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ORIGINAL ARTICLE

Treatment of large impacted proximal ureteral stones: randomized comparison of minimally invasive percutaneous antegrade ureterolithotripsy versus retrograde ureterolithotripsy

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Abstract

Objective To provide appropriate evidence for treatment planning of patients with an impacted proximal ureteral stones ≥1.5 cm in size, by analyzing the therapeutic outcomes for those undergoing minimally invasive percutaneous antegrade ureterolithotripsy and retrograde ureterolithotripsy.

Patients and methods From September 2010 to November 2011, eligible patients with impacted proximal ureteral stones ≥1.5 cm in size referred to our institute were considered for this study. The closed envelope method was used to randomize the enrolled patients to mini-PCNL (30) or retrograde ureterolithotripsy (29). The efficiency quotient (EQ) was calculated to specifically address the efficiency for both the techniques. All preoperative and postoperative data for both groups were recorded.

Results The initial stone-free rate was 93.3 % in the mini-PCNL group and 41.4 % in the URSL group ($p < 0.001$). However, the overall stone-free rate at the 1-month follow-up visit after initial treatment was 100 % in the mini-PCNL group and 89.7 % in the URSL group ($p = 0.07$). The EQs for the mini-PCNL and URSL groups were 0.83 and 0.50, respectively.

Conclusions Our study shows that mini-PCNL removal of large impacted proximal ureteral calculi can achieve higher stone-free rates and safe.

Keywords Mini-percutaneous · Antegrade · Retrograde · Ureterolithotripsy · Proximal ureteral stones

Introduction

Management of large impacted proximal ureteral calculi remains challenging for urologists. Various treatment options have been proposed for large proximal ureteral stones such as SWL, URSL, and percutaneous nephrolithotomy. SWL (often requiring multiple sessions and stent placement) has poor overall success rates in the treatment of large stones with a significant possibility of residual fragments. SWL also may not be feasible due to coexisting anatomical abnormalities or comorbidity. The reported stone-free rates are 89–100 % when semi-rigid or flexible ureterorenoscopy with holmium:YAG laser lithotripsy (URSL) is used in managing proximal ureteral calculi [1–7]. However, some large and impacted proximal ureteral stone are difficult to approach using retrograde ureterorenoscopy. The main problem is in that the inflammatory, edematous mucosa or fibroepithelial polyp that is often found enveloping the impacted calculus may impede calculus exposure and impair lithotripsy or a tortuous ureter, and unusual angulations of the ureter. Although open surgery is rarely used as first-line therapy, patients with large, impacted, proximal ureteral stones may sometimes require open surgery or laparoscopic ureterolithotomy. In order to avoid more risk of open surgery, other minimally invasive options such as percutaneous nephrolithotomy (PCNL) or mini-percutaneous antegrade ureterolithotripsy have been proposed in this setting. PCNL was introduced as an alternative treatment for large renal and proximal ureteral stones and achieved success in the 1980s [8]. Minimally invasive PCNL (mini-PCNL), which is

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modified PCNL using a miniature endoscope by way of a small access tract, can be routinely performed to manage stones in the kidney and proximal ureter [9].

In this study, we report our experience of the management of impacted, proximal ureteral stones ≥1.5 cm in diameter and compare the treatment outcomes in patients undergoing minimally invasive percutaneous antegrade ureterolithotripsy and retrograde ureterolithotripsy.

Patients and methods

From September 2010 to November 2011, eligible patients with impacted proximal ureteral stones ≥1.5 cm in size referred to our institute were considered for this study. The proximal ureter was defined as the portion extending from the ureteropelvic junction to the lower border of the fourth lumbar vertebra. Impacted ureteral stones (IUS) is defined as a stone that remains fixed at the same site with hydronephrosis for more than 1 month. Patients with the calculi in the kidney (≥10 mm) or the bilateral or distal ureter and those with serum creatinine (Scr) concentrations >1.5 mg/dL were excluded from the study. Patients were preoperatively evaluated with a history, physical examination, and image system (including a plain roentgenogram for the kidneys, ureters, and bladder, ultrasound, and computed tomography). Preoperative laboratory evaluation included urinalysis, urine culture, coagulation profile, Scr level, and complete blood count. Patients with a known urinary tract infection received specific antimicrobic culture before URSL or PCNL until the urine culture turned to negative. Intravenous urography (IVU) and a radionuclide renal scan were used to document renal function in all patients. The closed envelope method was used to randomize the enrolled patients to mini-PCNL (30) or retrograde ureterolithotripsy (29). Informed consent was obtained before surgery.

