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Comparison of efficacy and safety of flexible ureteroscopy and mini-percutaneous nephrolithotomy for 2-3 cm renal calculi in women: a single-center study

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Abstract. – OBJECTIVE: This study aimed to compare the efficacy and safety of flexible ureteroscopic lithotripsy (FURSL) and mini-percutaneous nephrolithotomy (mPCNL) in the treatment of 2-3 cm renal calculi in women.

PATIENTS AND METHODS: Clinical data of 186 patients who underwent mPCNL (n=96) and FURSL (n=90) surgery in our hospital from June 2018 to February 2023 were collected. Several parameters were assessed and compared between the two groups, including operation duration, length of hospital stay, cost of hospitalization, pain intensity measured by the visual analogue scale (VAS), patient comfort assessed using the Bruggrmann Comfort Scale (BCS), decrease in hemoglobin levels, changes in blood urea nitrogen (BUN), fluctuations in serum creatinine (Scr), hypersensitive C-reactive protein (hs-CRP) levels, complication rates, immediate post-operative stone-free rate (RSFR), and long-term stone-free rate (LSFR).

RESULTS: The comparative analysis of patient age, body mass index (BMI), stone size, computed X-ray tomography (CT) value of stones, number of stones, and comorbidities revealed no statistically significant differences between the mPCNL and FURSL groups ($p>0.05$). The mPCNL cohort exhibited a markedly lower duration of operation ($p<0.001$) and BCS score ($p<0.001$) compared to the FURSL cohort. Nonetheless, the mPCNL cohort demonstrated significantly higher hospitalization expenses ($p<0.001$), length of hospital stay ($p<0.001$), VAS score for pain ($p<0.001$), and level of hemoglobin decrease ($p<0.001$) in comparison to the FURSL cohort. Moreover, the immediate post-operative stone-free rate (RSFR) was significantly higher in the mPCNL group ($p=0.007$). The long-term stone-free rate (LSFR), however, showed no significant difference between the two groups ($p=0.160$). Furthermore, the FURSL group exhibited significantly fewer overall complications in contrast to the mPCNL group ($p=0.006$).

CONCLUSIONS: mPCNL and FURSL are both safe and effective surgical methods for treating 2-3 cm renal calculi in women. However, FURSL holds distinct advantages, including minimally invasive procedure, accelerated recovery, reduced cost, and lower incidence of complications.

Key Words:

Flexible ureteroscopic lithotripsy, Mini-percutaneous nephrolithotomy, Kidney stones, Female, Safety, Effectiveness.

Introduction

Renal calculi, which make up 40-50% of all urinary system calculi, are a common urological condition. Men have a 10.34% incidence rate of kidney stones compared to a 6.62% rate in women[1,2]. The pathogenesis of kidney stones remains incompletely understood but may involve factors like genetics, metabolism, infections, environment, diet, anatomy, and medication use[3,4]. Presently, the mainstay surgical interventions for kidney stones encompass flexible ureteroscopic lithotripsy (FURSL) and percutaneous nephrolithotomy (PCNL). Numerous recent studies[5-8] advocate mini-percutaneous nephrolithotomy (mPCNL) as the preferred method for treating kidney stones measuring 2-3 cm in diameter. However, mPCNL is associated with shortcomings, including invasiveness, risk of postoperative bleeding and infection, extended hospital stay, and slower recovery. Particularly for elderly female patients, postoperative bed

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rest can increase the risk of life-threatening complications such as deep vein thrombosis and pulmonary embolism[5-7]. FURSL, a natural path for internal lithotripsy, offers advantages like minimal invasiveness, low cost, minor bleeding, and fewer complications[8-10]. On the downside, it necessitates early placement of double J stents, possesses lower phase I stone removal efficiency, and poses a higher risk of infection[9-11]. Consequently, FURSL is typically recommended for treating kidney stones smaller than 2 cm in diameter[8-10]. In recent years, advancements in laser lithotripsy technology have facilitated the application of FURSL for treating kidney stones larger than 2 cm[5-10]. Recently, the incidence rate of renal calculi in female patients has witnessed a significant uptick[11]. Given the narrow width of the female urethra, endoscopic surgery for straight urinary tracts is prone to infections[12,13]. Consequently, the selection of a surgical treatment strategy for kidney stones in women necessitates a comprehensive appraisal. Reports focusing on surgical modality choice for 2-3 cm kidney stones in women remain sparse. This study retrospectively analyzed the clinical data from female patients who underwent mPCNL and FURSL procedures in our hospital from June 2018 to February 2023. It aims to delve into the effectiveness of mPCNL and FURSL in treating 2-3 cm kidney stones in women.

