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ORIGINAL PAPER

The role of super-mini percutaneous nephrolithotomy (SMP) in the treatment of symptomatic lower pole renal stones (LPSs) after the failure of shockwave lithotripsy (SWL) or retrograde intrarenal surgery (RIRS)

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Abstract

To assess the safety and efficacy of super-mini percutaneous nephrolithotomy (SMP) in the treatment of symptomatic lower pole renal stones (LPSs) after the failure of shockwave lithotripsy (SWL) or retrograde intrarenal surgery (RIRS), we retrospectively evaluated 44 patients with symptomatic LPSs with previously failed SWL or RIRS and consequently underwent SMP from October 2014 to March 2016. The percutaneous renal access was performed 12–14F with C-arm fluoroscopy or ultrasonographic guidance. Stone disintegration was performed using either Holmium laser or pneumatic lithotripter. Perioperative parameters along with operations were assessed in detail. A total of 44 patients (mean age 49.1 ± 13.7 years) were included in the study. Stone size was 18.4 ± 6.0 mm (range 9–29), operative time was 63.9 ± 32.7 min (range 14–145) and hospital stay was 2.8 ± 1.2 days (range 1–5). The hemoglobin drop was 12.4 ± 8.8 g/L (range 0–31), and no patients required blood transfusion. Complete stone-free status was achieved in 40 (90.9%) patients. Clinically insignificant residual fragments were observed in three (6.8%) patients and only one (2.3%) patient had a 6 mm residual calculus. A total of three minor complications (urinary tract infection, hemorrhage resolved by hemostatics and renal colic requiring analgesics) were observed postoperatively. For symptomatic LPSs after the failure of SWL or RIRS, SMP is a safe and efficient auxiliary option and even might be an alternative to SWL or RIRS, while further considering the stone-free rates and stone-related events.

Keywords Super-mini percutaneous nephrolithotomy · Lower pole renal stones · Shockwave lithotripsy · Retrograde intrarenal surgery

Abbreviations

SMP	Super-mini percutaneous nephrolithotomy
LPSs	Lower pole renal stones
SWL	Shockwave lithotripsy
RIRS	Retrograde intrarenal surgery
CIRF	Clinically insignificant residual fragments
EAU	European Association of Urology
PCNL	Percutaneous nephrolithotomy
SFR	Stone-free rate
KUB	A plain film of the kidney, ureter and bladder.
CT	Computed tomography.
SSD	Skin-to-stone distance

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Introduction

With the advancement of instruments and the accumulation of surgical techniques and experiences, a wide selection of treatment modalities for upper urinary tract stones is recommended by the European Association of Urology (EAU) guidelines. The application of different treatments is categorized depending on stone size, location and pelvicalyceal system anatomy. The anatomical feature of lower pole calyx leads to the uncertain treatment outcomes while compared to other stone locations; so it is still a controversial topic for the treatment of lower pole renal stones (LPSs), especially for those LPSs after failed shockwave lithotripsy (SWL) or retrograde intrarenal surgery (RIRS), the choice of repeated SWL or RIRS treatment, percutaneous nephrolithotomy (PCNL) or other auxiliary treatment is undefined.

Although the noninvasive nature and minimal required anesthesia are the inherent advantages of SWL, the unpredictable stone-free rate (SFR) and higher retreatment rate are its main drawbacks [1, 2]. RIRS is a less invasive procedure performed through natural orifice, but the success rate is restricted by the collecting system anatomy, especially for LPSs [3]. Compared to SWL and RIRS, PCNL is the most invasive endourologic modality with the highest SFR [1, 4]. Each technique has its own indications and limitations. Appropriate treatment modality is particularly important for the best treatment outcomes for LPSs.

The super-mini-PCNL (SMP) is a recent addition to the options for standard and current mini-PCNL; the SMP system was first introduced in 2012. The basic components of SMP are a 7-F miniature nephroscope with enhanced irrigation capability and a modified nephrostomy access sheath with continuous negative pressure suction [5]. The improvements of SMP aimed at keeping the high SFR and decreasing the postoperative complications. We present our experience with SMP in the treatment of patients with LPSs after the failure of SWL or RIRS.

Patients and methods

This study was approved by the Institutional Ethic Committee of First Affiliated Hospital of Guangzhou Medical University.

