Comparison of mini-percutaneous nephrolithotomy and retroperitoneal laparoscopic ureterolithotomy for treatment of impacted proximal ureteral stones greater than 15 mm

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Abstract

Background: The optimal treatment for large impacted proximal ureteral stones remains controversial. The aim of this study was to evaluate the efficacy, safety, and potential complications of mini-percutaneous nephrolithotomy (MPCNL) and retroperitoneal laparoscopic ureterolithotomy (RPLU) in the treatment of impacted proximal ureteral stones with size greater than 15 mm.

Methods: A total of 268 patients with impacted proximal ureteral stones greater than 15 mm who received MPCNL or RPLU procedures were enrolled consecutively between January 2014 and January 2019. Data on surgical outcomes and complications were collected and analyzed.

Results: Demographic and ureteral stone characteristics found between these two groups were not significantly different. The surgical success rate (139/142, 97.9% *vs.* 121/126, 96.0%, $P = 0.595$) and stone-free rate after 1 month (139/142, 97.9% *vs.* 119/126, 94.4%, $P = 0.245$) of RPLU group were marginally higher than that of the MPCNL group, but there was no significant difference. There was no significant difference in the drop of hemoglobin between the two groups (0.8 ± 0.6 *vs.* $0.4 \pm 0.$ 2 g/dL, $P = 0.621$). The mean operative time (68.2 ± 12.5 *vs.* 87.2 ± 16.8 min, $P = 0.041$), post-operative analgesics usage (2/121, 1.7% *vs.* 13/139, 9.4%, $P = 0.017$), length of hospital stay after surgery (2.2 ± 0.6 *vs.* 4.8 ± 0.9 days, $P < 0.001$), double J stent time (3.2 ± 0.5 *vs.* 3.9 ± 0.8 days, $P = 0.027$), time of catheterization (1.1 ± 0.3 *vs.* 3.5 ± 0.5 days, $P < 0.001$), and time of drainage tube (2.3 ± 0.3 *vs.* 4.6 ± 0.6 days, $P < 0.001$) of MPCNL group were significantly shorter than that of the RPLU group. The complication rate was similar between the two groups (20/121, 16.5% *vs.* 31/139, 22.3%, $P = 0.242$).

Conclusions: MPCNL and RPLU have similar surgical success and stone clearance in treating impacted proximal ureteral stones greater than 15 mm, while patients undergoing MPCNL had a lower post-operative pain rate and a faster recovery.

Keywords: Laparoscopy; Nephrostomy; Percutaneous; Ureteral calculi

Introduction

Impacted proximal ureteral stones usually refer to the stones that remain in the same location of the upper ureter for more than 2 months.[1,2] The stone can adhere to the ureteral wall and prevent the passage of the guidewire. This condition is often complicated by hydronephrosis, infection, and pathological lesions, such as ureteral polyps at the stone site.[3] It is essential to remove the impacted proximal ureteral stones in a timely fashion to relieve obstruction and protect renal function.

It has been reported that extracorporeal shockwave lithotripsy (SWL) and ureteroscopic lithotripsy (URS) are minimally invasive but less effective in stone-free rate (SFR) in case of treatment of large impacted proximal ureteral stone compared to mini-percutaneous nephrolithotomy (MPCNL) and retroperitoneal laparoscopic ureterolithotomy (RPLU) in some research studies.[4] In addition, MPCNL or RPLU may be considered as an alternative when SWL or URS is not indicated or failed.[5] Our previous study has shown that RPLU could provide better SFR than URS for impacted upper ureteral stones greater than 12 mm.[6]

Although MPCNL and RPLU are considered to be effective in the treatment of large impacted proximal ureteral stone, the pros and cons of these two surgical approaches remains controversial.[7] The current literature lacks robust evidence in identifying the most appropriate approach. Therefore, we conducted this study to investigate and compare the success rate, SFR, and complications of

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MPCNL and RPLU in the treatment of impacted proximal ureteral stones greater than 15 mm.

Methods

Ethical approval

This research was reviewed and approved by the Ethics Committee at the Shanghai Jiao Tong University Medical School Affiliated Ruijin Hospital. Informed consent was obtained from all the individual participants included in this study. All procedures performed in this research involving human participants were in accordance with the ethical standards of the institution.

Clinical materials

From January 2014 to January 2019, the clinical data 268 patients who consecutively underwent MPCNL or RPLU for impacted proximal ureteral stones greater than 15 mm were retrospectively analyzed. All patients enrolled were examined by means of three experienced urologists with extensive experience in both procedures. Perioperative, intra-operative, and post-operative data were collected accordingly in the two groups.

