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Original Article

# Management of symptomatic caliceal diverticular calculi: Minimally invasive percutaneous nephrolithotomy versus flexible ureterorenoscopy

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## Abstract

**Objective:** To retrospectively evaluate appropriate treatment for patients with symptomatic caliceal diverticular calculi, by comparing the therapeutic outcomes for those undergoing minimally invasive percutaneous nephrolithotomy (MPCNL) and flexible ureterorenoscopy (F-URS).
**Methods:** From March 2009 to May 2014, 36 consecutive patients with caliceal diverticular calculi were divided into 2 groups: 21 patients underwent MPCNL, and 15 were treated by F-URS. All procedures were performed by one surgical group, which ensured relatively constant parameters. Patient characteristics, operative time, hospital stay after surgery, stone-free rate, symptomatic improvement rate, complications, diverticular obliteration, and stone composition were analyzed retrospectively in the 2 groups.
**Results:** Patient preoperative variables were comparable between the two groups, with no significant difference ($P > 0.05$). Mean operative time was 136.9 ± 22.8 min in the MPCNL group and 117.3 ± 24.3 min in the F-URS group ($P = 0.019$). Hospital stay was significantly longer in the MPCNL group than in the F-URS group (9.4 ± 3.1 *vs.* 6.9 ± 2.1 days, $P = 0.010$). The stone-free rates after MPCNL and F-URS were 90.5% (19/21) and 60.0% (9/15), respectively ($P = 0.046$). Additionally, 71.4% (15/21) of patients in the MPCNL group and 46.7% (7/15) of patients in the F-URS group had symptomatic improvement at the 6-month follow-up ($P = 0.175$); the rates of complications in the 2 groups were 19.0% (4/21) and 13.3% (2/15), respectively ($P = 0.650$). Complete diverticular obliteration was achieved in 16 (76.2%) cases in the MPCNL group and 5 (33.3%) cases in the F-URS group ($P = 0.017$). The distributions of calcium oxalate and hydroxyapatite in the stones were 66.7% (14/21) and 33.3% (7/21), respectively, in the MPCNL group; however, the distributions in the F-URS group were 46.7% (7/15) and 53.3% (8/15), respectively ($P = 0.310$).

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**Conclusion:** MPCNL is an effective method for the treatment of caliceal diverticular calculi. However, F-URS is an alternative technique in selected patients with a patent infundibulum, despite lower stone-free rates than with MPCNL. Fulguration of the diverticular lining with a high-power holmium laser and permitting the cavity to collapse are useful to increase the chance of diverticular obliteration.


*Keywords:* Caliceal diverticular calculi; Minimally invasive percutaneous nephrolithotomy; Flexible ureterorenoscopy

## Introduction

Caliceal diverticula are smooth-walled, urine-filled cystic cavities lined with nonsecretory, transitional cell epithelium; these cavities communicate with the collecting system through a narrow diverticular neck. Caliceal diverticula are uncommon, and have been observed in 0.21−0.45% of routine intravenous urography (IVU) studies.[1] Caliceal diverticula are usually asymptomatic, but can cause pain, infection, calculus formation, abscess formation, hematuria, and sepsis.

The incidence of calculus formation in caliceal diverticula is reportedly 10−50%.[2] With advancements in technique, treatment has become progressively less invasive. Current minimally invasive treatments for patients with symptomatic caliceal diverticular calculi include extracorporeal shock wave lithotripsy (ESWL), flexible ureterorenoscopy (F-URS), percutaneous nephrolithotomy (PCNL), and laparoscopy. PCNL and F-URS have been reported to be associated with a better stone and symptom-free outcome.[3] Since its introduction, the holmium laser has been used for the treatment of various urologic diseases. Its unique coagulating and cutting ability allows multiple procedures, such as holmium laser enucleation of the prostate (HoLEP) and stone fragmentation. In addition, incision or fulguration of the diverticular neck is performed with the holmium laser in the treatment of caliceal diverticular calculi.[4,5]

In the present study, we retrospectively evaluated the safety and effectiveness of minimally invasive percutaneous nephrolithotomy (MPCNL) and F-URS for the treatment of symptomatic caliceal diverticular calculi.

