Comparison of the efficacy of different surgical approaches for complicated impacted proximal ureteric calculi based on a new scoring standard: a matched-pair analysis

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Research Article

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Abstract

**Objective:** To compare the clinical efficacy of Ureteroscopic lithotripsy (URSL) and percutaneous nephrolithotomy (PCNL) in the treatment of complicated impacted proximal ureteric calculi based on a new scoring standard.

**Methods:** The data of 45 patients with complicated impacted proximal ureteric calculi underwent URSL were collected in this retrospective study between January 2015 and April 2021. During the same period, PCNL was used in 171 patients with complicated impacted proximal ureteric calculi. 45 patients were selected as the control group and matched at a 1:1 ratio to index URSL cases in regards to age, sex, BMI. Peri-operative data were compared between the two groups.

**Results:** All 90 operations were successfully completed. Compared to the URSL group, the surgical duration of the PCNL group was significantly shorter (53.69 ± 25.07 min vs. 73.46 ± 27.12 min, p < 0.05), stone-free rate (SFR) was significantly higher (93.3% vs. 68.9%, p < 0.05), and total treatment cost was lower (US $1678.61 ± 714.86 vs. US $3901.45±1069.46, p < 0.05). Conversely, the URSL group had a shorter hospital stay (3.68 ± 2.70 d vs. 6.39 ± 3.34 d, p < 0.05). There was significant difference in complication rate between the two groups in regards to Clavien grade I, II, or III complications (20.0% in URSL group vs. 8.9% in PCNL group, p=0.32).

**Conclusion:** PCNL had a better SFR and higher surgical efficacy, whereas URSL had a shorter perioperative period, but a lower initial SFR. PCNL is often more advantageous for complicated impacted proximal ureter stone.

Introduction

Urolithiasis is a common medical condition. Its incidence by the age of 70 years is 11–13% in men and 5.6-7.0% in women. Ureteric calculi can adversely affect kidney function and cause life-threatening sepsis. According to the latest urological guidelines, extracorporeal shock wave lithotripsy (ESWL), ureteroscopic lithotripsy (URSL), and percutaneous nephrolithotomy (PCNL) are the most commonly used treatment methods for proximal ureteral calculi. Wu et al. conducted a meta-analysis and found that URSL should be regarded as the standard treatment for large proximal ureteral calculi. A retrospective analysis conducted by Bozkurt et al. found that PCNL is a safer and more effective treatment for impacted proximal ureteral calculi. Li et al. revealed that the treatment options for impacted proximal ureteral calculi depend on the location of the stone relative to the superior boundary of the fourth lumbar vertebra. However, thus far, no scoring systems have been developed to guide the treatment of upper
ureteral calculi. In this study, after analyzing the existing data, high-risk factors associated with the characteristics of stones were preoperatively assigned scores, and the better surgical plan for the complicated impacted upper ureteral stones can be decided based on the scores.

**Methods**

**Clinical materials**

A total of 412 patients with impacted proximal ureteral stones eligible for treatment between January 2015 and April 2021 were included in the study. According to the Chinese urological guidelines, the proximal ureter is defined as the area from the junction of the renal pelvis and ureter to the upper edge of the sacroiliac joint (or the lower edge of the fourth lumbar vertebra), confirmed using imaging segmentation as a reference. The inclusion criteria for impacted calculi are as follows: the stone has been retained in the ureter for at least 4 weeks; previously failed ESWL; hydronephrosis in the ipsilateral renal pelvic collecting system is over 1 cm; and ureteral stricture or polyp formation near the stone. Patients who met any two of these criteria were diagnosed with impacted proximal ureteral calculi. Exclusion criteria included the following: patients requiring treatment for kidney stones or bilateral ureteric stones at the same time; patients with solitary kidney, and other renal abnormalities; and patients who were lost to follow-up during the study period. Authors had access to information that could identify individual participants during or after data collection.

The definition and scoring standards for preoperative high-risk factors associated with stones were selected based on findings from existing literature. These high-risk factors included whether the diameter of the stone was > 2 cm, stone density was > 1000 HU, there was a history of lithotripsy, the degree of hydronephrosis was greater than moderate, and there was infection. Scores for high-risk factors associated with stones were then assigned (yes = 1, no = 0). Complicated stone case was defined as total stone score ≥ 3 (table-1).

