Int J Clin Exp Med 2016;9(9):18537-18542
www.ijcem.com /ISSN:1940-5901/IJCEM0031399

Original Article

Comparison of efficacy and safety between flexible ureteroscopy-assisted percutaneous nephrolithotomy and percutaneous nephrolithotomy monotherapy for the treatment of complicated renal calculi

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Received April 28, 2016; Accepted August 5, 2016; Epub September 15, 2016; Published September 30, 2016

Abstract: Objective: Percutaneous Nephrolithotomy (PCNL) is one of the most effective methods for treating renal calculi. However, complicated renal calculi cannot be completely cleared through rigid nephroscopy with a single tract, whereas PCNL using multiple tracts increases the surgical risk and prolongs the post-operative recovery time. Multi-functional ureteroscopy with active and passive flexibility could provide an alternative option for the treatment of complicated renal calculi. This study aimed to compare the efficiency and safety between flexible ureteroscopy-assisted percutaneous nephrolithotomy (FURA-PCNL) and percutaneous nephrolithotomy (PCNL). Methods: From January 2013 to August 2014, 168 patients who underwent either PCNL or FURA-PCNL were included in this retrospective study. Major outcomes including stone free rate and postoperative complications were then compared between these two surgical groups. Other pre-operational and peri-operational parameters were also analyzed. Results: Ninety patients received PCNL and 78 received FURA-PCNL. The average surgical time for FURA-PCNL was significantly shorter than for PCNL ($P<0.05$). Both the decreases in the hemoglobin and the damages to renal function were milder for FURA-PCNL versus PCNL ($P<0.05$). The stone-free rate for FURS-PCNL was significantly higher than PCNL. Based on the Clavien grade, the postoperative complication rate was similar between two treatments ($P>0.05$). Conclusions: This study demonstrates that FURS-PCNL is safer, more efficient, and more versatile compared to PCNL for the treatment of complicated renal calculi.

Keywords: Flexible ureteroscopy, percutaneous nephrolithotomy, complicated renal calculi

Introduction

Recently, percutaneous nephrolithotomy (PCNL) has become the primary treatment option to treat renal calculi larger than 2 centimeters in diameter [1]. However, because PCNL utilizes rigid nephroscopy, this procedure is susceptible to renal parenchyma and pelvis injury. Furthermore, it shows limited value in treating multiple and complicated renal calculi using only one channel. Multiple channels or multiple operations are needed but they increase the risk of complications, including hemorrhage and renal parenchymal damage [2]. In comparison to PCNL, retrograde intrarenal surgery (RIRS) and flexible ureteroscopy (FURS) have their respective advantages and disadvantages [3]. It has gradually become more acceptable to treat complex upper urinary calculi by two or even more methods combined [4]. Therefore, a retrospective study was designed to compare the efficacy and safety between flexible ureteroscopy-assisted percutaneous nephrolithotomy (FURA-PCNL) and percutaneous nephrolithotomy (PCNL) in treating complicated renal calculi.

Patients and methods

Patients

From January 2013 to August 2014, patients diagnosed as complicated renal calculi were included in this study. The inclusion criteria were patients with 1) either symptomatic or asymptomatic renal calculi over 2 centimeters in diameter; 2) no surgical contraindications, or urinary tract obstructions, and did not require treatment by an emergency operation; 3) no fever or pyuria before operation, and 4) steady blood pressures and blood sugar levels. Exclusion criteria were: 1) serum creatinine >451 μmol/L, 2) a contracted ureteropelvic junction (UPJO), 3) cardiopulmonary insufficiency, 4) complicating pregnancy, 5) leukocytes in routine urinalysis ≥2+, positive urine culture, or pyonephrosis, or 6) requirement for a second operation because of hemorrhage or loss of normal tract or other abnormal factors, which caused the termination of the operation. A total of 168 patients were included in the final analysis, with 90 patients treated by PCNL and 78 by FURA-PCNL. All procedures performed in studies involving human participants were in accordance with the ethical standards of the Peking University. Informed consent was obtained from all individual participants included in the study.