## Materials and methods

### *Patients*

From March 2009 to May 2014, 36 patients with caliceal diverticular calculi were enrolled in this retrospective, nonrandomized study. These patients were treated either by F-URS (15 patients) or MPCNL (21 patients). In addition, all patients in both groups had a single diverticulum. The characteristics of the patients and stones in both treatment groups are summarized in Table 1; both groups were comparable regarding age, gender, stone size, caliceal diverticular location, and other characteristics. The indications for treatment included flank pain, hematuria, or recurrent urinary tract infections caused by stone burden, as well as patient choice. The choice between the different techniques was based on a joint decision by surgeons and patients; the patients were appropriately informed about the procedures and possible complications. Generally, patients with a patent infundibulum on intravenous urography (IVU) were treated by F-URS, whereas patients with stenotic infundibulum on radiography were managed with MPCNL.

### *Minimally invasive percutaneous nephrolithotomy*

All MPCNL procedures were performed under general anesthesia. The patient was first placed in a

Table 1
Demographic data and stone characteristics.

| Characteristics | MPCNL ($n$ = 21) | F-URS ($n$ = 15) | $P$ |
|---|---|---|---|
| Age, years | 41.7 ± 9.8 | 44.5 ± 9.0 | 0.376[a] |
| Men/women, $n$ | 9/13 | 5/10 | 0.738[b] |
| Left/right, $n$ | 12/9 | 10/5 | 0.732[b] |
| Stone size, mm | 18.5 ± 6.2 | 14.7 ± 5.2 | 0.062[a] |
| Caliceal diverticular location, $n$ | | | 0.368[b] |
| Upper pole | 5 | 6 | |
| Midkidney | 7 | 6 | |
| Lower pole | 9 | 3 | |
| Caliceal diverticular size, mm | 39.1 ± 15.8 | 35.8 ± 12.6 | 0.502[a] |

Values are expressed as mean ± standard deviation or $n$. MPCNL: minimally invasive percutaneous nephrolithotomy; F-URS: flexible ureterorenoscopy.

[a] Mann−Whitney $U$ test.

[b] Fisher's exact test.

modified lithotomy position, and a retrograde 5-F ureteral catheter with open tip was inserted to the target renal pelvis under cystoscopic vision. Urine specimens from the ipsilateral renal pelvis were collected for bacterial culture, and normal saline was perfused simultaneously through a retrograde ureteral catheter to facilitate puncturing. The catheter allowed retrograde instillation of contrast material or methylene blue to easily identify the caliceal diverticular neck. The patient was then turned to a prone position with a pack under the abdomen to minimize lumbar lordosis. According to location of the caliceal diverticulum, the puncture point was selected in the 11th intercostal space or below the 12th rib between the scapular line and the posterior axillary line. Under the guidance of fluoroscopy or ultrasonography, puncture was performed with a 17.5-gauge coaxial needle into the target caliceal diverticulum. A 0.038-inch guidewire was inserted into the diverticulum and a 1.0-cm skin incision was made. The dilatation of the percutaneous tract was performed over the guidewire with a series of dilators from 8-F to 16-F, and a same-sized peel-away sheath was placed as the access port. An 8/9.8-F rigid ureteroscope was inserted to inspect the diverticulum and the stone was fragmented by holmium laser (550-μm optical fiber, 1.0 J × 20 Hz). The fragments were flushed out of the diverticulum through the peel-away sheath using an endoscopic pulsed perfusion pump, or were extracted with forceps. After all stone material was removed, the cavity was inspected to verify that no renal papilla was present. Subsequently, 10 ml of methylene blue-stained saline was gently injected through the ureteral catheter to identify the diverticular neck. A guidewire was inserted into the renal pelvis through the infundibulum. The neck of the diverticulum was incised radially with the holmium laser (550-μm optical fiber, 1.0 J × 10 Hz), avoiding deeper lying pericaliceal vessels in the anteroposterior plane. A ureteral balloon dilator was passed over the guidewire, and the infundibulum was dilated up to 16 F; the diverticular cavity was then fulgurated with high-power holmium laser (2.0 J × 40 Hz) under direct vision. Once the diverticular neck could not be found or traversed with the guidewire, fulguration of the diverticular cavity was performed directly or by creation of a neoinfundibulum into the collecting system as an alternative.[6] In the end, a 6-F double-J stent was inserted in the ureter, and a 14-F nephrostomy tube was passed across the diverticular neck into the collecting system, the balloon of which was injected with 3 ml normal saline and placed in the renal pelvis. Appropriate antibiotics and furosemide were administrated to avoid urinary tract infection and water intoxication during the MPCNL procedure.