Patients and Methods

Case Collection

This study retrospectively analyzed clinical data from 186 patients who underwent miniaturized percutaneous nephrolithotomy (mPCNL) or flexible ureteroscopy and laser lithotripsy (FURSL) in our hospital between June 2018 and February 2023. Patients were classified into two groups based on their surgical intervention: the mPCNL group (n=96) and the FURSL group (n=90). Inclusion criteria comprised: (1) female patients, aged 20 years and above; (2) confirmed diagnosis of kidney stones through urinary ultrasound, intravenous pyelography, and computed tomography (CT) scans, with the stone size ranging from 2.0-3.0 cm; (3) patients undergoing surgical intervention for kidney stones for the first time; and (4) the patient and their family members' consent to the procedure, which was indicated by signing an informed consent form. The exclusion criteria encompassed: (1) patients who underwent any surgical procedure other than mPCNL and FURSL; (2) individuals diagnosed with hematological disorders predisposing them to bleeding; (3) individuals with severe liver and kidney dysfunction potentially influencing the study results; (4) patients with a previous history of surgical treatment for kidney stones; (5) patients with concurrent infections in other organs or febrile illnesses; and (6) cases with incomplete patient data and information. All patients involved in the study and their families provided informed consent, and the study was approved by the Ethics Committee of the 909th Hospital of Xiamen University.

Surgical Methods

The specific procedural methodologies and standard practices for miniaturized percutaneous nephrolithotomy (mPCNL) and flexible ureteroscopy and laser lithotripsy (FURSL) are consistent with those previously reported in the literature[13-16]. In this study, patients in the FURSL group had double J stents placed two weeks prior to the procedure. The surgery was performed under general anesthesia, with patients positioned in the lithotomy position. A Wolf Fr8 ureteroscope was employed to remove the double J stent through the urethra. Subsequently, an Fr14 ureteroscope sheath (Cook Medical, Bloomington, Indiana, USA) was inserted under the guidance of a zebra guidewire, followed by the insertion of an Olympus electronic ureteroscope (Olympus, Tokyo, Japan). The laser pulse energy for the FURSL procedure was set to 1.0-1.2 J, operating at a frequency of 20-25 Hz, and employing 200 μm laser fibers. Post-FURSL, all patients retained an Fr4.8 double J stent. The mPCNL procedure involved a target renal caliceal puncture guided by ultrasonography. Following the puncture, a zebra guidewire was used to facilitate a "one-step" expansion into an Fr18 operative channel. Subsequently, a pneumatic lithotripter was utilized to fragment the stones. Post-mPCNL, all patients retained an Fr4.8 double J stent and an Fr16 nephrostomy tube. Postoperative assessment of the immediate postoperative stone-free rate (RSFR) and long-term stone-free rate (LSFR) was achieved using abdominal plain films, ultrasound, or CT scans. RSFR refers to the proportion of patients with no significant residual stones or residual stones measuring <3 mm in diameter, assessed on the second postoperative day[17]. LSFR, on the other hand, pertains to the proportion of patients with no noticeable residual stones or residual stones measuring less than 3 mm in diameter, assessed one-month post-surgery[17].

Clinical Evaluation Indicators

Clinical data such as age, stone size, computed X-ray tomography (CT) value of stones, operation time, hospitalization time, hospitalization cost, RSFR, and LSFR were collected and analyzed for the two groups of patients. On the first day after surgery, the VAS and BCS were used to evaluate patient pain and comfort. hemoglobin, hypersensitive C-reactive protein (hs-CRP), blood urea nitrogen (BUN), and serum creatinine (Scr) were collected and analyzed before and within 4-6 hours after surgery.

