Fluoroscopy-free Moses Technology Holmium Laser for Treating Stones Associated with Infundibular Stenosis: a retrospective safety and efficacy cohort study

Liu Haitao
the Third Medical Center of Chinese PLA General Hospital

Chen Xin
the First Medical Center of Chinese PLA General Hospital

Chen Zhiqiang
the Third Medical Center of Chinese PLA General Hospital

Yi Long
the Third Medical Center of Chinese PLA General Hospital

Zhang Xu (✉ xzhang@foxmail.com)
the Third Medical Center of Chinese PLA General Hospital

Mai Haixing
the Third Medical Center of Chinese PLA General Hospital

Research Article

Keywords: retrograde intrarenal surgery (RIRS), infundibular stenosis, Holmium Laser, Moses technology, Intrarenal surgery, X-ray free

Posted Date: October 31st, 2022

DOI: https://doi.org/10.21203/rs.3.rs-2205734/v1

License: ☕️ This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License
Abstract

**Background:** Traditional flexible ureterorenoscopy (f-URS) with holmium laser for treatment of stones associated with intrarenal infundibular stenoses is performed with the aid of fluoroscopy. The use of C-arm and X-ray machines exposes both surgeons and patients to dangerous radiation. To eliminate radiation hazards, we applied X-ray free retrograde intrarenal surgery (RIRS) to treat stones associated with intrarenal infundibular stenoses.

**Purpose:** To review our experience with retrograde intrarenal surgery (RIRS) for treatment of stones associated with intrarenal stenoses and present a treatment protocol on this basis.

**Patients and Methods:** From March 2022 to August 2022, the records of 25 patients—7 women (28%) and 18 men (72%) who had undergone f-URS by a single urologist at Chinese PLA General Hospital with the same type of flexible ureteroscopes using Moses Technology holmium laser for calculi in infundibular stenosis were reviewed. The follow-up visit ranged from 4 to 6 weeks with plain radiography of the kidneys, ureters, and bladder and either renal ultrasonography or noncontrast CT. We statistically analyzed the differences in age, gender, BMI, operation time, postoperative hospital stay, stone size and site number and size of associated calyces, and other factors between the successful treatment group and the failed treatment group. Then multivariate logistic regression was used to further analyze the independent risk factor of success rate of stones associated with intrarenal stenoses.

**Results:** It was able to successfully identify stenoses and perform lithotripsy for 23 (92.0%) patients, and percutaneous nephrolithotomy was used for 2 failed patients. The surgery time was 45-180 minutes, with an average of 93.2 minutes. The postoperative hospital stay was 2-9 days, with an average of 3.4 days. According to the definition set by this study, the success rate was 72.0% (18/25 patients) of which 11 (44.0%) patients were stone free (SF) and 7 (28.0%) patients had clinically insignificant residual fragments (CIRFs). The success rate of lower calyx calculus treatment was 40.0%, the success rate of upper and middle calyx calculus treatment was 93.3%; there was a statistical difference between the two groups (P=0.004). The success rate of ventral calculus treatment was 69.2%, and the success rate of dorsal calculus treatment was 75.0%; there was no significant statistical difference between these two success rates (P=0.748). The success rate was 86.7% when a single calyx was involved in the infundibular stenosis, and the success rate was 50.0% when multiple calyces were involved; there was a statistical difference between these two success rates (P=0.045). The diameter of calyx dilation did not affect the success rate of the surgery (P=0.562). There were no severe complications such as ureteral avulsion and perforation during the surgery. All patients had their ureters removed on the second day after the surgery.

**Conclusion:** Calyx neck incision and lithotripsy technique under flexible ureterorenoscopy with Moses technology Holmium Laser is a safe and effective procedure with fewer complications. With a similar success rate as the traditional X-ray-guided balloon dilation technique, it has higher patient satisfaction and better promotion value. RIRS works best for patients at the upper and middle poles of kidney, while it also be attempted in patients with stones located in the lower calyx. With the development of flexible
ureteroscope technology and the advancement of corresponding medical devices, RIRS provides a safe and minimally invasive technique for patients with stones associated with infundibular stenoses. It features a good promotion value.