Minimally invasive PCNL was performed with the patients under general anesthesia. In the lithotomy position, an 8/9.8F ureteroscope was inserted into the urinary bladder and a 5F ureteral catheter inserted into the ureter. The distal end of a 5F ureteral catheter was fixed to the 18F Foley bladder catheter. Then, the patient was turned prone position. Fluoroscopic guidance was used for stone location, and an 4F puncture needle was used to puncture the collecting system. The middle calix was punctured (although upper caliceal access can provide more direct access down the ureter than middle caliceal access, it could take more damage to body). When the needle was safely positioned in the collecting system (as ascertained by urine flow through the needle), contrast material was given through the needle to make the collecting system visible under fluoroscopy. A 0.038-inch guidewire was inserted through the needle into the collecting system. After making a small skin incision, the needle was removed. The dilatation procedure was performed under fluoroscopic guidance, and isotonic saline was used for irrigation and visualization. The nephrostomy tract was dilated with fascial dilators up to 12F–18F, a corresponding peel-away sheath was inserted above the last dilator, the dilators were removed, a rigid 8.5/9.8F ureteroscope (Richard Wolf) was inserted, and then the peel-away sheath was inserted further and guided by the ureteroscope until the tip of it reached ureteropelvic junction. Holmium:YAG laser lithotripsy was used for stone fragmentation in all cases; small stone fragments were removed by irrigation, and larger fragments were removed with stone forceps. Continuous irrigation and/or intermittent manual pumping of irrigant was done to maintain a clear ureteroscopic view when appropriate. At the end, double J (DJ) was placed antegrade in all patients.

Ureteroscopic lithotripsy was completed under spinal or general anesthesia in the lithotomy position with intravenous antibiotic prophylaxis. In the majority of cases, retrograde access to the upper urinary tract was obtained over a safety guidewire with a 8.5/9.8F semi-rigid ureteroscope (Richard Wolf, Knittlingen, Germany). When the stone was difficult to visualize, and to look for residual fragments, a 7.4 F fiber-optic flexible ureteroscope was used, usually with the aid of an access sheath (Gyrus ACMI, Southborough, MA, USA). A holmium:YAG laser (Dornier Medical Systems, Germany) using a 365 μm (rigid ureteroscope) or 200 μm (Olympus digital flexible ureteroscope) fiber or lithoclast lithotripsy was used to disintegrate the calculi. Sterile saline was used as irrigation under hydrostatic pressure. Intermittent irrigation was used to obtain a clear operative visual field. The laser energy was set at 1–1.5 J per pulse, and the frequency was between 5 and 15 Hz. A DJ stent was placed retrograde in all patients. Stone manipulation was carried out using wires, laser fiber, and a variety of Dormia/Gemini baskets.

Postoperative imaging including KUB and ultrasound was conducted to monitor the recovery from hydronephrosis and to verify stone passage. Treatment outcomes were determined based on evidence of being stone-free on KUB or ultrasound after 2 weeks and 1 month. IVU and radionuclide renal scanning were performed about 3 months after the operation to confirm the stone-free rates (SFRs), document any ureteral stricture formation, and verify renal function. The stent was removed with the patient under local anesthesia on an outpatient basis if there were no residual stones >4 mm in size on follow-up X-ray. Failure of the procedure, intraoperative and postoperative morbidity, operative time, hospital stay, time of convalescence, stone clearance at discharge home and at follow-up, and preoperative and postoperative split renal function were compared between the two groups of patients.

Preoperative and postoperative hemoglobin concentrations in the patients who underwent the mini-PCNL procedure were also recorded.

Data were processed using SPSS 15 for Windows. The results are presented as mean ± standard deviation. All of the parameters were analyzed statistically using the unpaired Student's t test and χ^2 test. A p value <0.05 was considered statistically significant. We used the efficiency quotient (EQ) to compare the efficiency of both treatment groups. EQ was calculated by the equation: EQ = [percentage stone-free/(100 % + percentage requiring re-treatment + percentage requiring an auxiliary procedure)] [6].

Results

Average patient age, the male-to-female ratio, Scr level, and stone size were similar between the two groups (Table 1). Also, there was no statistically significant difference between the groups in the time from diagnosis to treatment. A total of 59 patients were included in this study, of whom 30 were treated by mini-PCNL and 29 were treated by URSL.

