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## **Efficacy of ultra-mini percutaneous nephrolithotomy and retrograde intrarenal surgery in the treatment of 2-3 cm lower calyceal stones.**

*Ya-Wei Guan, Xing Ai, Zhi-Hui Li, Guo-Hui Zhang, Zhuo-Min Jia and Jing-Fei Teng*

Department of Urologic Surgery, The Third Medical Center, Chinese PLA (People's Liberation Army) General Hospital, Beijing, China.

**Key words:** ultra-mini percutaneous nephrolithotomy; retrograde intrarenal surgery; kidney stone; efficacy.

**Abstract.** We aimed to compare the efficacy and safety of ultra-mini percutaneous nephrolithotomy (UMP) and retrograde intrarenal surgery (RIRS) for the management of lower calyceal stones. A group of 136 patients with a single lower calyceal stone (2-3 cm in diameter) was divided into the UMP or RIRS groups. The average operation time in the RIRS group was significantly longer than that in the UMP group, and the intraoperative blood loss in the former was markedly less than that in the latter. Besides, in the RIRS group, the decreased value of postoperative Hb was obviously lower, the postoperative hospital stay was evidently shorter, and the total hospitalization expenses were markedly less than those in UMP group were. Moreover, the success rate of the first-stage lithotripsy in the UMP group was notably higher than that in RIRS group. The RIRS group had an obviously lower VAS score but a markedly higher BCS score than the UMP group six hours after surgery. At 24 h after operation, the levels of serum CRP, TNF- $\alpha$  and IL-6 in patients in both groups were remarkably increased, and they were evidently lower in the RIRS group than those in the UMP group were. Three days after surgery, the levels of serum CRP, TNF- $\alpha$  and IL-6 were notably lower in the UMP group than those in RIRS group were. RIRS and UMP are safe and effective in the treatment of 2-3 cm lower calyceal stones. The first-stage UMP is characterized by a high stone-free rate (SFR), short operation time and low postoperative infection risk, while RIRS is associated with less blood loss and low total expenses.

## **Eficacia de la nefrolitotomía percutánea ultramini y la cirugía intrarrenal retrógrada en el tratamiento de cálculos caliceales inferiores de 2-3 cm.**

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**Palabras clave:** ultra-mini nefrolitotomía percutánea; cirugía intrarrenal retrógrada; cálculo renal; eficacia.

**Resumen.** Nuestro objetivo fue comparar la eficacia y seguridad de la nefrolitotomía percutánea ultramini (UMP) y la cirugía intrarrenal retrógrada (CRIR) en el manejo quirúrgico de los cálculos caliceales inferiores. Un grupo de 136 pacientes con un solo cálculo calicial inferior (2-3 cm de diámetro) se dividió en un grupo UMP o un grupo CRIR. El tiempo de operación promedio en el grupo CRIR fue significativamente más largo que en el grupo UMP, y la pérdida de sangre intraoperatoria en el primero fue marcadamente menor que en el segundo. Además, en el grupo CRIR, el valor disminuido de la Hb postoperatoria fue obviamente menor, la estancia hospitalaria postoperatoria fue evidentemente más corta y los gastos totales de hospitalización fueron notablemente menores que los del grupo UMP. Además, la tasa de éxito de la litotricia de primera etapa en el grupo UMP fue notablemente más alta que en el grupo CRIR. El grupo CRIR tuvo una puntuación VAS obviamente más baja pero una puntuación BCS marcadamente más alta que el grupo UMP a seis horas después de la operación. A las 24 h después de la operación, los niveles séricos de PCR, TNF- $\alpha$  e IL-6 en los pacientes de ambos grupos aumentaron notablemente y fueron evidentemente más bajos en el grupo CRIR que en el grupo UMP. Tres días después de la operación, los niveles séricos de PCR, TNF- $\alpha$  e IL-6 fueron notablemente más bajos en el grupo UMP que en el grupo CRIR. Los procedimientos CRIR y el UMP son seguros y eficaces en el tratamiento de cálculos caliceales inferiores de 2-3 cm. El UMP de primera etapa se caracteriza por tener una tasa libre de cálculo (SFR) alta, un tiempo de operación corto y un riesgo de infección posoperatorio bajo, y el RIRS se caracteriza por una menor pérdida de sangre y gastos totales bajos.