**Introduction**

Infundibular stenosis refers to a dilated calyx passing through narrow infundibulum into the renal pelvis. Infundibular stenosis is not uncommon and may be congenital or acquired[1]. The incidence of calculi in infundibular stenosis is 10–50%[2]. These stones are formed due to poor urine drainage and colonization by urease-producing microorganisms [3].

Renal calculus of different etiologies with infundibular stenosis presents a potential challenge for surgical treatment. Historically, open surgery has been used to remove these stones, but minimally invasive methods including extracorporeal shock wave lithotripsy (ESWL), percutaneous nephrolithotomy (PCNL), ureteroscopy and laparoscopic techniques, are now being used. ESWL has been used in the past as a non-invasive treatment, however, due to the narrowed infundibulum is not been addressed, the stone-free rate is very low (4%-58%)[4, 5]. The stone-free rates of PCNL is high (>80%), but it is difficult to remove stones for the ventral calculus [6, 7]. Because PCNL allows for ablation of the diverticulum cavity, risk of recurrence is less[8–10]. Although the results previously reported were ambiguous, advances in optical fiber and laser technology have improved the role of retrograde intrarenal surgery (RIRS) in infundibular stenosis and other intrarenal stenosis associated with precluding passage of stones or disintegrated stone gravel.

The development of flexible ureterorenoscopy (f-URS) instruments associated with a holmium laser made the use of the ureterorenoscope more efficient with less morbidity. We report our experience with f-URS using Moses technology Holmium Laser in 25 patients with stones associated with intrarenal stenosis.

**Material And Methods**

From March 2021 to August 2022, the records of 25 patients—7 women (28%) and 18 men (72%) who had undergone f-URS using a holmium laser for calculi in infundibular stenosis were reviewed. Their ages ranged from 37 to 71 years (mean ± standard deviation; 55.3 ± 2.0). All patients underwent f-URS with holmium laser treatment (Lumenis PulseTM 120H with MOSES Technology) at Chinese PLA General Hospital by a single urologist with same type of flexible ureteroscopes (STORZ FLEX-XC). Of 25 patients, 15 (60%) had calculi in the upper and middle calyx, while 10 (40%) had calculi lower calyx. The average stone burden was 19mm (range 6–30 mm). CT scan was used to valuate stone size and location and to identify possible infundibular stenosis (Fig. 1A&B).

All patients with infundibular stenosis underwent stenosis incision using Moses technology Holmium Laser under a flexible ureteroscope combined with lithotripsy. CT scan or CTU examination was performed before the surgery to evaluate the anatomical site of the stenosis and the calculus condition
Antibiotics were administered intravenously 30 min before the surgery. After general anesthesia, the patients were placed in the lithotomy position. After disinfection and sheeting, an 8-9.8F rigid ureteroscope (27002LK, STORZ, Germany) was used to observe the ureteral orifice, a 0.038 inch hydrophilic guide wire (Cook Medical, Springfield, MO, USA; w-035150, Fr/Ch 0.035/0.89 mm, 150 cm in length) was inserted, and a rigid ureteroscope was inserted along the guide wire to probe the ureter till the renal pelvis. The end of the hydrophilic guide wire was placed in the renal pelvis. After the rigid ureteroscope was retracted, the hydrophilic guide wire was fixed on the surgical drape. Afterwards, a ureteral access sheath (12-14F Flexor, Cook Urological, Spencer, IN) was placed below the UPJ along the hydrophilic guide wire.