The inclusion criteria were patients with a single upper ureteral stone (located below the ureteropelvic junction to the superior aspect of the fourth lumbar vertebrae). The maximal diameter of the stone was greater than 15 mm measured by either kidney-ureter-bladder (KUB) plain film or non-contrast CT (NCCT) if the patient had a radiolucent calculi and the stone stayed in the same position of ureter more than 2 months. Patients with a failed history of SWL or URS for the same ureter stone were included. The exclusion criteria were patients with a history of open or laparoscopic surgery of the ipsilateral kidney or ureter, concomitant stones in the distal ureter or kidney, active infection, a non-functioning kidney, coagulopathy, pregnancy, urinary tract abnormalities, or severe comorbidities that is unable for them to tolerate during the surgical position or general anesthesia.

The severity of hydronephrosis was assessed by ultrasound. Laboratory tests including blood routine examination, creatinine, and urine analysis were also performed. All patients underwent midstream urine culture and were treated with appropriate antibiotics to control the infection before surgery. KUB plain film was performed on the morning of the operation day to determine the exact location of the stone.

Ultrasound-guided MPCNL operative technique

All the patients were placed in the lithotomy position under general anesthesia and a 6-Fr ureteral catheter was inserted to the target ureter under cystoscopy. The patient was subsequently rotated to the prone position. An 18-gauge puncture needle was inserted percutaneously into the middle calyx under complete ultrasound-guidance. A guide wire was then inserted through the calyceal puncture into the renal pelvis. An 8-Fr fascial dilator was employed initially, and the caliber was increased gradually by progressive 2-Fr fascial dilators along the guide wire until the percutaneous puncture was dilated to 16 Fr. A matched peel-away sheath was inserted into the renal collecting system. The stone was fragmented with Holmium laser (Lumenis PowerSuite60w, 550 fiber, Santa Clara, California, USA) and removed by 8/9.8-Fr rigid ureteroscope (Storz, Germany). The stone debris was flushed out by water flow produced by an endoscopic perfusion pump (Haoke Medical Corporation, China). A 16-Fr nephrostomy tube was performed for drainage of kindey at the end of the operation.

RPLU operative technique

The operation process of RPLU refers to the article we have already published in the year 2015.[6] The procedure is performed through three ports under general anesthesia. Retroperitoneal space was expanded through the first trocar at middle axillary line. Under direct vision, 10- and 5-mm trocars were inserted in the anterior and posterior axillary lines under the 12th rib, respectively. Laparoscopic instruments were inserted to isolate the ureter segment containing stone. Ureter above stones was clamped with hollow forceps to avoid stone dislodgement. The obstructed segment of ureter was incised to facilitate stone removal. Afterward, a 6-Fr double J (DJ) stent was inserted into the distal and proximal ends of the ureter. The ureteral incision was closed with 4-0 Vicryl sutures by interrupted technique, and an 18-Fr drain was placed in the retroperitoneum. The drain was removed 3 days after RPLU if no urine leakage.

The KUB plain film was performed on the first postoperative day to confirm the position of the DJ stents. Residual fragments were evaluated using KUB or NCCT if the patient had a radiolucent calculi a month after the operation. The success of the procedure and the stone free were defined as whether the procedure was successfully completed, and the stone was completely removed. The decision for adjuvant treatment was made based on the size and location of the residual stones. The modified Clavien–Dindo grading system was used for classification of complications.[8]

Statistical analysis

All the statistical analyses were performed with SPSS version 22.0 statistical software (IBM Corp, New York, USA). Continuous variables and categorical variables were expressed as mean ± standard deviation and n (%), respectively. Independent-sample t-test was carried for continuous variables and Pearson Chi-square or Continuity Correction test for categorical variables. P values of <0.05 were considered statistically significant.

Results

There were 126 patients in MPCNL group and 142 patients in RPLU group. There were no statistically significant differences between the two groups in terms of the stone size (16.6 ± 1.4 *vs.* 16.8 ± 1.7 mm, $P = 0.312$) and the severity of hydronephrosis (22.3 ± 5.5 *vs.* 24.3 ± 6.3 mm, $P = 0.481$). There was also no difference

in age, sex, body mass index, and side where the stone was located between the two groups. The detailed clinical data of patients in two groups are listed in Table 1.