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### **INTRODUCTION**

Urinary calculi are widely prevalent worldwide. The incidence rate of urinary calculus in North America, Europe and Asia is 7~13%, 5~9% and 1~5% respectively. In southern China, the incidence rate of renal calculus can reach 28%, which is the most common urinary disease in young adults.

About 83.2% of renal calculus present in 21~50 years-old-people. The lower calyx stone is a common type of kidney stone, accounting for 36% of those<sup>1,2</sup>. Percutaneous nephrolithotomy (PCNL) and retrograde nephrolithotomy (RIRS) are the main surgical methods for treatment of lower calyceal calculi. Although the stone-free rate (SFR) of standard channel and microchannel PCNL

is high, the trauma caused by PCNL is obviously greater than that caused by RIRS<sup>3</sup>. RIRS is considered to be the gold standard for the treatment of lower calyceal stones, but it has been discovered in clinical application that because of the bending angle, lower calyceal stones are often in the blind area of vision and cannot be taken out. Furthermore, as the supporting lithotripsy tool is only 200  $\mu\text{m}$  holmium laser and the ureter is thin, the lithotripsy efficiency is low, the stone-free rate is low, and the operation time is long<sup>4,5</sup>. Ultra-mini percutaneous nephrolithotomy (UMP) causes smaller traumas compared with traditional standard channel and microchannel PCNL (mPCNL), and UMP has a higher lithotripsy efficiency, a higher stone-free rate, and more advantages in treating 1-2 cm stones than the RIRS, so increasingly more attention is being paid to UMP<sup>6-8</sup>. However, there remains a controversy over surgical methods for 2-3 cm lower calyceal stones.

In this study, the efficacy and safety of RIRS and UMP in the treatment of 2-3 cm lower calyceal stones were compared, so as to provide a strong basis for the surgical methods for 2-3 cm lower calyceal stones.

## MATERIALS AND METHODS

### Research objects

**Methods:** The clinical data of 136 patients with a single lower calyceal stone (2-3 cm in diameter) were collected. These patients were admitted to our hospital from March 2018 to December 2019, and had indications for RIRS and UMP treatment. According to the random number table method, the patients were randomly divided into two groups, 68 patients in each group were treated with UMP and RIRS, respectively. The inclusion criteria included: (1) patients aged 18-71 years old; (2) the diameter of lower calyceal calculi was 2-3cm; (3) those with no fever or pyuria before operation; (4) those with Visual Analog Scale

(VAS) pain score  $\leq 3$  points; (5) those with stable blood pressure and blood glucose; (6) those whose examination results of bleeding time and coagulation time were normal after they stopped oral anticoagulants such as aspirin or warfarin for two weeks; (7) those with no congenital malformations or urinary obstructions that need to be treated with an emergency operation. The exclusion criteria were as follows: (1) patients with lower calyceal stones  $< 2$  cm or  $> 3$  cm, (2) those complicated with stones in the renal pelvis, middle and upper renal calyx, ureter or other parts, (3) those with severe hydronephrosis, (4) those complicated with severe abnormal heart, liver or kidney functions, or (5) those with severe coagulation disorder or bleeding tendency. Among the 136 patients, there were 88 males and 48 females aged 35-77 years old, with an average age of  $52.68 \pm 9.49$  years old. No statistically significant differences were found in the baseline data between the two groups, which were comparable (Table 1,  $p > 0.05$ ). All the subjects signed an informed consent in accordance with the Helsinki Declaration. This study was approved by the Ethics Committee of the Chinese PLA General Hospital.