*Flexible ureterorenoscopy*

With the patient under spinal or general anesthesia in the lithotomy position, intravenous antibiotics were given. Initially, a semirigid 8/9.8-F ureteroscope was used to place a 0.038-inch hydrophilic guidewire into the renal collecting system. A ureteral access sheath (9.5/11.5-F or 12/14-F) was inserted over the guidewire. When the access sheath could not be advanced in patients with ureteral stricture or tight ureter, a 6-F double-J stent was placed to dilate the ureter and the procedure was performed 2–4 weeks later. An 8-F flexible ureteroscope was then introduced into the sheath for a comprehensive inspection of the renal pelvis. Under the guidance of fluoroscopy, contrast was injected into the collecting system and identification of the diverticular neck was performed. Automatic flow irrigation at a pressure of 100 $mmH_2O$ with a manual pump was used to improve visualization. Once a hydrophilic guidewire had been passed through the infundibulum and coiled in the diverticulum, the infundibulum of the caliceal diverticulum was incised gradually with the holmium laser (200 μm optical fiber, 1.0 J × 10 Hz), and the calculi were pulverized in a worm-eaten pattern with low energy and high frequency (0.8 J × 25 Hz). Subsequently, all stones were fragmented into a gravel size of less than 2 mm and small fragments could be removed with small caliber baskets or washed out of the diverticulum with a perfusion pump. Sustained low-pressure flushing allowed us to optimally visualize renal pelvis and maintain low intrapelvic pressure. No procedure was performed to fulgurate the diverticular cavity. A 6-F double-J stent was placed at the conclusion of the procedure. Stone fragments were sent for analysis to assess composition, and all urine specimens were cultured. The double-J stent would be removed 4 weeks later. Renal ultrasonography (US) or plain abdominal radiography of the kidney, ureter, and bladder was performed at postoperative 48 h to assess stone-free status and location of drainage tubes. The resolution of the caliceal diverticulum was assessed with noncontrast computed tomography (CT) or IVU at 3 months postoperatively.

*Statistical analysis*

Statistical analysis was performed using SPSS 13.0 (SPSS Inc., Chicago, IL, USA). Continuous data were presented as mean ± standard deviation (SD) and categorical data as counts or proportions (%). Categorical variables were analyzed using Chi-squared tests or Fisher's exact tests. If the distribution was normal, statistical analysis of continuous variables was performed using the Student's *t* tests. However, the Mann−Whitney *U* test was used to evaluate continuous variables with a skewed distribution. $P < 0.05$ was considered as statistically significant.