Operative outcomes

Table 2 shows the operative outcomes of the two groups in detail. About five patients in the MPCNL group did not complete the procedure, including two patients converted to RPLU directly because of the ureteroscope could not touch the stone due to distortion of the ureter above the stone and three patients underwent staged MPCNL because purulent urine was seen after percutaneous nephrostomy. The three patients in the RPLU group failed to undergo the procedure because the stone migrated proximally back into the renal pelvis intraoperatively, including one patient converted to open surgery immediately and two patients converted to flexible ureteroscopy (FURS) combined with Holmium laser lithotripsy after 4 weeks. The surgical success rate in RPLU group was higher than that in MPCNL group (139/142, 97.9% *vs.* 121/126, 96.0%, $P = 0.595$); however, there was no statistical difference between these two groups. There was no significant difference in SFR between the two groups after 1 month (139/142, 97.9% *vs.* 119/126, 94.4%, $P = 0.245$). The operative time (68.2 ± 12.5 *vs.* 87.2 ± 16.8 min, $P = 0.041$), length of hospital stay (LOS) after surgery (2.2 ± 0.6 *vs.* 4.8 ± 0.9 days, $P < 0.001$), DJ stent duration (3.2 ± 0.5 *vs.* 3.9 ± 0.8 days, $P = 0.027$), time of catheterization (1.1 ± 0.3 *vs.* 3.5 ± 0.5 days, $P < 0.001$), and time of nephrostomy or drainage tube (2.3 ± 0.3 *vs.* 4.6 ± 0.6 days, $P < 0.001$) were also significantly shorter in MPCNL group than in RPLU group.

The complication rate was higher in RPLU group than in MPCNL group (20/121, 16.5% *vs.* 31/139, 22.3% $P = 0.242$), but there was no statistical difference between the two groups, shown in Table 3 for details. Six patients had a post-operative fever over 38°C, but no septic shock occurred and no patient had severe post-operative bleeding which needed transfusion or digital subtraction angiography intervention in MPCNL group. KUB plain film showed that there were two cases of abnormal position of DJ stent in MPCNL group and eight cases in RPLU group on the first day after operation. Post-operative

Table 1: Demographic and stone characteristics of patients who underwent MPCNL or RPLU for impacted proximal ureteral stones greater than 15 mm.

Characteristics	MPCNL group ($n = 126$)	RPLU group ($n = 142$)	Statistics	P
Age, years	48.5 ± 5.5	52.3 ± 6.3	$t = 0.297$	0.712
BMI, kg/m^2	24.8 ± 3.1	25.1 ± 2.7	$t = 0.376$	0.655
Gender, *n*			$\chi^2 = 0.331$	0.564
Male	78	83		
Female	48	59		
Laterality, *n*			$\chi^2 = 0.252$	0.614
Left	66	70		
Right	60	72		
Stone size, mm	16.6 ± 1.4	16.8 ± 1.7	$t = 1.066$	0.312
Nephrohydrosis, mm	22.3 ± 5.5	24.3 ± 6.3	$t = 0.721$	0.481
CT value, HU	892.5 ± 132.5	990.4 ± 146.8	$t = 0.979$	0.334
Anticoagulants, *n* (%)	6 (4.8)	9 (6.3)	$\chi^2 = 0.312$	0.575
Positive urine culture, *n* (%)	8 (6.4)	9 (6.3)	$\chi^2 = 0.007$	0.997
Previous failed SWL, *n* (%)	13 (10.3)	15 (10.6)	$\chi^2 = 0.010$	0.948
Previous failed URS, *n* (%)	6 (4.8)	8 (5.6)	$\chi^2 = 0.103$	0.749

BMI: Body mass index; MPCNL: Mini-percutaneous nephrolithotomy; RPLU: Retroperitoneal laparoscopic ureterolithotomy; SWL: Extracorporeal shockwave lithotripsy; URS: Ureteroscopic lithotripsy.

Table 2: Operative outcomes of patients who underwent MPCNL or RPLU for impacted proximal ureteral stones greater than 15 mm.

Outcomes	MPCNL group ($n = 126$)	RPLU group ($n = 142$)	Statistics	P
Success rate, *n* (%)	121/126 (96.0)	139/142 (97.9)	$\chi^2 = 0.281$	0.595
Operation time, min	68.2 ± 12.5	87.2 ± 16.8	$t = 2.078$	0.041*
Down of hemoglobin, g/dL	0.8 ± 0.6	0.4 ± 0.2	$t = 0.389$	0.621
LOS after surgery, days	2.8 ± 0.6	4.9 ± 0.9	$t = 3.692$	<0.001*
SFR after 1 month, *n* (%)	119/126 (94.4)	139/142 (97.9)	$\chi^2 = 1.349$	0.245
Double J stent duration, weeks	3.2 ± 0.5	3.9 ± 0.8	$t = 2.209$	0.027*
Time of catheterization, days	1.1 ± 0.3	3.5 ± 0.5	$t = 3.958$	<0.001*
Time of drainage tube, days	2.3 ± 0.3	4.6 ± 0.6	$t = 4.352$	<0.001*
Follow-up, months	16.3 ± 0.5	18.2 ± 0.6	$t = 0.402$	0.613

* $P < 0.05$ was considered as statistically significant. LOS: Length of hospital stay; MPCNL: Mini-percutaneous nephrolithotomy; RPLU: Retroperitoneal laparoscopic ureterolithotomy; SFR: Stone-free rate.