All patients underwent preoperative computed tomography (CT) examination of the urinary system; Patients’ demographic data, such as age, sex, body mass index (BMI), past history of kidney operation were recorded. Preoperative laboratory tests included urinalysis, urine culture, blood count, coagulation function and creatinine levels. Prophylactic antibiotics were preoperatively administered in all patients, and those with positive urine cultures were treated with sensitive antibiotics to control infection. Due to the retrospective nature of the study, the need for informed consent was waived; additionally, the study design was approved by the ShengJing hospital ethics review board, all methods were performed in accordance with the relevant guidelines and regulations.

45 patients in the URSL group were identified as complicated impacted proximal stone (total stone score ≥ 3). The matching of the 45 patients from among those 171 PCNL patients was done by propensity score method. During the same period, PCNL was performed in 171 patients with complicated impacted proximal stone. From this cohort, we selected 45 patients to serve as the control group. The 45 patients
were matched at a 1:1 ratio to index URSL cases with respect to age, sex, BMI. When more than one possible match were available, controls were labeled with a random number generator within Excel (Microsoft Corp, Redmond, WA, USA) and PCNL data corresponding to the highest random numbers assigned were selected as controls. Both of the procedures was the standard of care at the time and whether patients would receive PCNL or URSL depended on the preference of the surgeon and availability of the equipment at the operation time. Operative data such as stone free rate, complication rate, cost, need for auxiliary treatment and postoperative hospital stay were evaluated.

Surgical technique

URSL:

For the semi-rigid ureteroscopic lithotripsy procedure, patients were placed in the lithotomy position under epidural or general anesthesia. An 8/9.8-F semi-rigid ureteroscope was advanced into the ureter via a safety guidewire. After the location of the stone was determined, it was directly managed by using a pneumoballistic or holmium laser.

For the flexible ureteroscopic lithotripsy, after successfully anesthetizing the patients, a holmium laser fiber was placed via a flexible ureterscope for stone fragmentation. Stone removal baskets were used routinely in URSL surgery to improve stone removal efficiency. The ureteral access sheath was routinely used in flexible ureteroscopic lithotripsy to avoid high irrigation pressure and facilitate the passage of stone fragments. A 6F D-J tube was routinely placed after the operation.

PCNL:

Patients were placed in the lithotomy position, and artificial hydronephrosis was induced after epidural or general anesthesia. After inserting the ureteral catheter, patients were turned to the prone position, and the target renal calyx was punctured under ultrasound guidance. A fascial dilator was used to continuously expand to the desired working tract. After advancing the nephroscope via the guidewire and determining the location of the stone, ultrasonic and pneumatic lithotripsy were used to break the stone and remove the stone fragments. A 6F D-J tube was routinely placed, and a nephrostomy tube was placed at end of the operation.

All patients who met the inclusion criteria were followed up within 3 months after operation to evaluate clinical efficacy. The degree of hydronephrosis was determined by measuring the anterior and posterior diameter of the hydronephrosis on CT. Hydronephrosis less than 2 cm was considered moderate. Surgical duration was defined as the time from placing the patients in the lithotomy position in the URSL group or placing the patients in the prone position in the PCNL group to the end of anesthesia. The SFR was defined as no residual stones on the urinary CT scan postoperative. Complications were analyzed using a modified Clavien classification; infectious complications were defined as postoperative Systemic Inflammatory Response Syndrome (SIRS) symptoms and bleeding complications were defined as postoperative blood transfusion and renal artery embolization. All patients underwent CT examination at
1 month postoperative to determine whether there were residual stones, ureteral stenosis, or hydronephrosis.

**Statistical analysis**

Data were analyzed by SPSS (version 22; IBM Corporation; Armonk, NY, USA). Continuous variables were compared with Student’s t and Mann-Whitney U tests. Proportions of categorical variables were analyzed using the chi-squared or Fisher’s exact test. A p value < 0.05 was accepted as statistically significant. All reported P values were two-sided.