A flexible ureteroscope was inserted into the renal pelvis along the ureteral access sheath to probe each calyx in the renal pelvis. The entry point of the infundibular stenosis in the renal pelvis appeared as a dimple under flexible ureteroscope observation. If there was calculus incarceration, part of the incarcerated calculi could be seen (Fig. 2A, B and C). A super smooth guide wire was inserted along the flexible ureteroscope to probe the opening at the stenosis, a 0.038 inch guide wire (or hydrophilic smooth wire) was passed through the flexible ureteroscope and the neck of the stenosis, and if possible, coiled inside. The guide wire was retracted if it could be passed. A 200 mm holmium laser fiber was used to break the incarcerated calculi at the stenosis, and a holmium laser was used to incise the infundibular stenosis. The flushing device was set at a pressure of 2.0 kPa and a flow rate of 0.1 L/min, and an automatic irrigation pump was used to improve visualization. The laser energy was adjusted to Moses mode (0.3J/80Hz). For a relatively thin stenosis, the renal pelvis mucosa can be incised firstly at the point of 6 or 12 o’clock to avoid the nourishing blood vessels in the renal parenchyma, and the passage was gradually expanded until the flexible ureteroscope can pass through the stenosis smoothly. If the passage of the stenosis cavity was long and narrow, the renal pelvis mucosa can be incised at the the point of 6 or 12 o’clock firstly, and then cruciate incision can be made at the point of 3 or 9 o’clock of stenosis incision. The laser incision was performed gradually and layer by layer according to the anatomy of the renal pelvis. It stopped when the fat layer was reached. When encountering small blood vessels, the laser action distance was increased, and the blood vessels were coagulated by laser energy before incision. For stones less than 5 mm, a nitinol basket (Cook, Microvasive) was usually used to remove them completely, hence reducing trauma to the mucosa. For stones that were too large to be removed with a basket alone, a 200-micron fiber was used for holmium laser fragmentation and vaporization. The goal of treating stones after intrarenal stenoses was to completely remove all fragments from the cavity. Fragments larger than 3 mm can also be removed from the kidney with a nitinol basket. The smaller residual stones were flushed out or expelled from the natural passage. Electrocautery of the mucosa was not attempted because there were no data to show a reduced recurrence rate. At the end of the surgery, a double-J-shaped stent was placed over the widened funnel and, if space permitted, coiled into the cavity; otherwise, the stent would be coiled in the renal pelvis.

The continuous variables were expressed as mean ± standard deviation (SD). Normally distributed continuous variables compared using Student’s t-test, while non-normally distributed continuous variables were compared using the Mann-Whitney U test. Categorical variables were compared using the chi-square
test or Fisher's exact test. The logistic regression analysis was used for multivariate analyses. The statistical analysis was performed using SPSS (version26; SPSS Institute Inc, Chicago, IL, USA), and the statistical significance was taken as a two-sided \( P \) value < 0.05.

**Results**

Of the 25 patients, 23 (92.0%) were able to locate the stenosis and perform lithotripsy. The infundibular stenosis of one of the 2 failed patients was located in the lower calyx, and incision cannot be performed for treatment because of exceeding the bending angle of the flexible ureteroscope. The infundibular stenosis of the other was located in the middle calyx, and no diverticulum opening was found during the surgery. Both cases underwent PCNL successfully. 5 patients (20.0%) with lower calyx had postoperative residual stone fragments greater than 3mm, including 2 patient who received complementary ESWL, 2 patient who received second-stage soft endoscopic treatment, and 1 patient who refused surgical treatment with routine follow-up. The surgery time was 45–180 minutes, with an average of 93.2 minutes. The postoperative hospital stay was 2–9 days, with an average of 3.4 days(Table 1.). The gross hematuria disappeared within 1–2 days after the surgery, and two cases had obvious gross hematuria that was improved after symptomatic hemostasis treatment.