### Treatment methods

**RIRS:** Before operation, a F6 double J stent was used routinely for two weeks. Then, the patient was placed in lithotomy position under general anesthesia, and the double-J tube was removed under rigid ureteroscopy. Guided by a zebra guide wire, it was observed whether there was distortion, stenosis or calculus of the ureter in the renal pelvis under the ureteroscopy. Later, the zebra guide wire was indwelt and the rigid ureteroscopy was removed. Next, a soft ureteroscopy sheath was placed along the zebra guide wire, and a soft ureteroscopy was inserted along the sheath, which was pushed up to the ureteropelvic junction to enter the renal pelvis. First, the upper calyx and the middle and lower calyces of the kidney were observed in succession. After the stones

**Table 1**  
Demographics and general clinical data of all studied patients.

Parameters	RIRS group n=68	UMP group n=68	p-value
Gender (Male/Female)	41/27	47/21	0.370
Age (years)	51.41±9.35	53.03±9.68	0.323
BMI (kg/m <sup>2</sup> )	23.25±3.54	23.79±3.29	0.359
Stone location			0.732
Left kidney	32 (47.1%)	35 (51.5%)	
Right kidney	36 (52.9%)	33 (48.5%)	
Stone diameter (cm)	2.60±1.61	2.51±1.47	0.734
Degree of hydronephrosis			0.500
Mild	58 (85.3%)	54 (79.4%)	
Moderate	10 (14.7%)	14 (20.6%)	
Preoperative use of double J tube	12 (17.6%)	6 (8.8%)	0.310
Stone CT value (Hu)	823.65±646.72	983.39±704.73	0.171
Systemic disease			
Hypertension	15 (22.1%)	18 (26.5%)	0.690
Coronary heart disease	4 (5.9%)	7 (10.3%)	0.531
Diabetes mellitus	9 (13.2%)	6 (8.8%)	0.585

Notes: RIRS: Retrograde intrarenal surgery; UMP: Ultra-mini percutaneous nephrolithotomy; BMI: Body Mass Index.

were found, the scope was retreated into the sheath, and a 200  $\mu$ m holmium laser fiber was inserted to powder the stones from the periphery to the center in the “worm-eaten” form with 8-15 W power. Then the larger stones were taken out through a stone-taking basket, and careful checking was performed to ensure that there was no residual stones  $\geq 3$  mm. Besides, the zebra guide wire was indwelt, and the F6 double-J stent catheter was placed under the guidance of the guide wire.

UMP: Under general anesthesia, the patients were firstly placed in the lithotomy position. Next, a F5 ureteral catheter was retrogradely indwelt under a cystoscope to

establish an artificial hydronephrosis by continuous water injection at the tail end. Then the patients were placed in the prone position, and a 16G puncture needle was utilized to puncture the target renal calyx under the location of color Doppler ultrasound. The smooth outflow of urine indicated a successful puncture. Subsequently, a J stent metal guide wire at the head end was indwelt, and it was observed from a color Doppler ultrasound that the tail end of the wire reached the kidney collecting system. Later, a 4 mm incision was made on the skin at the puncture site, and the channel was dilated using F10 and F14 fascia dilators in turn along the guide wire. After that, the F13 UMP

sheath was pushed along the guide wire, and the UMP nephroscope was inserted to observe the renal collecting system and look for stones. Thereafter, lithotripsy was carried out using a 200  $\mu\text{m}$  holmium laser under the lithotripsy power of 10-20 w, during which stones were broken into fragments <3 mm. After flushing in the ureteral catheter combined with the inner wall of the outer sheath, the stone fragments were washed out using the endoscope sheath through the vortex formed at the head end of the endoscope. At the end of lithotripsy, nephrostomy fistula and double-J stent catheters were not indwelt.

### Observational indicators

The operation time, intraoperative blood loss, postoperative hospital stay, total hospitalization expenses, incidence rate of postoperative complications and other indicators were compared between the two groups of patients. Hemoglobin (Hb) was determined one day before and one day after operation, and the decreased value of Hb was evaluated by comparing the preoperative and the postoperative Hb levels. The pain of patients was evaluated using the VAS scale (0-10 points), in which 0 point = no pain at all, 1-3 points = tolerable slight pain, and for those with  $\geq 4$  points, pethidine hydrochloride (1 mg/kg) was intramuscularly injected for analgesia at an interval of more than four hours. The complications of patients were recorded according to the modified Clavien classification system. In the meantime, the Bruggmann comfort scale (BCS) was also recorded. Five ml fasting venous blood was collected before operation, 24 hours after operation and three days after operation. The serum levels of CRP, IL-6 and TNF in the two groups were compared and analyzed by ELISA.