## Results

As indicated in Table 2, the mean operative time was 136.9 ± 22.8 min in the MPCNL group and 117.3 ± 24.3 min in the F-URS group, respectively, showing a significant difference ($P = 0.019$). Similarly, hospital stay was significantly longer in the MPCNL group (9.4 ± 3.1 *vs.* 6.9 ± 2.1 days, $P = 0.010$). For these patients, the stone-free rates after MPCNL and F-URS were 90.5% and 60.0%, respectively, showing a significant difference ($P = 0.046$). Of 8 patients with residual fragments (RF), 2 with significant residual fragments (SIRF) underwent ESWL conservatively as outpatients, and 6 with clinically insignificant residual fragments (CIRF) underwent routine follow-up. Additionally, 71.4% of patients in the MPCNL group and 46.7% in the F-URS group had symptomatic improvement at the 6-month follow-up ($P = 0.175$); however, the rates of complications in the 2 groups were 19.0% and 13.3%, respectively, with no significant difference ($P = 0.650$). Four complications occurred in the MPCNL group. One patient suffered from severe bleeding caused by a delayed post-operative arteriovenous fistula; 1 patient needed to change antibiotic for bacteremia; 2 patients suffered from urine leakage and pneumothorax, respectively. Furthermore, 2 patients had bacteremia or subcapsular hematoma in the F-URS group. No Clavien grade I complications were noted in the 2 groups. All patients had a reduction in diverticular size in both groups. Complete diverticular obliteration was achieved in 16 (76.2%) cases in the MPCNL group and 5 (33.3%) cases in the F-URS group, respectively, showing a significant difference ($P = 0.017$). Stone analyses were similar between the 2 groups; the respective composition distribution of calcium oxalate and hydroxyapatite was 66.7% and 33.3% in the MPCNL group while the composition distribution in the F-URS group was 46.7% and 53.3%, respectively ($P = 0.310$).

Table 2
Comparisons of postoperative clinical data and outcomes.

| Items | MPCNL ($n = 21$) | F-URS ($n = 15$) | *P* |
|---|---|---|---|
| Operative time, min | 136.9 ± 22.8 | 117.3 ± 24.3 | 0.019[a] |
| Hospital stay after surgery, d | 9.4 ± 3.1 | 6.9 ± 2.1 | 0.010[a] |
| Stone-free, *n* (%) | 19 (90.5) | 9 (60.0) | 0.046[b] |
| Symptomatic improvement, *n* (%) | 15 (71.4) | 7 (46.7) | 0.175[b] |
| Complications, *n* (%) | 4 (19.0) | 2 (13.3) | 0.650[b] |
| Clavien grade, *n* | | | 1.000[b] |
| II | 2 | 1 | |
| III | 1 | 1 | |
| IV | 1 | 0 | |
| Diverticular obliteration, *n* (%) | 16 (76.2) | 5 (33.3) | 0.017[b] |
| Stone analysis, *n* (%) | | | 0.310[b] |
| Calcium oxalate | 14 (66.7) | 7 (46.7) | |
| Hydroxyapatite | 7 (33.3) | 8 (53.3) | |

Values are expressed as mean ± standard deviation or *n* (%). MPCNL: minimally invasive percutaneous nephrolithotomy; F-URS: flexible ureterorenoscopy.
[a] Mann−Whitney *U* test.
[b] Fisher's exact test.

## Discussion

The choice of treatment for symptomatic caliceal diverticular calculi is based on the diverticular size and location, the presence or absence of a patent infundibulum, the amount of overlying parenchyma, and the surgeon's experience. ESWL, PCNL, F-URS, and laparoscopy are the 4 principal minimally invasive modalities for treating caliceal diverticular calculi.

Although ESWL is usually the first choice of treatment for caliceal diverticular calculi, a narrow diverticular neck prevents free passage of stone fragments. ESWL can achieve stone-free rates of only 4−20%, and provide symptomatic improvement in 36−70% of patients.[7,8] Since the aims of treatment of caliceal diverticular calculi are the removal of the stone and improvement of drainage or complete control of the diverticulum by obliteration, ESWL as monotherapy for caliceal diverticular calculi is controversial.