According to the definition set by this study, the success rate was 72.0% (18/25 patients) of which 11(44.0%) patients were stone free (SF) and 7 (28.0%) patients had clinically insignificant residual fragments (CIRFs). The success rate of lower calyx calculus treatment was 40.0%, the success rate of upper and middle calyx calculus treatment was 93.3%; there was a statistical difference between the two groups (\( P = 0.004 \)) (Table 3). The success rate of ventral calculus treatment was 69.2%, and the success rate of dorsal calculus treatment was 75.0%; there was no significant statistical difference between these two success rates (\( P = 0.748 \)). The success rate was 86.7% when a single calyx was involved in the infundibular stenosis, and the success rate was 50.0% when multiple calyces were involved; there was a statistical difference between these two success rates (\( P = 0.045 \))(Table 2.). The diameter of calyx dilation did not affect the success rate of the surgery (\( P = 0.562 \)) (The postoperative hospital stay was 2–9 days, with an average of 3.4 days()). There were no severe complications such as ureteral avulsion and perforation during the surgery. Two patients developed fever symptoms (body temperature over 38.5°C) within 48 hours after the surgery, and were given active anti-infection treatment. After symptomatic treatment such as volume dilation and voltage stabilization, the symptoms of both cases were rapidly stabilized and cured. All patients had their ureters removed on the second day after the surgery.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Treatment success</th>
<th>Treatment failure</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (SD) years</td>
<td>55.0(10.5)</td>
<td>56.1(8.1)</td>
<td>0.244</td>
</tr>
<tr>
<td>Gender</td>
<td>4(16%)</td>
<td>3(12%)</td>
<td>0.302</td>
</tr>
<tr>
<td>Female</td>
<td>14(56%)</td>
<td>4(14%)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI (SD)kg/m²</td>
<td>25.1(4.3)</td>
<td>25.4(2.4)</td>
<td>0.168</td>
</tr>
<tr>
<td>Diabetes</td>
<td>3(12%)</td>
<td>3(12%)</td>
<td>0.169</td>
</tr>
<tr>
<td>YES</td>
<td>15(60%)</td>
<td>4(16%)</td>
<td></td>
</tr>
<tr>
<td>NO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>7(28%)</td>
<td>4(16%)</td>
<td>0.409</td>
</tr>
<tr>
<td>YES</td>
<td>11(44%)</td>
<td>3(12%)</td>
<td></td>
</tr>
<tr>
<td>NO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>History of surgery</td>
<td>9(36%)</td>
<td>2(8%)</td>
<td>0.332</td>
</tr>
<tr>
<td>YES</td>
<td>9(36%)</td>
<td>5(20%)</td>
<td></td>
</tr>
<tr>
<td>NO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urinary Infections</td>
<td>10(40%)</td>
<td>4(16%)</td>
<td>0.943</td>
</tr>
<tr>
<td>YES</td>
<td>8(32%)</td>
<td>3(12%)</td>
<td></td>
</tr>
<tr>
<td>NO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation time (SD) minutes</td>
<td>89.4(25.4)</td>
<td>102.9(44.9)</td>
<td>0.784</td>
</tr>
<tr>
<td>Postoperative hospital stay (SD) days</td>
<td>3.3(1.6)</td>
<td>3.9(1.7)</td>
<td>0.286</td>
</tr>
</tbody>
</table>
**Table 2**
Stone and Dilated calyx Information

<table>
<thead>
<tr>
<th>Variable</th>
<th>Treatment success</th>
<th>Treatment failure</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stone Size (SD) cm</td>
<td>1.9(0.7)</td>
<td>2.0(0.7)</td>
<td>0.583</td>
</tr>
<tr>
<td>Stone CT Value</td>
<td>661.2(268.7)</td>
<td>710.3(204.8)</td>
<td>0.382</td>
</tr>
<tr>
<td>Stone Number</td>
<td>6(24%)</td>
<td>2(8%)</td>
<td>0.819</td>
</tr>
<tr>
<td>Single</td>
<td>12(48%)</td>
<td>5(20%)</td>
<td></td>
</tr>
<tr>
<td>Multiple</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper and middle calyx</td>
<td>14(56%)</td>
<td>1(4%)</td>
<td>0.004</td>
</tr>
<tr>
<td>Yes</td>
<td>4(16%)</td>
<td>6(24%)</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position of calyx</td>
<td>9(36%)</td>
<td>4(16%)</td>
<td>0.748</td>
</tr>
<tr>
<td>Ventral</td>
<td>9(36%)</td>
<td>3(12%)</td>
<td></td>
</tr>
<tr>
<td>Dorsal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calyceal dilation diameter (SD) cm</td>
<td>2.9(0.7)</td>
<td>3.3(0.9)</td>
<td>0.562</td>
</tr>
<tr>
<td>Number of associated calyces</td>
<td>13(52%)</td>
<td>2(8%)</td>
<td>0.045</td>
</tr>
<tr>
<td>Single</td>
<td>5(20%)</td>
<td>5(20%)</td>
<td></td>
</tr>
<tr>
<td>Multiple</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 3**
Multivariate Logistic regression analysis of dilated calyces for independent risk factors of surgical success

<table>
<thead>
<tr>
<th>Factor</th>
<th>B</th>
<th>SE</th>
<th>Wald X2</th>
<th>P Value</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>upper and middle calyx</td>
<td>3.265</td>
<td>1.437</td>
<td>5.162</td>
<td>0.023</td>
<td>1.566 438.041</td>
</tr>
<tr>
<td>Associated calyces number</td>
<td>2.159</td>
<td>1.341</td>
<td>2.593</td>
<td>0.107</td>
<td>0.626 120.052</td>
</tr>
<tr>
<td>Stone Number</td>
<td>-0.648</td>
<td>1.876</td>
<td>0.119</td>
<td>0.730</td>
<td>0.013 20.681</td>
</tr>
<tr>
<td>Calyceal dilation size</td>
<td>-0.866</td>
<td>1.024</td>
<td>0.716</td>
<td>0.398</td>
<td>0.057 3.128</td>
</tr>
</tbody>
</table>