Table 3: Complications according to the Clavien grading system (*n* [%]).

Items	MPCNL group ($n=121$)	RPLU group ($n=139$)	χ^2	*P*
Grade 1				
Urine leakage	–	8		–
Temporary fever	5 (4.1)	1 (0.7)	2.003	0.157
Post-operative analgesic	2 (1.7)	13 (9.4)	7.047	0.017*
Perirenal hematoma	1 (0.8)	0	0.010	0.945
Grade 2				
UTI with fever >38°C	6 (5.0)	1 (0.7)	2.987	0.085
Transfusion	–	–		–
Grade 3				
Abnormal position of double J stent	2 (1.7)	8 (5.8)	2.142	0.164
Ureteral stricture managed by laparoscopic ureteroplasty	4 (3.3)	1 (0.7)	1.134	0.288
Grade 4/5	0	0		–
Total complications	20 (16.5)	31 (22.3)	1.371	0.242

*$P<0.05$ was considered as statistically significant. MPCNL: Mini-percutaneous nephrolithotomy; RPLU: Retroperitoneal laparoscopic ureterolithotomy; UTI: Urinary tract infection; –: Not applicable.

analgesic requirement in RPLU group was higher than that in MPCNL group (2/121, 1.7% *vs.* 13/139, 9.4%, $P=0.017$). Urine leakage occurred in eight patients in RPLU group between 4 and 10 days.

All patients had a follow-up for about 12 to 46 months. Four patients in MPCNL group and one patient in RPLU group were diagnosed with ureteral stricture due to aggravated hydronephrosis after the operation and underwent laparoscopic ureteral plastic surgery.

Discussion

Impacted proximal ureteral stones lead to hydronephrosis, urinary tract infection, and even loss in renal function. SWL, URS/FURS, PCNL, and laparoscopic lithotomy (LU) are safe and effective surgical methods for impacted proximal ureteral stones in various studies.[9,10] However, the debate regarding this approach is the most effective and safe approach remains controversial, and multicenter randomized controlled trials of different treatments for impacted proximal ureteral stones are still scarce.[11,12] European Association of Urology Guidelines on urolithiasis recommend SWL or URS as first-line treatment, PCNL or LU are recommended for selected cases.[13] URS is a safe, effective, and minimally invasive method for the treatment of ureteral calculi, however, proximal ureteral stones can migrate back to the renal pelvic easily when treated by URS. Some articles reported that PCNL and LU are more effective than URS and SWL without significant increase in complications and recommended that PCNL might be the best option for impacted proximal ureteral stones owing to its higher successful rate and similar complication incidence compared with URS.[14,15] PCNL and LU for treatment of impacted proximal ureteral stones attracted more and more attention in recent years.

MPCNL has been used for the treatment of renal calculi and upper ureteral stone due to its low likelihood of trauma to the renal parenchyma. MPCNL was associated with a significant reduction in intra-operative bleeding, LOS, and pain after operation, accompanied by a reduction in the percutaneous renal access from 24/26 to 16/18.[16,17] LU which can be performed by transperitoneal or retroperitoneal procedure is a minimally invasive alternative to open surgery. LU plays an important role in the treatment of upper ureteral calculi, especially large and hard stone. LU avoids percutaneous renal access injuries that exist in PCNL, but it is a relatively more complicated procedures and can only be performed by surgeons with certain skillset.[18] The SFR of LU was higher than that of ESWL and URS and even higher than that of PCNL.[12,15] As compared with retroperitoneal procedure, transperitoneal procedure was significantly associated with pain, higher tramadol requirement, ileus, and longer hospital stay, but the learning curve of the retroperitoneal procedure was longer than that of the transperitoneal procedure. There was no difference in SFR between transperitoneal and retroperitoneal procedures.[19]

According to our study, the success rate and SFR in RPLU group were higher than those of MPCNL group, but the difference was not statistically significant. The drop in hemoglobin was higher in MPCNL group on the first day after the operation, but there was no blood transfusion requirement in MPCNL group and no statistical difference between the two groups. This result is inconsistent with previous report, for example, Topaloglu *et al*[20] reported that PCNL had a greater amount of blood loss, which may be related to their use of the 30F Amplatz sheath compared with PCNL (24–30F), MPCNL (16–18F) can reduce bleeding has been well reported.[4] Therefore, less bleeding in our results may be associated with smaller percutaneous renal access.