Statistical Analysis

SPSS 20.0 (IBM Corp., Armonk, NY, USA) was used for data analysis. K-S one-sample test was used for normal distribution assessment. Normally distributed measurement data are expressed as mean ± standard deviation (x±s), and *t*-test was used for comparison between groups. The count data were expressed as frequency or rate (%) and were analyzed by Chi-square test or Fisher's exact test. Non normal data are represented by the median, and non-normal distribution data are analyzed by Mann-Whitney U test. Statistical significance was considered when $p<0.05$.

Results

Comparison of General Clinical Data Between Two Groups of Patients

As shown in Table I, there was no statistically significant difference between the mPCNL group and the FURSL group in terms of age, BMI, stone size, CT value of stones, number of stones, and comorbidities ($p>0.05$). This result suggests that the clinical baseline data of the two groups of patients are similar, and the two groups of patients are comparable.

Comparison of Surgery-Related Indicators and Stone Clearance Rate Between Two Groups of Patients

As shown in Table II, the mPCNL group showed significantly lower operation time (48.62±7.87 *vs.* 59.21±8.59, $p<0.001$) and BCS score (1.135±0.78 *vs.* 2.54±0.72, $p<0.001$) compared to the FURSL group. However, the mPCNL group showed significantly higher hospitalization costs (1.77±0.17 *vs.* 1.37±0.14, $p<0.001$), length of stay (5.92±1.61 *vs.* 3.91±0.82, $p<0.001$), VAS score (3.47±1.16 *vs.* 1.20±1.16, $p<0.001$), and hemoglobin decrease value (10.71±3.34 *vs.* 3.58±1.43, $p<0.001$) compared to the FURSL group. In terms of stone clearance rate, the mPCNL group had a significantly higher RSFR (94.79% *vs.* 82.22%, $p=0.007$) compared to the FURSL group. However, in terms of LSFR (96.87% *vs.* 92.22%, $p=0.160$), there was no statistically significant difference between the two groups.

Changes in Blood-Related Indicators Before and After Surgery in Two Groups of Patients

As shown in Table III, there was no statistically significant difference in preoperative BUN, Scr, and hs-CRP between the mPCNL group and the FURSL group. The postoperative BUN (6.96±0.84 *vs.* 6.17±0.86, $p<0.001$) and hs-CRP (25.73±5.41 *vs.* 21.94±5.17, $p<0.001$) in the mPCNL group were significantly higher than those in the FURSL group, but Scr (67.83±5.80 *vs.* 67.48±5.37, $p=0.670$) showed no statistical difference. Meanwhile, the preoperative and postoperative differences in BUN (2.16 ±0.75 *vs.* 1.25±0.62, $p<0.001$), Scr (10.25±6.46 *vs.* 8.17±3.07, $p=0.006$), and hs-CRP (18.89±5.22 *vs.* 14.88±6.25, $p<0.001$) in the mPCNL group were significantly higher than those in the FURSL group.

Table I. Comparison of basic data between the two groups.

Parameter		mPCNL (n=96)	FURSL (n=90)	*p*-value
Age (years)		46.01±9.88	46.82± 9.01	0.558
BMI (kg/m^2)		21.75±2.52	21.22±2.65	0.173
Stone size		2.69±0.27	2.64±0.23	0.188
CT value of stones		974.35±163.36	949.68±162.98	0.304
Number of stones:	Single stone	51 (53.12%)	52 (57.77%)	
	Multiple stones	33 (34.37%)	28 (31.11%)	
	Staghorn calculi	12 (12.50%)	10 (11.11%)	0.361
Diabetes		6 (6.25%)	6 (6.67%)	0.908
Hypertension		14 (14.58%)	12 (13.33%)	0.806
Coronary heart disease		10 (10.41%)	7 (7.77%)	0.533

Table II. Comparison of surgery-related indicators and stone clearance rate between two groups of patients.

Parameter	mPCNL (n=96)	FURSL (n=90)	*p*-value
Operation time (min)	48.62±7.87	59.21±8.59	<0.001
Hospitalization expenses (10,000 yuan)	1.77±0.17	1.37±0.14	<0.001
Hospital stay (d)	5.92±1.61	3.91±0.82	<0.001
Hemoglobin decrease value (g/L)	10.71±3.34	3.58±1.43	<0.001
VAS score	3.47±1.16	1.20±1.16	<0.001
BCS score	1.135±0.78	2.54±0.72	<0.001
RSFR (%)	91 (94.79%)	74 (82.22%)	0.007
LSF (%)	93 (96.87%)	83 (92.22%)	0.160

VAS: Visual analogue scale; BCS: Bruggrmann comfort scale; RSFR: recent stone free rate; LSFR: long-term stone free rate.