The early postoperative lithotripsy and the SFR were evaluated based on the kidney ureter bladder (KUB) on the first day after operation. According to the diameter of residual stones, the next treatment plan was

decided. Physical vibration lithotripsy was used to treat residual stones whose diameter was  $\leq 4$  mm; the patients with residual stone diameter  $\geq 5$ mm were treated with extracorporeal shock ultrasonic lithotripsy. Double-J catheters were taken out 2-4 weeks after operation. In the follow-up, renal CT plain scan was performed to re-evaluate the SFR 3-4 weeks after operation. Standards for stone-free state were as follows: There was no residual stone or the diameter of the residual stone was  $\leq 2$  mm, and the stone was asymptomatic, non-obstructive and non-infectious<sup>9</sup>.

### Statistical methods

SPSS 22.0 was adopted for statistical analysis. Measurement data were expressed as mean  $\pm$  standard deviation ( $\bar{x} \pm s$ ). Inter-group comparisons and pairwise intragroup comparisons were conducted by the *t* test. Count data were expressed as percentage (%) and compared using the  $\chi^2$  test or Fisher's Exact Test.  $p < 0.05$  represented that the difference was statistically significant.

## RESULTS

### Operation of the two groups of patients

The average operation time in RIRS group was significantly longer than that in UMP group [(50.4 $\pm$ 9.8) min vs. (42.4 $\pm$ 8.3) min,  $p < 0.001$ ], and the intraoperative blood loss in the former was markedly less than that in the latter [(7.2 $\pm$ 2.7) mL vs. (17.5 $\pm$ 4.6) mL,  $p < 0.001$ ]. Besides, in RIRS group, the decreased value of postoperative Hb [(5.0 $\pm$ 3.4) g/L vs. (7.9 $\pm$ 3.7) g/L,  $p = 0.003$ ] was obviously lower, the postoperative hospital stay [(2.6 $\pm$ 1.4) days vs. (3.8 $\pm$ 1.6) days,  $p = 0.006$ ] was evidently shorter, and the total hospitalization expenses [(17,300 $\pm$ 1,300) Yuan vs. (24,700 $\pm$ 1,800) Yuan,  $p < 0.001$ ] were notably less than those in UMP group. Moreover, the success rate of the first-stage lithotripsy in UMP group [94.1% (64/68)] was higher than that in RIRS group [77.9%

(53/68)], showing a statistically significant difference ( $p=0.012$ ).

The RIRS group had an obviously lower VAS pain score [(2.8±0.8) points vs. (4.6±1.1) points,  $p=0.011$ ] but a markedly higher BCS score [(2.5±0.8) points vs. (1.8±0.7) points,  $p=0.026$ ] than the UMP group 6 h after operation. However, there were no statistically significant differences in VAS score [(1.5±0.7) points vs. (1.9±0.7) points,  $p=0.258$ ] and BCS score [(3.4±0.6) points vs. (2.9±0.5) points,  $p=0.317$ ] at 24 h after operation between the two groups of patients ( $p>0.317$ ) (Table 2).

#### Incidence rate of related surgical complications of the two groups of patients

The incidence rate of the complications of patients was recorded according to the modified Clavien complication classification system. No complications of grade 3 or above occurred in both groups, and there were no patients needing blood transfusion due to massive hemorrhage or sharp decrease in Hb