Evaluation

All patients were retrospectively reviewed and analyzed. Patients were evaluated according to the criteria as follows: 1) Basic conditions were recorded before the operation; evaluation included measurement of hemoglobin (Hb), hematocrit (Hct), and estimated glomerular filtration rate (eGFR). 2) Results of the examination were recorded before the operation, including KUB, CT, and IVP to estimate the size and position of the stones. 3) We recorded the operative time, volume of blood loss, hospital stay after the operation, intraoperative and postoperative complications and renal function two days after operation. 4) KUB was used for follow-up imaging of the renal calculi 3 days after operation. The operation was considered to be successful and stone-free if KUB or CT showed no obvious retained stones or residual fragments with a diameter <3 mm and patients were without clinical symptoms 4 weeks after surgery.

Surgical procedures

Both PCNL and FURA-PCNL were conducted according to the standard procedures by the same surgical team.

PCNL: With the patient maintained in a lithotomy position, a 6 F occlusion ureteral catheter (Bard Medical Division, C. R. Bard, Inc) was placed at the ureteropelvic junction of the target ureter. The patient was then turned to a prone position, and percutaneous access was achieved under ultrasonographic and fluoroscopic guidance. Lithoclast lithotripsy (LAKH Medical instrument Co., Ltd) was then performed using a 20.8 F nephroscope (Richard Wolf medical instruments corporation) for stone fragmentation. All procedures were performed completely with a single tract. A 16 F nephrostomy tube (CLINY Create Medic Co., Ltd) was inserted at the end of the procedure. The nephrostomy was removed 1 week later unless ancillary PCNL was considered necessary.

FURA-PCNL: The patient was maintained in the Galdakao-modified Valdivia position throughout the operation (patient in the supine position, with two bags below the flank), which had the advantages of allowing both retrograde and antegrade access. Two urologists worked simultaneously to fragment the renal stones. One urologist performed flexible ureteroscopy, while the other performed PCNL. A 12/14 F ureteral access sheath was inserted under fluoroscopic guidance, to allow the frequent passage of the ureteroscope (Olympus URF-P5) to the site of the renal calculi. A 200- or 365-Im YAG laser fiber was used in conjunction with FURS to fragment the renal calculi. Stones were broken into fragments using a lithoclast, and smaller fragmented stones were washed through the sheath by retrograde irrigation. A 5 F Double-J ureteral stent was inserted into the urinary tract, and an 18 F nephrostomy tube (CLINY) was also inserted. The nephrostomy was removed 3 days after surgery, and the ureteral stent was removed 1 month later.

Complication evaluation

Postoperative complications including fever, infection, and bleeding were graded and analyzed statistically according to the Clavien-Dindo grading system.

Statistical analysis

Data were analyzed by SPSS version 14.0 software (SPSS Inc., Chicago, IL). All quantitative data were presented as mean ± standard deviation (SD). The means were compared via T-test, and the difference in the proportions of the two samples was determined by a chi-

Table 1. Patient characteristics and preoperative parameters

	PCNL	FURA-PCNL	*P* value
Number of patients	90	78	
Sex			0.066
Male (%)	63 (70)	42 (53.8)	
Female (%)	27 (30)	36 (46.2)	
Age (years)	50.3 ± 1.2	49.6 ± 3.3	0.063
Hb (g/dL)	13.5 ± 0.5	13.6 ± 0.2	0.100
Hct (%)	41.5 ± 0.6	41.2 ± 1.3	0.051
BMI (kg/m^2)	24.6 ± 0.7	24.5 ± 0.4	0.138
eGFR (mL/min/1.73 m^2)	73.1 ± 3.2	71.9 ± 4.8	0.056

Notes: PCNL: percutaneous nephrolithotomy; FURA-PCNL: flexible ureteroscopy-assisted percutaneous nephrolithotomy; Hb: hemoglobin; Hct: hematocrit; BMI: body mass index; eGFR: estimated glomerular filtration ratio.

Table 2. Features of Renal Calculi between two treatment groups

	PCNL	FURA-PCNL	*P* value
Stone size (mm)	32.5 ± 3.7	33.4 ± 2.5	0.071
Mean CT density (HU)	1052.3 ± 66.8	1068 ± 32.6	0.061
Side			0.521
Left (%)	57 (63.3)	54 (69.2)	
Right (%)	33 (36.7)	24 (30.8)	
Stone location			0.670
Upper pole	16 (17.8)	15 (16.7)	
Middle pole	12 (13.3)	10 (12.8)	
Lower pole	28 (31.1)	18 (23.1)	
Renal pelvis	34 (37.8)	35 (44.9)	

Notes: PCNL: percutaneous nephrolithotomy; FURA-PCNL: flexible ureteroscopy-assisted percutaneous nephrolithotomy.

square test. P<0.05 denoted a statistical significance between two groups. Power calculation revealed a power of 96.1% with a total of 168 patients and if the stone free rate of PCNL was 80% of that of FURA-PCNL group.