**Results**

All operations were completed successfully and at one time, and there was no conversion to open surgery and secondary surgery. There was no significant difference regarding age, sex, body mass index, creatinine level, clinical features of the stones between the URSL and PCNL groups (\(p > 0.05\)). (Table-2)

Overall, the length of hospital stay was significantly longer in the PCNL group than that in the URSL group, but the surgical duration was significantly shorter and SFR was significantly higher in the PCNL group than in the URSL group (\(p < 0.05\)). No secondary procedures such as second look PCNL or URSL were performed in this series. There was a significant difference in the total cost of treatment between the two groups, with a much lower cost in the PCNL group (Table-3).

Based on the modified Clavien grading standards, there were no complications greater than grade IV (sepsis shock, bleeding requiring nephrectomy, or death) in the two groups. However, there was significant difference in complication rate between the two groups in regards to Clavien grade I, II, or III complications (20.0% in URSL group vs. 8.9% in PCNL group, \(p = 0.32\); Table 4). There were 5 cases with grade I complications, all of which had postoperative renal colic that was treated with analgesics (3 in the URSL group and 2 in the PCNL group). Postoperative infection occurred in 6 patients in the URSL group and all the patients were successfully treated with antibiotics. Serious postoperative hematuria occurred in one patient after PCNL and the patient was treated with embolization after failure to control the bleeding. (Table-4).

**Discussion**

The choice of management for complicated impacted proximal ureteral calculi has been controversial for a long time, but the ultimate goal is for patients to be completely stone-free and to avoid complications. Some clinical factors may play important role, in addition to experience of the surgeon.\(^{15,16}\)

Ureteroscopic lithotripsy mainly includes semi-rigid ureteroscopy and flexible ureteroscopy. URSL is generally safe and provides rapid postoperative recovery, but URSL also has significant disadvantages. Poor irrigation control leads to stone fragments being flushed backward into the renal collection system. Urinary tract infections are also serious complications of URSL, and severe cases can lead to urosepsis.
and even septic shock. The main mechanism of infection is high intraoperative irrigation pressure, resulting in the reflux of bacterial endotoxins into the circulation system. Study has showed that the use of ureteral access sheaths (UAS) can significantly decrease intro-renal pressure during URSL. Holmium laser lithotripsy increases the risk of ureteral stricture. Famet al. reported that the incidence of ureteral stricture after operation is 3–24%. Ureteral stricture can be caused by thermal damage during holmium laser lithotripsy. Thermal effect can damage epithelial structure and blood supply of the ureter wall. However, no patients with ureteral stricture after URSL were identified in the present study.

The advantage of PCNL lies in its high SFR; Gdor et al. found that the success rate of ureteroscopy in the treatment of impacted ureter stones is only 56%. PCNL has advantages in both the initial and overall stone clearance efficiency when compared to URSL. Study has shown that the adjuvant surgery rate of URSL is also much higher than that of PCNL. PCNL also has many serious complications such as damage to the adjacent organs, hemorrhage and severe postoperative infections.

In order to achieve better surgical outcomes, the choice of management is quite important. Based on the findings from the previous studies, five preoperative stone-related high-risk factors (stone diameter, stone hardness, history of previous lithotripsy, and degree of hydronephrosis, infection) were selected for evaluation and analysis in the present study. After scoring and grouping preoperative high-risk factors of the stones, the patients were classified as complicated cases (score ≥ 3 points) group. In the complicated cases, the operation time and complication rate of URSL significantly increased, whereas SFR was quite low. These findings indicate that comparing with that of PCNL, the efficacy of URSL on complicated cases is much lower.

However, the present study has some limitations. First, the study was a retrospective analysis that was conducted among patients enrolled at a single center. Second, the number of patients included was relatively small. A prospective, multi-center, randomized controlled trial will be expected in the future to validate the scoring system.

In conclusion, for complicated impacted proximal ureter stone, PCNL had a better SFR and higher surgical efficacy, whereas URSL had a relatively shorter perioperative period, but a much lower initial SFR. Thus, when choosing a better treatment method for complicated impacted proximal ureteral calculi, we believe that PCNL is the preferred choice over URSL.

Declarations

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Authors’ contributions
Yan Song designed the study and conducted the trial. LvWen Zhang wrote the manuscript. Xiang Fei analyze the data. All authors have read and approved the manuscript.