Laparoscopic management of symptomatic caliceal diverticula has been reported as a promising and effective technique, with correction of the anatomic abnormality that led to stasis and stone formation. It was recently reported that successful robotic-assisted laparoscopic management of a caliceal diverticular calculus had been performed, showing one more application of this emerging technology.[9] A transperitoneal or retroperitoneal approach may be considered, according to the preference of the surgeon and the location of the diverticula. Nevertheless, its indications are limited; some researchers have reserved use of the laparoscopic technique only for posteriorly located diverticula with a thin, overlying renal parenchyma, and for anterior caliceal diverticula, which are normally difficult to access via the caliceal neck using endoscopic treatment. Therefore, the main minimally invasive modalities for treating caliceal diverticular calculi are F-URS or PCNL. The combination of the 2 methods seems to be preferable for the identification of the diverticular neck in some cases.

With improvement of the actively deflectable F-URS and application of the holmium laser, ureteroscopic approaches for the treatment of caliceal diverticular calculi have become possible. F-URS can produce a high success rate and a long-term symptom-free period, and the results are not affected by the diverticular location. In addition, the F-URS procedure is advantageous with respect to a shorter hospital stay and absence of major complications.[10,11]

PCNL has been reported to be associated with a better stone and symptom-free outcome. However, PCNL can still be associated with significant morbidity, such as severe hemorrhage, injury to surrounding viscera, sepsis, loss of the kidney, or even death. Small tracts may result in fewer injuries to the renal parenchyma. Compared with standard PCNL, MPCNL can decrease the complication rate, preserve renal function and achieve good stone clearance.[12–15] Kontak et al[16] reported the successful treatment of caliceal diverticula without stones using a mini-perc technique, and specifically stated that smaller percutaneous tracts may decrease blood loss, permit excellent visibility, and allow favorable endoscopic maneuverability within the diverticulum. The MPCNL approach, therefore, should be considered a less-invasive alternative to standard percutaneous treatment for caliceal diverticula.

Sophisticated preoperative planning before performing MPCNL is necessary. Preoperative noncontrast-enhanced CT evaluation of patients with caliceal diverticular calculi can help in planning safe percutaneous access to decrease the risk of organ injury. In addition, preoperative three-dimensional CT also has been described as a valuable tool for obtaining percutaneous access.[17] During the MPCNL procedure, once the guidewire has passed into the diverticulum and the infundibulum has been incised with the holmium laser, the perfusion pressure should be lowered, to avoid damage to renal function and redundant absorption of irrigation fluid. If a prolonged operative time causes more fluid to be absorbed, intraoperative administration of diuretics is appropriate, and has also proven effective in preventing intrarenal reflux. If the stenotic infundibulum cannot be traversed with a guidewire or identified, creation of a neoinfundibulum into the collecting system or direct fulguration of the diverticular lining is advisable. However, neoinfundibulotomy cannot be performed when the diverticulum is located anteriorly.

Generally, the major disadvantage of mini-perc technique is longer operative time caused by obscured field visibility and the need for fragmentation of stones into small particles suitable for the small sheath. In our opinion, it is important to select the holmium laser energy for lithotripsy effects and stone-free rates. The holmium laser was set at a low energy level and a high rate to pulverize the calculi in a worm-eaten pattern in our study. The stones were fragmented until they were deemed small enough to be passed easily without steinstrasse. Fragments larger than 2 mm were extracted with forceps to shorten the operative time. The increased operative time in the MPCNL group in our series was mainly caused by fulguration of the diverticular cavity. Several authors have suggested a significant advantage of PCNL over F-URS for caliceal diverticular calculi with regard to stone-free and symptom-free rates, with a slightly increased risk of complications.[3] Our results are similar to those previously reported. A stone-free rate of 90.5% in the MPCNL group was obviously higher than that in the F-URS group, in which only 60.0% were rendered stone-free. Major problems in F-URS were maintaining adequate deflection of the F-URS and identifying a diverticular neck. Although the 200-μm optical fiber allowed full deflection of a flexible ureteroscope, facilitating treatment of often difficult-to-access lower pole caliceal diverticula, the position of lower pole caliceal diverticula with an acute lower pole infundibulopelvic angle affected stone clearance in the F-URS group. The MPCNL group was associated with symptomatic improvement rate similar to that of the F-URS group. We believe that these 2 technologies successfully eliminated urinary stasis and reduced the pressure of the caliceal diverticula by correcting anatomic abnormalities.