Results

Patient characteristics

The characteristics of the patients were summarized in **Table 1**. The preoperative parameters of the two groups did not differ significantly.

Renal calculi data

The characteristics of the renal calculi (stones) were summarized in **Table 2**. There were no significant differences between the two groups regarding the side, size, location, and density of the removed stones. The calculi were mostly located in the lower pole and renal pelvis.

Surgery data

The relevant surgical parameters were summarized in **Table 3**. The surgery time, including time for patient preparation (e.g. sterilization of operating field) and positioning for PCNL and FURA-PCNL was 64.7 ± 12.8 and 59.8 ± 17.6 minutes, respectively. The surgery time for FURA-PCNL was significantly shorter than for PCNL (P=0.039). The Hb drop of PCNL patients and FURA-PCNL patients was 1.62 ± 0.12 and 1.57 ± 0.18 g/dL, respectively. The amount of bleeding with FURA-PCNL was significantly lower than with PCNL (P=0.034). Renal function, as determined by the eGFR, was dropped by 3.15 ± 0.95 and 2.75 ± 1.25 ml/min/1.73 m^2 in the PCNL and FURA-PCNL groups, respectively. It was obvious that the kidney damage by PCNL was more severe than the damage caused by FURA-PCNL (P=0.020). Compared with PCNL, the hospital stays for patients who underwent FURA-PCNL were significantly shorter (P=0.028).

Stone-free rate

Stone-free rate (SFR) results were summarized in **Table 3**. Initial stone-free status was achieved in 52 (57.8%) PCNL patients and 67 (85.9%) FURA-PCNL patients. The SFR was higher in the FURA-PCNL patients (P=0.014). Ancillary treatment was more frequently required in patients who underwent PCNL compared to those who underwent FURA-PCNL. Nine FURA-PCNL patients required ancillary treatment, specifically five shock wave lithotripsy (SWL), two ureteroscopy (URS), and two repeat PCNL procedures. Of the patients who underwent PCNL, 35 required additional therapy, including 20 SWL, 8 URS, 4 repeated PCNL, and 3 patients that required combination therapy involving SWL and a repeated PCNL. The final SFR was much higher in FURA-PCNL patients (96.2%) than in PCNL patients (80.0%) (P=0.004).

Table 3. Surgery parameters

	PCNL	FURA-PCNL	*P* value
Operative time (min)	64.7 ± 12.8	59.8 ± 17.6	0.039
Hb drop (g/dL)	1.62 ± 0.12	1.57 ± 0.18	0.034
Hct drop (%)	2.32 ± 0.28	2.41 ± 0.23	0.026
eGFR drop (ml/min/1.73 m^2)	3.15 ± 0.95	2.75 ± 1.25	0.020
Hospital stay	11. 3 ± 1.2	10.8 ± 1.7	0.028
Initial stone free (%)	52 (57.8)	67 (85.9)	0.014
Ancillary treatment	35	9	
SWL	20	5	
URS	8	2	
Second PCNL	4	2	
Mixed	3	0	
Final stone free (%)	72 (80.0)	75 (96.2)	0.004

Notes: PCNL: percutaneous nephrolithotomy; FURA-PCNL: flexible ureteroscopy-assisted percutaneous nephrolithotomy; SWL: shock wave lithotripsy; URS: ureteroscopy.

Table 4. Intraoperative and postoperative complications

	PCNL	FURA-PCNL	*P* value
Fever (>39.0°C)	8 (8.9)	6 (7.7)	0.923
Steinstrasse (%)	6 (6.7)	1 (1.3)	0.176
Hemorrhage (%)	3 (3.3)	4 (5.1)	0.847
Clavien grade			0.219
I	73 (81.1)	67 (85.9)	
II	11 (12.2)	10 (12.8)	
III	6 (6.7)	1 (1.3)	
≥IV	0	0	

Notes: PCNL: percutaneous nephrolithotomy; FURA-PCNL: flexible ureteroscopy-assisted percutaneous nephrolithotomy.