The mean treatment time and postoperative hospital stay were significantly lower in the URSL group than in the mini-PCNL group. However, The initial stone-free rate was 93.3 % in the mini-PCNL group and 41.4 % in the URSL group ($p < 0.001$). The overall stone-free rate at the 1-month follow-up visit after initial treatment was 100 % in the mini-PCNL group and 89.7 % in the URSL group ($p = 0.07$). The EQs for the mini-PCNL and URSL groups were 0.83 and 0.50, respectively. Seven patients had combined renal stones (<10 mm), and we were able to remove both renal and proximal ureteral stones simultaneously. In the mini-PCNL group, there were six patients who had a transient postoperative fever, which was controlled with appropriate antibiotics and supportive treatment. No patients had massive blood loss requiring transfusion. No urinary tract perforation or adjacent organ injury occurred during the procedure. One patient had steinstrasse over the distal ureter after mini-PCNL treatment, no any additional therapy be used, and the stone passed spontaneously within 2 week. The preoperative and postoperative hemoglobin concentrations for patients undergoing percutaneous procedures were 129.7 ± 12.5 and 125.0 ± 14.3 g/dL, respectively, and there was no statistically significant difference between them ($p = 0.703$).

In the URSL group, Stone Retrieval Basket (Cook Medical S-4 FR-4 FR-70) was used in 21 patients. Nine patients who had stones or bigger stone fragments showed upward migration during the procedure, and upward-migrating stone fragments were the leading cause of URSL treatment failure. Of those nine patients with stones, seven were subsequently treated by Olympus digital flexible URS, one underwent mini-PCNL treatment, and another patient underwent ESWL after 1 week. Of 14 patients with residual stones >4 mm in size who underwent URS, auxiliary procedure to achieve a stone-free state, 3 patients who underwent ESWL and 6 patients who have medical therapy with tamsulosin, stone passed spontaneously for only 5 patients within 3 week. Two patients failed due to tortuous and angulation of the ureter, one of them was transferred to ureterolithotomy. Another patient was transferred to mini-PCNL. Complications including blood loss requiring transfusion, ascending stones, urinary tract perforation, transient postoperative fever, flank pain, and hematuria were recorded (Table 2).

Table 1 Mean patient age, gender, Scr, and stone size

	Mini-PCNL	RIRS	p value
Mean age (range) (years)	42.5 ± 10.1	44.22 ± 13.0	0.153
Male-to-female ratio	1:0.81	1:0.64	0.45
Mean stone size (range) (mm)	17.27 (15–25)	16.23 (15–25)	0.189
Stone location (left/right)	16/14	12/17	0.35
Serum creatinine (scr) (μmol/L)	78.6 ± 10.6	76.9 ± 9.77	0.22

Discussion

The proximal ureteral stone is one of the most common stone illnesses in modern society. Long-term IUS may cause interruption of urinary flow and progressive back-pressure on the ureter and kidneys, resulting in hydroureteronephrosis. Although a small-caliber rigid or flexible ureteroscope combined with holmium laser lithotripsy is rapidly becoming first-line treatment for large impacted proximal ureteral calculi [4], the main problem in URSL for some long-term IUS is failure to gain access to the stone. Large impacted calculi located in the upper ureter may result in a significantly tortuous ureter and are difficult to approach using retrograde ureteroscopy. The inflammatory, edematous mucosa, or fibroepithelial polyp that is often found enveloping the impacted calculus may impede calculus exposure and impair lithotripsy [9–15]. On the other hand, continuous high-pressure irrigation for obtaining a clear operative visual field may result in an ascending stone. If the ureteroscope can overcome the tortuous ureter and edematous mucosa to reach the stone, the stone or stone fragments may be washed back to the renal pelvis or calices by outflow of irrigant, and thus cannot be reached

Table 2 Stone-free rates for patients with RIRS and mPCNL

	URS	mPCNL	p value
Range minus operating (mean)	45–100 (66.7)	50–135 (96.2)	0.032
Range minus fluoroscope (mean)	1–2	1–5	
Postoperative hospital stay (days)	1.9 ± 1.3	4.6 ± 1.8	0.034
% Initial stone-free rate	41.4 (12/29)	93.3 (27/30)	0.000
% Auxiliary procedures rate	79.3 (23/29)	20.0 (6/30)	0.000
% Retreatment rate	0	0	
% Overall stone-free rate	89.7 (26/29)	100 (30/30)	0.07
Efficacy quotient (EQ)	50.0	83.3	
Operation-related complications			
Fever	5	17	0.002
Pain	12	15	0.506
Ureteral perforation	1	0	
Significant gross hematuria	5	15	0.007
Blood loss required transfusion	0	0	
Upward-migrating stone	9	0	

and removed using a rigid or semi-rigid ureteroscope [15–17, 27–29].