Bas et al[11] reported a series of 54 cases of caliceal diverticular stones in which F-URS or PCNL was used to treat caliceal diverticular calculi. The results showed the incidence of Clavien III complications in the PCNL group was markedly higher than that in the F-URS group. Furthermore, F-URS is minimally invasive and has few complications and a shorter hospital stay.[15,18] In our study, there were complications in 4 patients with MPCNL and in 2 with F-URS. No significant difference was observed in the incidence of complications between the 2 groups, which indicates that multicenter studies are needed to assess the associated complication rates accurately. In our series, the severe complication in the

MPCNL group was bleeding caused by a delayed arteriovenous fistula in 1 case, after an uneventful postoperative course of 1 week. The hematuria ended before the scheduled angiography to embolize the fistula. We concluded that a successful mini-perc access established by color Doppler ultrasound-guided puncture reduced the risk of renal vessel injury and improved visibility. Some authors suggest that ultrasound-guided puncture facilitates identification of caliceal diverticula during F-URS, and improves the success rate of F-URS surgery.[19]

Although the need for cavity ablation or destruction is a controversial issue, most authors support the use of fulguration of the diverticulum at the time of PCNL.[20] Hulbert et al[21] reported excellent results without fulguration of a smaller diverticular cavity and suggested that the trauma associated with the percutaneous dilation process will lead to the formation of granulation tissue and subsequent diverticular obliteration. However, fulguration was recommended for large volume diverticula in order to decrease the area of supporting renal parenchyma and allow the cavity to collapse. Some authors reported a success rate of complete diverticular ablation of 86% when the wall was fulgurated, compared to only 50% when it was not. Our results were similar to those previously reported: completely ablated diverticula in 76.2% of patients undergoing fulguration in the MPCNL group compared with 33.3% of patients not undergoing fulguration in the F-URS group.[22] We believe that fulguration of the diverticular lining and allowing the cavity to collapse can maximize the chance of diverticular obliteration. Kim et al[23] described percutaneous diverticular fulguration without cannulation or dilation of the infundibulum. All diverticula had decreased in size and 87.5% had completely resolved at follow-up of 3 months.

In our study, stone analysis of both groups revealed a similar calcium oxalate and hydroxyapatite composition in caliceal diverticular calculi. Most studies reported that metabolic derangements, rather than urinary stasis alone, are major factors contributing to stone formation. Recent studies have shown that all patients in the diverticulum group had at least one metabolic abnormality, including hypercalciuria, hyperuricosuria, hyperoxaluria, and hypocitraturia. Interestingly, the most common abnormality was a low urine volume, suggesting that urinary stasis also promotes stone formation.[24,25] At present, surgical intervention can eliminate urinary stasis and correct anatomic abnormalities. Nevertheless, adequate evaluation is important in the management of metabolic derangements. Evaluation should also be performed in the period before or after surgery in order to guide further treatment.

## Conclusion

In summary, MPCNL is an effective method for the treatment of caliceal diverticular calculi. However, F-URS is an acceptable alternative technique in selected patients with a patent infundibulum, despite lower stone-free rates than with MPCNL. Fulguration of the diverticular lining by using the high-power holmium laser and allowing the cavity to collapse are useful for increasing the chance of diverticular obliteration.

## Conflicts of interest

The authors declare that they have no conflicts of interest.

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