A total of 44 patients who underwent SMP to treat the symptomatic LPSs after the failure of SWL or RIRS from October 2014 to March 2016 were retrospectively reviewed. All the procedures were performed at a single tertiary unit by a single surgeon who had experienced over 5000 cases of mini-PCNL. Among the study population, 23 and 21 patients had residual LPSs following SWL and RIRS, respectively.

Before surgery, patients were well-informed about the technique, and informed consent was obtained from all patients. All patients underwent preoperative biochemical and radiologic evaluation routinely. Patients with positive preoperative urine culture were treated with appropriate antibiotics according to the antibiogram results and local microbiology protocol at least 72 h preoperatively. All patients with negative urine cultures were treated with a single prophylactic dose of broad-spectrum antibiotics on induction. The stone size and location were assessed by intravenous urography and/or non-contrast CT.

The stone burden was defined as the largest diameter of the largest calculus on plain abdominal radiograph of the kidneys, ureters and bladder (KUB). The summation of the diameters of the stones was recorded in cases with multiple stones. Operative time was recorded from the first percutaneous renal puncture to the completion of stone removal. The duration of hospitalization was rounded to the nearest whole day and calculated from the day of surgery to the day of discharge. SFR was evaluated by KUB or low-dose CT on postoperative day 1, if necessary, at 3 months. No observed fragment was classified as completely stone free. Clinical insignificant residual fragments (CIRF) were defined as asymptomatic fragments smaller than 2 mm without obstruction. The chemical compositions of the stones were analyzed using infrared spectroscopy. The complications were classified according to the Clavien grading system [6].

SMP technique

We have published the detailed procedure of SMP technique previously [5, 7]. Under general anesthesia, a 5F ureteral catheter was inserted into the collecting system in a retrograde fashion in the lithotomy position. The patient was then turned to prone position, percutaneous access was achieved by an 18-guage coaxial needle to puncture the selected calyx under fluoroscopic or ultrasonographic guidance and a 0.035 flexible tip guidewire was inserted into the collecting system. Nephrostomy tract was established using metal dilators (12–14F depending on the stone burden). Corresponding size of suction evacuation sheath was then placed. The sheath was connected to the specimen collection bottle via the oblique branch of a metal connector. A rubber cap, with a center aperture, was placed at the end of the straight proximal of the connector. The miniaturized endoscope was inserted into the sheath through the metal connector. The stone was visualized and lithotripsy was performed using either a holmium–yttrium–aluminium–garnet laser with a laser fiber or pneumatic lithotripter for stone fragmentation. With active and continuous suction, the tiny stone fragments would pass through the space between the scope and the sheath then exit through the oblique sluice. For larger fragments, the scope was slowly withdrawn to the end of the connector to form an unimpeded channel so that the large fragments could pass through the oblique side port. A basket was used for difficult aspirated fragments. The negative pressure could be adjusted by either partially or completely occluding the pressure vent. The main irrigation was delivered into the working channel of the endoscope sheath using a pump.

At the end of procedure, fluoroscopic images were taken to assess stone clearance. ''Totally tubeless'' (no ureteral stent and nephrostomy tube) was placed in cases without residual stone fragment and significant bleeding. A JJ ureteric stent was placed only when there was evidence of pelviureteric junction obstruction, presence of significant pelvicalyceal blood clots after the lithotripsy and presence with significant residual stones. Indications for nephrostomy tube placement included significant residual stone fragments, which would require a second-look procedure and significant pelvicalyceal blood clots or bleeding after the lithotripsy.

Table 1 Demographics and stone characteristics

Characteristics	Value
N	44
Mean age (years) (range)	49.1 ± 13.7 (15–79)
Male/female, *n*	26/18
Laterality, *n* (%)	
Left	25 (56.8)
Right	19 (43.2)
BMI, kg/m^2 (range)	23.8 ± 3.4 (17.2–31.3)
Stone size, mm (range)	18.4 ± 6.0 (9–29)
Stone site, *n* (%)	
Single	39 (88.6)
Multiple	5 (11.4)
Stone density, HU (range)	887.0 ± 293.6 (243–1500)
Failure of SWL, *n* (%)	23 (52.3)
More than one ESWL before SMP, *n* (%)	9 (20.5)
Failure of RIRS, *n* (%)	21 (47.7)
More than one RIRS before SMP, *n* (%)	0
Both ESWL and RIRS before SMP	0