in the two groups. Six patients in RIRS group and four patients in UMP group had fever, with the body temperature of  $<38.5^{\circ}\text{C}$  and blood routine showed only a slight increase in white blood cell count, and no bacteria were detected in blood and urine culture. The patient only received physical cooling treatment. Fourteen patients in the RIRS group and 19 patients in the UMP group had postoperative pain with the VAS score  $>6$  points, and they were treated with analgesic drugs. Besides, nausea and discomfort occurred in three patients and one patient in the two groups, respectively, and they underwent treatment with antiemetic drugs. There were two patients and zero patient had low serum sodium in the two groups, respectively, and they were supplemented with sodium. Moreover, the urinary tract infection rate of the UMP group was significantly lower than that of the RIRS group ( $P<0.05$ ). The examinations showed that the two patients with urinary tract infection in the UMP group had blood leukocytes  $>10\times 10^9/\text{L}$  and urine leukocytes  $>90/\mu\text{L}$ . After the application of antibacterial drugs

**Table 2**  
Comparison of surgery parameters and postoperative vas, bcs scores of patients in the two studied groups.

Parameters	RIRS group n=68	UMP group n=68	p-value
Operation time (min)	50.4±9.8	42.4±8.3	0.001
Blood loss (mL)	7.2±2.7	17.5±4.6	0.001
Postoperative Hb decrease (g/L)	5.0±3.4	7.9±3.7	0.003
Postoperative hospital stay time (day)	2.6±1.4	3.8±1.6	0.006
Hospitalization expenses (ten thousands yuan)	1.73±0.13	2.47±0.18	0.001
VAS score (points)			
6 h postoperative	2.8±0.8	4.6±1.1	0.011
24 h postoperative	1.5±0.7	1.9±0.7	0.258
BCS score (points)			
6 h postoperative	2.5±0.8	1.8±0.7	0.026
24 h postoperative	3.4±0.6	2.9±0.5	0.317

Notes: RIRS: Retrograde intrarenal surgery; UMP: Ultra-mini percutaneous nephrolithotomy; VAS: Visual analogue scale; BCS: Bruggmann comfort scale.



for three days, the blood and urine routine returned to normal in reexaminations. In addition, there were three patients and one patient suffered from hypertension in the RIRS and UMP groups, respectively, and they took oral nicardipine tablets. All complications returned to normal after symptomatic treatment. No complications such as impairment of renal function, serious urinary system injury and urinary sepsis occurred in any patient after operation. There was significant difference in the incidence of urinary tract infection between the two groups ( $p < 0.05$ ), and there was no significant difference in the risk of fever, pain, nausea and vomiting, electrolyte disorder, hypertension, blood transfusion and complications above grade 3 ( $p > 0.05$ ). (Table 3).

#### Expression levels of serum inflammatory factors in patients before and after treatment

Immediately before operation, there were no statistically significant differences in the levels of serum C-reactive protein (CRP), tumor necrosis factor-alpha (TNF- $\alpha$ ) and interleukin-6 (IL-6) between the two groups ( $p > 0.05$ ). At 24 h after operation, the levels of serum CRP, TNF- $\alpha$  and IL-6 in

the two groups of patients were remarkably increased, and they were evidently lower in RIRS group than those in UMP group ( $p < 0.001$ ). At 3 days after operation, the levels of serum CRP, TNF- $\alpha$  and IL-6 in the two groups of patients remarkably declined compared with those at one day after operation, and they were notably lower in UMP group than those in RIRS group ( $p < 0.05$ ) (Table 4).

#### Postoperative follow-up results of patients

In the UMP group, KUB was reexamined on the first day after operation, and it was found that the diameter of residual stones was  $\leq 4$  mm in four cases, and physical vibration lithotripsy was given one week after operation. On the first day after operation, the KUB showed that 15 patients had residual stones, and two patients had residual stones  $\geq 5$  mm in diameter in RIRS group. On the third day after operation, they were given extracorporeal shock wave lithotripsy as an auxiliary treatment combined with stone removal using the lithotripter. In RIRS group, there were 11 cases of small residual stones (stone diameter  $\leq 4$  mm) after operation, all of which were treated by physical vibration *in vitro*. No UMP or RIRS treatment were