However, in contrast to the needs for the ureter to be incised and sutured, the preserved integrity of the ureter in MPCNL group was better than that of RPLU group, the corresponding time of catheterization, the time of drainage tube, and the time of DJ stent after operation in MPCNL group is shorter, therefore, LOS after surgery in MPCNL group was shorter. These results have not been explored in previous studies. The difference in the need of analgesic drugs after operation between the two groups shows that

MPCNL procedure is associated with less post-operative pain than that of RPLU. Urine leakage occurred in eight patients between 4 and 8 days in RPLU group may be attributed to suboptimal suturing of the ureter, which resulted in subsequent prolonged LOS.

Ureteral stricture is one of the most serious complications after ureteral stone surgery. Ultrasound showed an increase in hydronephrosis in follow-up and enhanced CT urography should be performed as soon as possible to confirm the ureteral stricture. Ureteroscopy may also be performed to detect the ureteral stricture. Long-term follow-up showed that the ureteral stricture occurred in both groups, our study showed that the incidence of ureteral stricture in RPLU group was lower than that of MPCNL group, but there was no statistical difference between these two groups. Laparoscopic ureteroplasty was performed and hydronephrosis was relieved during the follow-up. The reason for high incidence of ureteral stricture in MPCNL group may be due to some mucosal injury from the thermal damage of Holmium laser and energy conduction of *in situ* lithotripsy, as well as polyps and chronic inflammation caused by the long-term obstruction of stones. However, RPLU is a "cold knife" operation and there is no thermal damage to the ureter.[21]

Post-operative fever and potential septic shock are the serious complications of PCNL. Some researchers believe that small percutaneous renal access can result in high intra-pelvic pressure, which can lead to increased post-operative infection.[22] The proportion of post-operative fever and infection in MPCNL group was higher than that of RPLU group.[23] There were six patients with fever higher than 38°C after operation but no cases of serious infections in MPCNL group, which may be due to the following three reasons. First, patients underwent pre-operative bacterial culture of midstream urine, sensitive antibiotic treatment was selected for bacteria before operation. Second, high-power Holmium laser combined with 550 fiber which can crush stones efficiently was used to shorten the operation time. Third, purulent urine was found after percutaneous nephrostomy in three patients and staged operation was performed. The relatively low incidence of infection in RPLU group may be associated with no elevated intra-pelvic pressure during the whole procedure.[24,25]

KUB plain film showed that abnormal position of DJ stent occurred in both groups on the first day after operation. The cases with abnormal position of DJ stent in RPLU group was more than that in MPCNL group. This discrepancy may be due to the differences in the surgical procedures in indwelling DJ stent. In RPLU group, there were eight cases in whom the DJ stent was not inserted into the bladder, but two cases in MPCNL group. The DJ stent that was not inserted into the bladder had to be removed under anesthesia through ureteroscopy. The chances of the patient being readmitted to the hospital will increase. We also found that if the DJ stent was not inserted into the bladder, it does not increase the proportion of urinary leakage. Urinary leakage did not occur in the eight patients with abnormal position of DJ stents. About eight patients with urinary leakage in RPLU group had normal DJ stents position. We speculate that the occurrence of urinary leakage is related to the suture of ureter. Abnormal position of DJ stent as the cause has not been mentioned in previous reports.

Our research had some limitations. It was a retrospective study from a single-center, however, there were no comparisons with other treatments used to treat large impacted proximal ureteral stones, such as SWL, URS, and FURS. The success rate of any endourologic treatment was affected by means of stone, clinical, anatomic, and technical factors. The selection criteria and outcome measures need to be standardized. Longer follow-up is essential to assess the long-term efficacy and safety of MPCNL and RPLU. Future studies may be conducted with multicenter randomized controlled trials including SWL, URS, FURS, MPCNL, and RPLU.

In conclusion, this study indicated that MPCNL and RPLU are both effective and safe in the case of impacted proximal ureteral stones greater than 15 mm, without significant difference in stone clearance and surgical success. It was also found that post-operative recovery time and hospitalization time favored MPCNL over RPLU.

Data availability

The datasets analyzed in the current study were available from the corresponding author on reasonable request.

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Conflicts of interest

None.

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