Table III. Changes in blood related indicators before and after surgery in two groups of patients.

Parameter		mPCNL (n=96)	FURSL (n=90)	*p*-value
BUN (mmoL/L)	Preoperative	4.70±0.90	4.91±0.82	0.099
	postoperative	6.96±0.84	6.17±0.86	<0.001
	Preoperative and postoperative differences	2.16±0.75	1.25±0.62	<0.001
Scr (μmoL/L)	Preoperative	57.58±6.37	59.31±6.53	0.069
	postoperative	67.83±5.80	67.48±5.37	0.670
	Preoperative and postoperative differences	10.25±6.46	8.17±3.07	0.006*
hs-CRP (mg/L)	Preoperative	6.84±2.32	7.06±1.93	0.492
	postoperative	25.73±5.41	21.94±5.17	<0.001
	Preoperative and postoperative differences	18.89±5.22	14.88±6.25	<0.001

BUN: blood urea nitrogen; Scr: Serum creatinin; hs-CRP: hypersensitive-c-reactive-protein.

Comparison of Surgical Complications Between mPCNL Group and FURSL Group of Patients

As shown in Table IV, the FURSL group has lower rates of complications than the mPCNL group (23.96% *vs.* 8.89%, p=0.006). Besides, the postoperative hematuria (9.67% *vs.* 14.81%, p<0.05) is also significantly lower in the FURSL group than in the mPCNL group (15.62% *vs.* 2.22%, p=0.002). However, there was no statistically significant difference between the two groups regarding postoperative massive bleeding, fever, urogenic sepsis, perirenal hematoma, peripheral organ injury, and ureteral injury (p>0.05).

Discussion

Selecting the appropriate surgical approach for the treatment of 2-3 cm kidney stones is currently a focal point in clinical research[18-21]. Therefore, when devising surgical strategies for treating 2-3 cm kidney stones in women, there is a pressing need to prioritize surgical methods that are characterized by minimal invasiveness, lower pain levels, and swift recovery times to facilitate rapid patient recuperation. While miniaturized percutaneous nephrolithotomy (mPCNL) boasts efficient stone clearance rates, the procedure is frequently associated with substantial

Table IV. Comparison of surgical complications between two groups of patients.

Parameter	mPCNL (n=96)	FURSL (n=90)	*p*-value
Postoperative massive bleeding	0 (0)	0 (0)	-
Postoperative hematuria	15 (15.62%)	2 (2.22%)	0.002*
Fever	5 (5.21%)	4 (4.44%)	0.808
Urogenic sepsis	1 (1.04%)	1 (1.11%)	0.963
Perirenal hematoma	2 (2.08%)	1 (1.11%)	0.599
Peripheral organ damage	0 (0)	0 (0)	-
Ureteral injury	0 (0)	0 (0)	-
Total complications	23 (23.96)	8 (8.89%)	0.006*

postoperative discomfort and complications, including potential damage to adjacent organs, bleeding, infection, and hematuria[18,19].