Funding
None

Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate
The study was approved by The Ethics Committee of the Shengjing Hospital of China Medical University. All patients provided written informed consent. We carried out the study in full accordance with the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

References
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Tables

Table-1

The definition and scoring standards for preoperative high-risk factors associated with stones

<table>
<thead>
<tr>
<th>Variables</th>
<th>yes</th>
<th>no</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sever Hydronephrosis</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Density of the stone</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Over 1000 HU</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diameter of the stone</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Over 2cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infection (fever or positive urine culture)</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>History of SWL, RIRS or PCNL of the same stone</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Abbreviations: RIRS, retrograde intrarenal surgery; PCNL, percutaneous nephrolithotomy; SWL, shock wave lithotripsy

Table-2

Demographic characteristics data of patients according to patients ‘group
<table>
<thead>
<tr>
<th>Parameter</th>
<th>RIRS group</th>
<th>PCNL group</th>
<th>t/χ² value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>54.40±11.17</td>
<td>52.82±12.58</td>
<td>0.890</td>
<td>0.116</td>
</tr>
<tr>
<td>Sex Male/Female</td>
<td>26/19</td>
<td>23/22</td>
<td>2.345</td>
<td>0.126</td>
</tr>
<tr>
<td>Body mass index</td>
<td>23.89±3.62</td>
<td>23.67±3.53</td>
<td>0.410</td>
<td>0.782</td>
</tr>
<tr>
<td>Creatinine</td>
<td>80.76±27.36</td>
<td>79.91±31.43</td>
<td>0.194</td>
<td>0.787</td>
</tr>
<tr>
<td>Stone hardness (1000 HU)</td>
<td>883.60±243.55</td>
<td>960.66±225.01</td>
<td>-4.88</td>
<td>0.649</td>
</tr>
<tr>
<td>Stone diameter (mm)</td>
<td>15.65±2.95</td>
<td>17.15±2.94</td>
<td>-3.33</td>
<td>0.759</td>
</tr>
<tr>
<td>Site of stones Left/Right</td>
<td>25/20</td>
<td>24/21</td>
<td>1.216</td>
<td>0.270</td>
</tr>
<tr>
<td>Preoperative infection Yes/No</td>
<td>8/45</td>
<td>11/45</td>
<td>2.719</td>
<td>0.35</td>
</tr>
<tr>
<td>History of SWL treatment Yes/No</td>
<td>15/45</td>
<td>13/45</td>
<td>0.386</td>
<td>0.535</td>
</tr>
</tbody>
</table>

Data are presented as means ± standard deviations (SD) or numbers. Abbreviations: RIRS, retrograde intrarenal surgery; PCNL, percutaneous nephrolithotomy; SWL, shock wave lithotripsy

Table-3

Intraoperative and Postoperative data according to patients’ group

<table>
<thead>
<tr>
<th>Parameter</th>
<th>RIRS group</th>
<th>PCNL group</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operation time (min)</td>
<td>73.46±27.12</td>
<td>53.69±25.07</td>
<td>0.000</td>
</tr>
<tr>
<td>Length of hospital stay (days)</td>
<td>3.68±2.70</td>
<td>6.39±3.34</td>
<td>0.000</td>
</tr>
<tr>
<td>Stone-free rate</td>
<td>31(68.9)</td>
<td>42(93.33)</td>
<td>0.000</td>
</tr>
<tr>
<td>Complication rate</td>
<td>9(20.0)</td>
<td>4(8.9)</td>
<td>0.037</td>
</tr>
<tr>
<td>Total cost of treatment(US $)</td>
<td>3901.45±1069.46</td>
<td>1678.61 ± 714.86</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Data are presented as means ± standard deviations (SD) or numbers and proportions.

Abbreviations: RIRS, retrograde intrarenal surgery; PCNL, percutaneous nephrolithotomy.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>RIRS group</th>
<th>PCNL group</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N=45</td>
<td>N=45</td>
<td></td>
</tr>
<tr>
<td>Grade 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>postoperative renal colic</td>
<td>3</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>Transient fever&lt; 38°C</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Grade 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bleeding requiring transfusion</td>
<td>1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nonseptic infections requiring additional antibiotics</td>
<td>6</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Grade 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade 3 a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bleeding requiring embolization</td>
<td>-</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Grade 4</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Grade 5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Overall (N, %)</td>
<td>9(20.0)</td>
<td>4(8.9)</td>
<td>0.032</td>
</tr>
</tbody>
</table>

Data are presented as n (%).