**Table 3**  
Comparison of postoperative complications of patients in the two studied groups.

Parameters	RIRS group n=68	UMP group n=68	p-value
Clavien grade 1			
Fever, $>38.5^{\circ}\text{C}$	6 (8.8%)	4 (5.9%)	0.744
Pain, VAS score $>6$ points	14 (20.6%)	19 (27.9%)	0.424
Nausea / vomiting	3 (4.4%)	1 (1.5%)	0.619
Transient electrolyte disturbance	2 (2.9%)	0 (0%)	0.496
Clavien grade 2			
Hypertension	3 (4.4%)	1 (1.5%)	0.619
Urinary system infection	13 (19.1%)	2 (2.9%)	0.003
Blood transfusion	0 (0%)	0 (0%)	1.000
Clavien grade 3	0 (0%)	0 (0%)	1.000

Notes: RIRS: Retrograde intrarenal surgery; UMP: Ultra-mini percutaneous nephrolithotomy.

**Table 4**  
Comparison of inflammatory factors of patients in the two studied groups.

	RIRS group n=68	UMP group n=68	p-value
CRP (mg/L)			
Immediate postoperative	4.21 ± 1.57	4.11 ± 1.33	0.689
1 day postoperative	25.68 ± 4.59	18.52 ± 5.28	0.001
3 days postoperative	19.83 ± 2.42	15.61 ± 2.74	0.001
TNF-α (pg/mL)			
Immediate postoperative	1.97 ± 0.79	1.88 ± 0.73	0.491
1 day postoperative	12.35 ± 2.54	9.84 ± 3.16	0.001
3 days postoperative	9.76 ± 1.31	7.79 ± 1.39	0.017
IL-6 (pg/mL)			
Immediate postoperative	5.85 ± 1.78	5.96 ± 1.91	0.729
1 day postoperative	28.74 ± 2.02	22.28 ± 2.12	0.001
3 days postoperative	23.58 ± 1.37	20.16 ± 1.72	0.003

Notes: RIRS: Retrograde intrarenal surgery; UMP: Ultra-mini percutaneous nephrolithotomy; CRP: C-reactive protein; TNF: Tumor Necrosis Factor; IL: Interleukin.

performed in both groups. At 3-4 weeks after operation, renal CT was applied for re-examinations to evaluate the SFR, which was 97.1% (66/68) in UMP group and 91.2% (62/68) in RIRS group, with no statistically significant difference ( $p=0.274$ ).

## DISCUSSION

Kidney stones are the most common type of urinary calculi, and 36% of them are lower calyceal stones<sup>10</sup>. Lower calyceal stones are often surgically treated, and RIRS and PCNL are the main surgical methods at present. Through PCNL, SFR can reach more than 90%, so it has become the first choice to treat kidney stones with a diameter greater than 2 cm<sup>11</sup>. However, PCNL will inevitably damage renal parenchyma and surrounding tissue structures, and easily lead to serious complications<sup>12</sup>. The traditional standard PCNL puncture channel is F22-26, the microchannel percutaneous nephrolithotomy (mPCNL) puncture channel is generally F16-20, and the UMP puncture channel is

only F12-14, so the trauma caused by UMP is smaller, with less blood loss and faster postoperative recovery. However, UMP requires higher precision of puncture and expansion. In addition, UMP is generally only suitable for 1-2 cm medium stones because of the thinner channel, and as the stones in the upper ureter, upper calyx and middle calyx can be treated by RIRS, UPM is the most suitable for treating 1-2 cm lower calyceal stones, and the lower calyx is the least accessible part in RIRS<sup>13,14</sup>.

However, it is difficult to treat lower calyceal stones with a diameter greater than 2 cm. Studies in other countries have shown that ureteroscopic holmium laser lithotripsy can achieve the same SFR as mPCNL with a low incidence rate of complications in the treatment of kidney stones with a diameter greater than 2 cm<sup>15</sup>. Aboumarzouk *et al.*<sup>16</sup> used ureteroscopy to treat lower calyceal stones with an average diameter of 3 cm. The SFR in the first stage was 75%, while that in the second stage was nearly 90%. Koyuncu *et al.*<sup>17</sup> used ureteroscopy and percutaneous nephroscopy to treat lower



