residual fragments. This helps prevent small fragments from migrating to the renal pelvis, improving the single-session stone-free rate to a level comparable to PCNL [17]. Supporting our results, Zeinelabden et al. [18] reported comparable stone-free rates between

Table 6. Clinical safety of the two groups

Indicators	fURS group (n=75)	PCNL group (n=77)	χ^2	P
Hyperpyrexia	4 (5.33)	3 (3.90)		0.717
Hematuria	1 (1.33)	5 (6.49)		0.210
Infection	2 (2.67)	4 (5.19)		0.681
Renal colic	3 (4.00)	0 (0.00)		0.118
Total	10 (13.33)	12 (15.58)	0.156	0.693

Note: fURS, flexible ureteroscopy; PCNL, percutaneous nephrolithotomy.

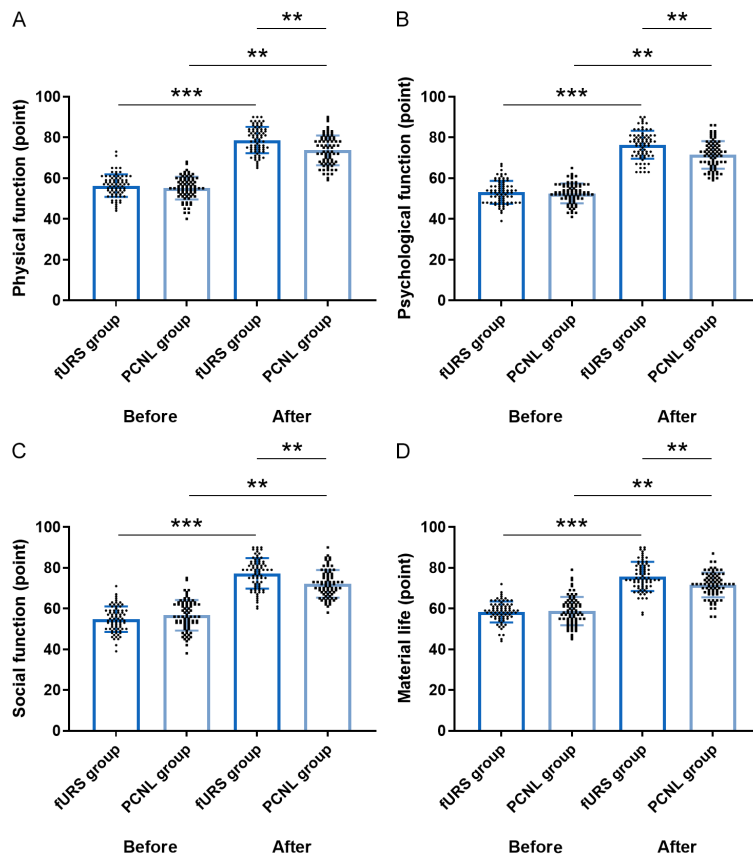


Figure 3. Quality-of-life assessment across groups. A. Physical function dimension scores of the GQOL-74 scale before and after surgery in fURS (n=75) and PCNL (n=77) groups. B. Pre- and post-operative psychological function scores in fURS (n=75) and PCNL (n=77) groups. C. GQOL-74 social function dimension scores before and after the operation in fURS (n=75) and PCNL (n=77) groups. D. Material life dimension scores of the GQOL-74 scale before and after surgery in fURS (n=75) and PCNL (n=77) groups. Note: GQOL-74, Generic Quality Of Life Inventory-74; fURS, flexible ureteroscopy; PCNL, percutaneous nephrolithotomy. **P<0.01; ***P<0.001.

PCNL and fURS for lower pole renal stones <2 cm. Additionally, fURS was associated with less bleeding and shorter HLOS than PCNL, with no significant difference in OT. This may be because fURS does not require tract creation and causes less tissue trauma [19]. Although PCNL has a high initial stone-free rate (up to

99%), it is more traumatic, leads to slower recovery, and carries risks of visceral injury and septic shock [20, 21]. The meta-analysis by Chen et al. [22] also found no differences in OT, fever, or infection rates, consistent with our findings. Furthermore, the fURS group had significantly lower VAS scores on days 1 and 3, suggesting better pain control. This may be because fURS is performed via the natural urinary tract, requiring only minimal dilation of the ureteral orifice. PCNL, in contrast, requires percutaneous puncture and tract formation, causing greater renal parenchymal and muscular injury and thus more postoperative pain [23]. Similarly, Qi et al. [24] found that fURS for 2-3 cm renal stones resulted in less pain, less bleeding, and shorter HLOS than PCNL.

Evidence suggests that UUC-induced obstruction can activate the renin-angiotensin system and renal inflammatory cascades, leading to hemodynamic imbalances. Surgical trauma may further exacerbate inflammation and hemorheological abnormalities [25, 26]. In this study, fURS was more effective in reducing postoperative IL-6, IL-8, and hs-CRP levels, indicating better suppression of the inflammatory response. Consistent with our findings, Xie et al. [16] reported lower inflammatory marker levels (IL-6 and CRP) with fURS than with PCNL in

patients with impacted upper ureteral stones and infection. Both groups showed postoperative increases in hemorheological parameters (PV, LS, HS, and HCT), but the changes were milder in the fURS group. The similar rates of adverse events between groups suggest that both procedures have comparable safety pro-

files. This may be related to the routine placement of a 5F double-J stent in both groups to ensure adequate urinary drainage. Although PCNL requires a nephrostomy tube (removed at 3 days), both groups received a 5F double-J stent (removed at 3 weeks), ensuring similar drainage. Despite greater surgical trauma with PCNL, the shorter nephrostomy tube indwelling time may partially offset complication risks. In a prospective RCT by Dutta et al. [27], fURS and PCNL showed no significant differences in OT or complications for 1-2 cm renal stones, aligning with our findings. Finally, fURS was associated with better postoperative QoL. This may be due to the earlier pain relief and faster recovery observed with fURS. Additionally, incorporating enhanced recovery protocols (ERAS) with PCNL may further improve QoL in infected UC patients, offering broader management insights [28].

This study has several deficiencies that need to be addressed in the future. First, health economic indicators were not assessed, limiting our ability to compare cost-effectiveness. Second, we did not perform multivariate analysis or develop a nomogram to identify predictors of efficacy, which would aid in risk stratification. Finally, long-term follow-up data are lacking. Future studies with 3-year follow-up are needed to evaluate the long-term prognosis of both procedures.

In summary, while PCNL offers higher efficacy for UUC, fURS provides comparable stone-free rates at 1 week and 1 month, similar OT and safety, along with advantages in blood loss, hospital stay, pain control, inflammatory suppression, and QoL.

Disclosure of conflict of interest

None.

Address correspondence to: Long Cai and Ling Zhou, Department of Urology, Renhuai People's Hospital, Renhuai 564500, Guizhou, P. R. China. E-mail: 15985075663@163.com (LC); Tel: +86-0851-22226846; E-mail: m13708524515_1@163.com (LZ)

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