**Discussion**

The RIRS technique was first reported in 1989 for the treatment of residual stones in caliceal diverticula after E-SWL. During the surgery, a 7-Fr balloon was used to dilate the diverticulum neck under fluoroscopy, and then an electrohydraulic lithotrite or holmium laser was used for lithotripsy before removing the fragments endoscopically with a lithotripsy basket or forceps, or (if < 1 mm) the fragments were
discharged Spontaneously. Steven G et al. reported on 108 symptomatic patients with stones associated with intrarenal stenoses treated with flexible ureteroscopy, where 94% of patients were successfully operated, and the lithotripsy success rate was 75%[11]. However, during the surgery, it was necessary to find the stenosis under X-ray guidance and perform balloon dilation of the stenosis under fluoroscopy. X-ray guidance has several distinct benefits. First, the stenosis can be located by contrast agent, and the guide wire and balloon catheter can be monitored in real time when they pass through the stenosis for dilation. Second, balloon dilation for patients with longer stenoses can reduce bleeding during the surgery compared with traditional laser incision. However, this surgery takes a long time and requires repeated fluoroscopy. During the process of balloon dilation, the dilation range and depth cannot be monitored in real time. Once a large blood vessel ruptures and hemorrages, it is likely to cause serious adverse consequences. After the surgery, it is prone to produce adverse reactions such as urinary extravasation due to rupture of the collecting system. At the same time, both patients and surgeons are exposed to large amounts of harmful radiation during the surgery. This kind of ionizing radiation may cause DNA damage, thereby increasing the risk of radiation-related diseases. Therefore, it is of great significance to explore a surgical method that can not only retain the advantages of X-ray-assisted balloon dilation, but also avoid intraoperative radiation damage. In our protocol, the stenosis of calyceal neck can be located and identified in the vast majority of patients (92.0%,23/25) by preoperative CT evaluation and intraoperative application of high definition digital flexible ureteroscopy without the assistance of X-ray fluoroscopy. This is similar to the results of the previous study by Chong et al.[12], which indicates that the success rate of finding the stenosis by a high-definition digital flexible ureteroscope is similar to that of traditional X-ray fluoroscopy.

Holmium laser has both cutting and coagulation properties, and its soft tissue penetration is less than 0.5 mm, allowing for precise incision. The 200 µm fiber can be used through a flexible ureteroscope, and the direction and depth of incision can be precisely controlled during the surgery. The application of holmium laser incision in the treatment of stones associated with intrarenal infundibular stenoses can overcome the disadvantages of X-ray-guided balloon dilation. It can also avoid occurrence of urinary extravasation complications due to excessive tearing of the collecting system during balloon dilation. The key to the treatment is the control of the energy during laser incision and the choice of the incision method. With the continuous advancement of laser fiber and laser equipment, the use of retrograde intrarenal surgery (RIRS), also known as flexible ureterorenoscopy (f-URS), has gradually increased in the treatment of stenotic lesions in caliceal diverticulum and renal pelvis. Its safety and efficacy are very satisfactory for suitable patients[13, 14]. We took the following measures to avoid bleeding of the stenotic segments arising from laser incision: Firstly, we used a super smooth guide wire to pass through the stenosis directly and tried to pass the flexible ureteroscope along the guide wire through the stenosis to observe the calyx above the stenosis under direct vision, and then retracted and assessed the length of the stenosis. This method is an accurate method for assessing stenoses by direct examination; Secondly, for a short stenosis, we adjusted laser to Moses mode (0.3J×80Hz) at the very beginning of incision to start coagulation of blood vessels in the mucosa. To avoid vascular bleeding due to deep incision (Fig. 3B), we performed incision layer by layer at the weak points (6 and 12 o’clock) of the mucosa of the stenosis.
and changed the incision site when any adipose tissue was encountered during incision (Fig. 3D & E); Thirdly, we used a water pump for perfusion (2Kpa 100ml/min) in the process of incision to maintain the dilation of the stenosis under a certain pressure (Fig. 3C), whilst laser accurately incised fibrous tissues at the rupture to avoid bleeding due to damage to blood vessels. For some patients, the stenosis was so narrow that even a guide wire could not easily pass. When this happened, we tried to use a hydrophilic guide wire, a thinner one or a guide wire with different stiffness to pass through the stenosis. For patients with long stenoses, in case we encountered blood vessels at the calyceal neck during layer-by-layer incision, we would keep laser away from the blood vessels, and seal the blood vessels with the thermal energy of laser before incision, which will be a good way to avoid bleeding (Fig. 3F). Moderate bleeding during the surgery may obstruct the surgical field of view and lead to increased surgical complications. In this case, the surgery should be terminated and a stent placed. Hemostasis was good for most patients. If bleeding persists, arteriography and embolization should be considered. After the hematuria was ceased, a second elective surgery can be planned. In our study, the incidence of intraoperative bleeding leading to surgical discontinuation was 12.0% (3/25).