The failure of ureteroscopic lithotripsy treatments may require open surgery or laparoscopic ureterolithotomy. PCNL was introduced as an alternative treatment for large renal stones, and the percutaneous approach for treatment of proximal ureteral stones has also achieved some success [8, 18]. Mini-PCNL, which is modified PCNL using a miniature endoscope by way of a small access tract, can be routinely performed to manage stones in the kidney and proximal ureter. Although debates have ensured on the potential advantages of mini-PCNL, it exhibited advantages with respect to hemorrhage, postoperative pain, and shortened hospital stays [18–23]. In mini-PCNL procedure, a rigid 8/9.8F ureteroscope instead of the traditional 26F–30F adult nephroscope is used. Consequently, the nephrostomy tract needed is only dilated to 14F–16F. After the ureteroscope is inserted into the collecting system, the peel-away sheath is further inserted under ureteroscopic guidance until the tip reaches the ureteropelvic junction, and thus prevents stone fragments from being washed back into the pelvis. During the procedure, intermittent manual pumping of irrigation through the ureteral catheter is done to prevent the stone fragments from dropping into the distal ureter. Since the stone fragments can only move in the proximal ureter, the stone is effectively cleared.

In the present study, the mean treatment time and postoperative hospital stay were significantly lower in the URSL group than in the mini-PCNL group. However, the initial stone-free rate was 93.3 % in the mini-PCNL group and 41.4 % in the URSL group ($p < 0.001$). The overall stone-free rate at the 1-month follow-up visit after initial treatment was 100 % in the mini-PCNL group and 89.7 % in the URSL group ($p = 0.07$). Using the concept of EQ, we can compare different treatment results with the needs for retreatment and auxiliary procedures. An ideal treatment has an EQ of 1, and if the EQ is <0.5, the treatment is considered insufficient because every patient requires another treatment or auxiliary procedure to achieve a stone-free state. In our study, the EQs for the mini-PCNL and URSL groups were 0.83 and 0.50, respectively, which is similar to other studies [5, 24, 25]. It demonstrates the advantage of the PCNL treatment over URSL therapy for large IUS. On the other hand, there are 9 patients who had stones or bigger stone fragments showing upward migration during the URSL procedure, and upward-migrating stone fragments were the leading cause of URSL treatment failure; of the nine patients with stones, seven were subsequently treated by Olympus digital flexible URS, in which ureteral access sheaths help facilitate efficient retrieval of multiple stone fragments and help maintain continuous drainage during prolonged intrarenal procedures [26–28].

The advantages of mini-PCNL were that almost all developed lithotripter probes can be used during percutaneous nephroscopic ureterolithotripsy, including electrohydraulic lithotripter, pneumatic lithotripter, ultrasonic lithotripter, and Ho:YAG laser lithotripter. The other advantage of PCNL is that any associated renal stones can be removed simultaneously. Smaller caliber, more nimble modern ureteroscopes are better able to reach the proximal ureter to target the stone. These tools and the multitude of baskets, graspers, and laser fibers that are deployed through their working channels are becoming more and more widely used to treat both renal and ureteral calculi. PCNL can achieve an initial stone-free rate from 86 to 98.5 % for stone sizes >15 mm in diameter, which is superior to that with any other treatment [13, 14]. In our series, 7 patients had combined renal stones and we were able to remove both renal and proximal ureteral stones simultaneously.

The complications of minimally invasive percutaneous nephroscopic ureterolithotripsy are similar to those of PCNL [18–20]. Bleeding is the main complication, and fever is the most encountered complication [20–23]. In most cases, bleeding can be managed conservatively, but about 2–5 % of patients may require a blood transfusion and very rarely arterial embolization [18–21]. With pre-operative prophylactic broad-spectrum intravenous antibiotics, the present incidence of transient fever was 25 % and no patient experienced severe sepsis [21–23]. In our study, the main complication was bleeding after the operation, which is also true with traditional PCNL, but the bleeding rate was lower for mini-PCNL patients than that for traditional PCNL using a traditional 24F–30F nephrostomy tract. No patients in our study required transfusion. There were no injuries to surrounding organs or pneumothorax in our patients. We believe that this could be attributed to the appropriate puncture route under ultrasonic and fluoroscopic guidance.

This investigation demonstrated that the percutaneous nephroscopic ureterolithotomy remains a safe and efficient treatment option for proximal ureter stone, especially when the stone size is >15 mm.

Conclusions

Our study shows that mini-PCNL removal of large impacted proximal ureteral calculi can achieve higher stone-free rates and safe.

Conflict of interest There is no conflict of interest.

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