Recent advancements in ureteroscopy technology and ancillary lithotripsy equipment have contributed to the refinement of FURSL techniques[20,21]. Due to its minimal invasiveness, quick recovery period, and reduced complications, FURSL has seen an increasing application in treating 2-3 cm kidney stones[20,21]. However, there is currently a scarcity of research comparing FURSL and mPCNL in the management of 2-3 cm kidney stones, particularly in female patients. This study aims to address this gap. Previous studies[20-22] have demonstrated several advantages of FURSL, including minimal blood loss, less traumatic impact, fewer complications, and rapid recovery, all thanks to the retrograde treatment of kidney stones via the natural lumen. Our study found that the FURSL group exhibited significantly lower hospitalization duration, costs, and hemoglobin drop compared to the mPCNL group. These results indicate that, compared to mPCNL, FURSL surgery aligns better with the principles of non-invasive procedures. Furthermore, FURSL is associated with lower medical costs and faster postoperative recovery. Notably, the operation time for the FURSL group in this study was significantly longer than that of the mPCNL group, which is in line with other research reports[20-22]. This elongation in operative time can likely be attributed to the smaller fiber diameter of the holmium laser used in FURSL, resulting in slower lithotripsy efficiency. In contrast, mPCNL employs pneumatic ballistic lithotripsy, characterized by higher lithotripsy efficiency and rapid removal of the pulverized stones. Regarding the recent stone-free rate (RSFR), the FURSL group showed a significantly lower percentage than the mPCNL group (82.22% *vs.* 94.79%, p=0.007). However, there was no significant difference between the two groups in terms of the long-term stone-free rate (LSFR), with rates of 96.87% and 92.22% for FURSL and mPCNL, respectively (p=0.160). These findings align with previous reports[20-25], suggesting comparable LSFR between FURSL and mPCNL in the treatment of 2-3 cm renal calculi. Given that female patients often have lower tolerance to pain and trauma, this factor warrants consideration in the treatment of 2-3 cm kidney stones. In our study, we found that the Visual Analogue Scale (VAS) score of the mPCNL group was significantly higher than that of the FURSL group, indicating more perceived pain, while the BCS score was significantly lower, indicating less patient comfort. However, FURSL, with its minimal trauma and insignificant postoperative pain, appears to be an excellent surgical choice for women with 2-3 cm kidney stones.

This study observed that both mPCNL and FURSL groups showed significant postoperative increases in Blood Urea Nitrogen (BUN), Serum Creatinine (Scr), and high-sensitivity C-reactive protein (hs-CRP). These increases suggest that both surgical procedures might induce some degree of renal injury and cause infection. However, the postoperative levels of BUN, Scr, and hs-CRP in the FURSL group were lower than those in the mPCNL group, both before and after treatment. This indicates that the degree of renal injury and infection risk in the immediate postoperative period is relatively lower in patients who underwent FURSL compared to those who underwent mPCNL. In terms of complications, our study revealed that the overall incidence of complications in the mPCNL group was significantly higher than in the FURSL group. However, neither group experienced severe complications such as major bleeding, peripheral organ damage, or ureteral injury. The literature suggests that the probability of major bleeding after PCNL surgery is around 3%, the incidence of bleeding necessitating blood transfusion is 5-8%, and the requirement for vascular intervention embolization treatment is 0.3-1.4%[26,27]. In our study, no major bleeding complications occurred in either the FURSL or mPCNL group. Nevertheless, the incidence of postoperative hematuria in the mPCNL group was significantly higher than in the FURSL group. This suggests that mPCNL surgery can lead to damage to renal blood vessels and renal parenchyma, compared to FURSL. Previous studies[25-27] have reported that the incidence of systemic inflammatory response syndrome in patients undergoing endoscopic surgery for kidney stones is approximately 8.6-11.4%. If not promptly managed, some patients may progress to urogenic sepsis or even death. In this study, both FURSL and mPCNL groups included patients with fever and urogenic sepsis. However, there was no significant difference between the two groups regarding fever and urogenic sepsis. This finding suggests that in terms of infection risk, FURSL and mPCNL have a similar safety profile in the treatment of 2-3 cm kidney stones in women.

Conclusions

In conclusion, both mPCNL and FURSL have been shown to be effective and safe treatment options for women with kidney stones in the 2-3 cm size range. However, FURSL has demonstrated certain advantages over mPCNL. These include less invasiveness, less postoperative pain, fewer complications, lower costs, and shorter hospital stays. Consequently, when considering the management of 2-3 cm kidney stones in women, FURSL appears to be a preferable choice due to these benefits.

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Informed Consent
All patients included in this study and their families signed informed consent forms,

Ethics Approval
This study was approved by the 909th Hospital of Xiamen University Ethics Committee.

Data Availability
All relevant data are available from the corresponding author.

Conflict of Interest
The authors declare no conflict of interest.

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Authors' Contributions
ZL and ZHR: designing the study, analyzing the extracted data, and writing the first manuscript draft. CWD and LH: searching the literature; extracting and analyzing the data. XWJ and GQH: analyzing the data; providing critical scientific input. ZL, LJY, and LMH: resolving discrepancies about the quality of the included studies, reviewing the manuscript, and providing critical scientific input. All authors approved the final version of this manuscript.

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