Since patients with stones and intrarenal strictures were also diagnosed with urinary tract infection, special care must be taken to rule out the infection before surgery. In the presence of the infection, appropriate antimicrobial treatment should be given before RIRS. Untreated bacteriuria is an absolute contraindication to RIRS. Ideally, the urine should be sterile at the time of surgery. If the urine culture is previously positive, appropriate antibiotic treatment should be performed at least 5 days prior to surgery. If persistent infection is suspected, especially diverticula or stones contain bacteria, stents should be placed and surgery should be postponed for at least 1 week, coupled with further coverage of antibiotics. Occasionally, intraoperative urine dipstick analysis for leukocytes and nitrites, or urine microscopy for Gram-stained bacteria, is used as a simple and rapid method for testing persistent urinary tract infection. In this case, surgery should be performed with caution and it is preferable to perform the operation until the infection has been controlled. In our surgery, we observed that our surgery time was 45–180 minutes, with an average of 93.2 minutes. In case of prolonged intrarenal surgery, the use of a 12/14F ureteral access sheath can also help keep intrarenal pressure low, thereby reducing the risks of infection and urinary extravasation. In case of urinary extravasation, it is best to abort surgery and place stents to minimize extravasation. Usually, such patients can be given a second surgery about 2 weeks later. In our study, ureteral stents were used in all surgical patients, and 2 patients developed fever after the surgery and recovered after symptomatic treatment. No related infectious complications occurred.

Clinical decisions for the treatment of stones associated with infundibular stenoses are based on: (1) Symptoms requiring intervention; (2) The location and orientation of the diverticulum; (3) The size of the diverticulum; (4) The stone burden in the diverticulum; (5) The initially selected treatment results.

All patients in this study had the symptoms of hematuria or waist discomfort, and they all actively required surgical treatment. The most important things when applying f-URS are stenosis identification, finding of the associated calyx and adequate deflection of the flexible ureteroscope in the dilated calyx. Due to the structural design of the flexible ureteroscope, the dilated calyx of less than 2 cm
(with a stone burden of less than 1.5 cm) is very suitable for RIRS [15]. For larger intact stones (over 1.5 cm), both intracorporeal (holmium laser) and extracorporeal (SWL) lithotripsy should be combined used to accelerate the stone removal process. If the stone is larger than 2 cm and the diverticulum size is larger than 3 cm, percutaneous nephrolithotomy combined with flexible ureteroscopy can be considered for treatment [9, 10, 16]. The locations of the upper and middle poles of kidney are ideal for RIRS. Chong et al reviewed 96 patients with stones in caliceal diverticula, 10% of which were lower pole diverticula. Stenoses were treated with balloon dilation or holmium laser incision. The success rate of the surgery was 90%, and all the failed patients were diagnosed with lower calyx stenosis, which was mainly due to the low success rate of balloon dilation in the stenosis of the lower pole of kidney. Meanwhile, the field of view of the lower calyx of the lower pole was apt to be affected by bleeding. In our study, the failure rate of renal lower pole surgery was 60.0% (6/10). Among the 6 failed patients, the opening of the calyx neck of 1 patient could not be found, and 5 patients had moderate oozing during incision. Batter and Dretler performed URS for 26 patients with symptomatic diverticulum, and 18 (69%) patients were successfully treated. The success rate of the lower pole diverticula was only 29%. Four patients were hospitalized due to complications related to pain control, bleeding, and sepsis[17].