Complications

The intraoperative and postoperative complications were summarized in **Table 4**. The number of patients that suffered hemorrhage during the PCNL and FURA-PCNL operations were 3 (3.3%) and 4 (5.1%), respectively (P=0.847). All of these patients achieved a stable condition after a blood transfusion. The postoperative complications included a transient fever of >38.5°C in 8 PCNL patients (8.9%) and 6 FURA-PCNL patients (7.7%) (P=0.923), which was promptly resolved with antibiotic therapy. The incidence of steinstrasse as a postoperative complication occurred in 6 (6.7%) PCNL patients and 1 (1.3%) FURA-PCNL patient (P=0.176). No patients had a Clavien grading score ≥IV. Based on the Clavien grade, postoperative complications were similar for each treatment modality.

Discussion

Complicated renal calculi is a common renal and urogenital disorder, including stag-horn calculi, multiple renal calculi, large renal calculi (>2 cm in diameter) and staghorn kidney stones, which cannot be radically cured by a single traditional open operation. PCNL has become the main method for treating such calculi. However, the existence of residual stones after the procedure is a main cause for decreases in operation success rates. According to Snyder reports, the persistence rate of renal stones is as high as 28%, if the complicated renal calculi are only treated by PCNL [5]. To combat this problem, Zeng Guohua adopted multiple channel minimally invasive percutaneous nephrolithotomy, which has a first-stage clearance rate of 64.3% and a second-stage clearance rate of 85.7% [6]. However, the increase in the number of puncture channels would accelerate the risk of the damage to the renal parenchyma and related viscera, leading to an increase in intra- and post-operative blood loss and transfusion volume [7]. On the other side, the flexible fibre-optic bundle of a ureteroscope can reach an upward bending angle of 275 and a downward angle of 185. Moreover, the ureteroscope can undergo active and passive bending, providing easy/ready access to every renal calyx. The entire renal collection system can be explored in up to 94% of patients, without experiencing any visually blind areas [8]. However, this technique requires longer surgical duration on average, especially if the diameter of renal calculi is over 20 mm and/or is a renal inferior calyx. The long time in a flexed position can cause damage to the ureteroscope due to the thermal effects of the laser. In addition, the renal pelvis and calyx are in the status of acute dilatation for a prolonged period. Therefore, even if the mucous membrane of the renal pelvis is not directly damaged during the operation, the renal pelvis will hemorrhage, to various degrees, which will decrease visibility within the surgical field, creating difficulties for lithotripsy and resulting in remaining stone residue [9, 10].

Considering the advantages and disadvantages of PCNL and FURS, we have adopted the method of flexible ureteroscopy-assisted percutaneous nephrolithotomy. According to our study, the combination of single tract PCNL with flexible ureteroscopy could effectively decrease the ratio of remaining stones. On the aspects of operation duration, hemorrhage volume, length of hospital stay and the ratio of clearance, the results for groups of patients treated by FURA-PCNL were significantly superior to those treated by PCNL. Furthermore, there are no significant differences in intra-and pro-operative complications between these two groups. These data indicate that the clinical effect of the combination of flexible ureteroscopy and percutaneous nephrolithotomy may be a better treatment regimen. We believe that nephroscopy mainly aims to clear large calculi, while flexible ureteroscopy helps to locate the position of calculi, while guiding nephroscopy to break the stone(s). In this way, damage caused to the renal parenchyma and pelvis by nephroscopy (when searching for calculi) could be avoided [11-13]. Moreover, the flexibility of the ureteroscope could assist in the elimination of smaller calculi and stones that are pushed into another renal calyx by water, which significantly improves the ratio of decomposition and the clearance of the complicated calculi [14, 15].

This research has some limitations. First, this was a retrospective study therefore it was susceptible to certain biases. The choice of surgical procedures on a single patient was made by experienced surgeons based on evaluation of his/her calculi. Therefore, the patient groups were not assigned randomly and it will lead to selection bias. Second, the comparison between two surgical groups could not rule out the differences on the other aspects of the procedure. For example, PCNL and FURA-PCNL used different sized nephrostomy tube while FURA-PCNL also involved ureteral stent left for 1 month post-operationally. These inconsistencies could not be ruled out in this study setting. Third, some data including radiation exposure time and anesthesia data were not collected.

Conclusion

Compared with PCNL, FURA-PCNL is safer, more efficient, and more versatile for the treatment of complicated renal calculi. Prospective studies are therefore needed to confirm the effectiveness of FURA-PCNL.

Disclosure of conflict of interest

None.

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