calyceal stones with a diameter greater than 2 cm. The SFR was as high as 90% one month after operation. Compared with that in the PCNL group in the same period, the SFR was as high as 90.6% one month after operation, displaying no statistically significant difference. Zeng *et al.*<sup>18</sup> applied UMP to treat lower calyceal stones with a diameter smaller than 25 mm, and the channel size was F12-14. The SFR could reach 95.8% three months after operation, and the incidence rate of postoperative complications, especially the blood loss, was significantly reduced, suggesting that UMP has a good application prospect in the treatment of kidney stones. The results of this study showed that compared with those in UMP, the average operation time was obviously prolonged, the postoperative hospital stay was markedly shortened, and the total hospitalization expenses were remarkably reduced in the RIRS group. However, the loss of Hb after operation in the UMP group was only  $(7.9 \pm 3.7)$  g/L due to the thinner operation channel, which was higher than that in RIRS group  $(5.0 \pm 3.4)$  g/L, but it notably declined in comparison with that after PCNL (9.6 g/L on average) reported in the literature<sup>19</sup>, indicating that the effect of UMP in reducing blood loss is satisfactory. In addition, there were no statistically significant differences in the VAS score and BCS score between the two groups of patients 24 h after operation, and the pain did not increase because of the puncture, implying that UMP has a slight impact on patients due to the small puncture channel.

The incidence rate of systemic inflammatory response syndromes after endoscopic stone surgery was 8.6-11.4%, and without timely treatment, the syndromes in some patients will develop into urinary sepsis and even cause death. It is reported that excessive intrapelvic pressure [ $>30$  mmHg (1 mmHg=0.133 kPa)] and long accumulation time ( $>50$  s) can evidently increase the incidence rates of postoperative fever and urinary sepsis<sup>20,21</sup>. The results of this study manifested that the postoperative fever rate

was 8.8% in the RIRS group and 5.9% in the UMP group. Besides, the level of inflammatory factors in the UMP group was also markedly lower than that in the RIRS group. This may be due to the fact that negative pressure suction was utilized during UMP, which reduced the pressure in the renal pelvis and the risk of infection.

SFR is an important indicator for evaluating the effectiveness of lithotripsy. According to a report, the included angle between the infundibulum of the lower calyx and pelvis affects the SFR of RIRS in treating lower calyceal stones. The smaller the included angle is, the lower the SFR will be<sup>22</sup>. In the treatment of lower calyceal stones using UMP, the lower calyx can be directly punctured, thus avoiding this effect. The results of this study illustrated that the SFR after the first-stage surgery in UMP group was significantly higher than that in RIRS group. It is believed that if the stone hardness is high and bleeding during operation affects the visual field, the operation time will be too long. Besides, if there is urinary tract infection before operation, secondary surgery or postoperative assisted lithotripsy should be considered, and the double-J stent catheter can be indwelt after operation, which is beneficial to both the first-stage RIRS and the postoperative lithotripsy.

This study was a retrospective study. The number of enrolled patients was limited, the follow-up time was short, the follow-up content was not comprehensive, and the long-term prognosis of patients was not analyzed. In the future, long-term follow-up multi-center studies with large sample sizes are needed to verify the conclusions of this study.

As a conclusion, RIRS and UMP are safe and effective in the treatment of 2-3 cm lower calyceal stones. The first-stage UMP is characterized by a high SFR, short operation time and low postoperative infection risk, while RIRS is featured with less blood loss and low total expenses.

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### Declaration of conflict of interest

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### Authors' ORCID numbers

- Yawei Guan: 0000-0001-7960-3135
- Xing Ai: 0000-0001-9043-4918
- Zhihui Li: 0000-0002-6282-1475
- Guohui Zhang: 0000-0003-1050-247X
- Zhuomin Jia: 0000-0002-1474-0128
- Jingfei Teng: 0000-0001-5294-3914

### Authorship contribution

- YG, XA, ZL: planning, results and final editing.
- YG, XA: writing of the paper.
- ZL, GZ, ZJ, JT: data collection and analyses.
- All authors approved the final version of the manuscript.

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