The overall surgical success rate was 72% (18/25) according to the definition of this study (finding and incision of the narrow calyx neck and complete removal of stones). We found that the locations of stones were associated with the success rates. Among them, the success rate of lower calyx calculus treatment was 40.0%, the success rate of upper and middle calyx calculus treatment was 93.3%; there was a statistical difference between the two groups (P = 0.004). The success rate of ventral calculus treatment was 69.2%, and the success rate of dorsal calculus treatment was 75.0%; there was no significant statistical difference between these two success rates (P = 0.748). The success rate was 86.7% when a single calyx was involved in the infundibular stenosis, and the success rate was 50.0% when multiple calyces were involved; there was a statistical difference between these two success rates (P = 0.045). Nevertheless, the diameter of calyx dilation did not affect the success rate of the surgery (P = 0.562). There was no significant correlation between the success rate of the treatment of stones associated with infundibular stenoses and the size, number and CT value of stones.

Conclusion

With the development of flexible ureteroscope technology and the advancement of corresponding medical devices, RIRS provides a safe and minimally invasive technique for patients with stones associated with infundibular stenoses. Calyx neck incision and lithotripsy technique under flexible ureterorenoscopy with Moses technology Holmium Laser is a safe and effective procedure with fewer complications. With a similar success rate as the traditional X-ray-guided balloon dilation technique, it has higher patient satisfaction and better promotion value. However, this study is of certain limitations. First, for patients whose stenosis is too narrow to pass the guide wire, it is difficult to find the infundibular stenosis, so that the surgery may not be performed successfully, and the RIRS treatment failure rate of the stenosis at the lower pole of kidney is high. Second, the study data merely represents a retrospective
analysis of findings from a single center. Third, the results of this study may have certain statistical biases due to the limited number of patients.

**Declarations**

**Ethics approval and consent to participate**

Our ureteroscopy outcomes were registered as an audit with the Ethics Committee Of Chinese PLA General Hospital. Registered audit code was S2022-154-01, with name ‘The Really world observation of single used digital ureterscopic’. All patients had given preoperative informed consent for this research purpose.

**Author contribution(s)**

Mai Haixing  Conceptualization, Methodology, Software

Chen Xin  Data curation, Writing Original draft preparation.

Chen Zhiqiang  Visualization, Investigation.

Zhang Xu  Supervision.

Yi Long  Software, Validation

Liu Haitao  Writing- Reviewing, Editing and statistical analysis

**ORCID iDs**

Mai Haixing  https://orcid.org/0000-0002-4054-0429

**Acknowledgements**

We thank Liu Haitao for his dedication in the statistical analysis and Yi Long for collecting the clinical data and organizing them on a database. We also thank Professor Zhang Xu for the supervision and the final editing of the paper. Our thanks go also to the Chinese PLA General Hospital Trust that allowed us to conduct this trial and to the patients who agreed for their anonymized operative details to be shared and used for this research.

**Funding**

The authors received no financial support for the research, authorship, and/or publication of this article.

**Conflict of interest statement**

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.
Availability of data and materials

Anonymised data and materials are available on request.

References


**Figures**

**Figure 1**

CT scan of infundibular stenosis: (A) CT of coronal view finding of infundibular stenosis;(B) CT of axial view showing calculus incarceration at the stenosis
Figure 2

Observation of infundibular stenoses by using a flexible ureteroscope: (A) Infundibular stenosis; (B) Infundibular stenosis with calculus incarceration; (C) Infundibular stenosis combined with infundibular calculus incarceration

Figure 3

Moses holmium laser incision of infundibular stenosis under flexible ureteroscope: (A) Infundibular stenosis found under flexible ureteroscope observation with mucosal nourishing blood vessels visible on the surface; (B) Laser coagulation of mucosal surface blood vessels; (C) Laser incision at the edge of the stenosis; (D, E) Layer-by-layer incision of the stenosis in the avascular area till the fat layer; (F) Layer-by-layer incision of stenosis calculi combined with long-segment stenosis

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- file.mp4
- media1.mp4
- media2.mp4
- media3.mp4