Results

A total of 44 patients with symptomatic LPSs after the failure of SWL or RIRS underwent SMP; 23 and 21 patients had residual LPSs following SWL and RIRS, respectively. Nine patients had more than one ESWL; no patient had more than one RIRS. In the present study, no patient has both ESWL and RIRS prior to SMP. The reasons RIRS failed were listed as follows, unable to find stone due to the changed anatomy of kidney because of open surgery preoperatively, unable to reach stone because of lower pole infundibulopelvic angle and ureteral stricture. Recurring pain was the primary symptom of these patients. The mean age was 49.1 ± 13.7 years (range 15–79). Male/female distribution was 26/18. The mean body mass index was 23.8 ± 3.4 kg/m^2 (range 17.2–31.3). The mean stone size was 18.4 ± 6.0 mm (range 9–29) with a mean stone density value of 887.0 ± 293.6 HU (range 243–1500). The demographic values are summarized in Table 1.

In the present study, the timing of patients underwent SMP relative to the prior procedure is 3 months–2 years. All patients were treated with a single-access tract, 8 of the 44 were 12F, while the remaining 36 patients were 14F. The operative time was 63.9 ± 32.7 min (range 14–145). The hospital stay was 2.8 ± 1.2 days (range 1–5). The hemoglobin drop was 12.4 ± 8.8 g/L (range 0–31). 31 of the 44 patients (70.5%) did not require any kind of upper tract drainage catheter (total tubeless). Among the remaining patients who did require catheters, 7 (15.9%) had JJ ureteric stent for 2–4 weeks; 3 (6.8%) had ureteric catheter for 1 day and 1 (2.3%) had nephrostomy tube placed. There were two patients that (4.5%) required both JJ stents and nephrostomy tube.

Among the 44 patients, 40 (90.9%) were completely stone free, three (6.8%) patients had CIRF and only one (2.3%) patient had a 6 mm residual calculus. The four cases with residual fragments were asymptomatic and chosen to be followed expectantly. Postoperative fever (> 38 °C) occurred in two patients (4.6%), one patient resolved by antipyretics (Clavien grade I), while another one required additional i.v. antibiotic management (Clavien grade II). One patient suffered postoperative severe hemorrhage and was resolved by hemostatics without further intervention (Clavien grade II). Analgesics were necessitated in three patients (6.8%) with renal colic (Clavien grade I). No other complications beyond grade III were noted. The perioperative parameters are listed in Table 2.

Stone composition analysis was available in all patients. Stone composition was calcium oxalate (77.2%), uric acid (9.1%), carbonate apatite (2.3%) and magnesium ammonium phosphate (11.4%) (Table 2).

All the patients had KUB postoperatively; seven patients who had negative stones or suspicious residual stones had non-contrast CT postoperatively. The completely stone-free rates were the same (Table 3).

Discussion

The optimal treatment of symptomatic LPSs is one of the controversial topics in endourology nowadays. Treatment modalities consist of SWL, RIRS and PCNL, which can be used for selected patients according to the stone sizes

Table 2 Perioperative variables

Characteristics	Value
Operative time, minutes (range)	63.9 ± 32.7 (14–145)
Duration of hospitalization, days (range)	2.8 ± 1.2 (1–5)
Hemoglobin drop, g/L (range)	12.4 ± 8.8 (0–31)
SFR, *n* (%)	
Completely stone free	40 (90.9)
CIRF	3 (6.8)
Rest	1 (2.3)
Complications, *n* (%)	
Fever (> 38 °C)	
Clavien grade I	1 (2.3)
Clavien grade II	1 (2.3)
Hemorrhage requiring hemostatics (Clavien grade II)	1 (2.3)
Postoperative pain (Clavien grade I)	3 (6.8)
Access sheath size, 12F/14F	
F 12, *n* (%)	8 (18.2)
F 14, *n* (%)	36 (81.8)
Tubeless, *n* (%)	41 (93.2)
Nephrostomy tube	3 (6.8)
JJ stent only	7 (15.9)
Ureteric catheter only	3 (6.8)
Total tubeless rate only	31 (70.5)
Stone composition, *n* (%)	
Calcium oxalate	34 (77.2)
Uric acid	4 (9.1)
Magnesium ammonium phosphate	5 (11.4)
Carbonate apatite	1 (2.3)

Table 3 Postoperative variables of SFR

Characteristics	Value	Completely SFR
Postoperative KUB, *n* (%)	44 (100)	40 (90.9)
Postoperative CT, *n* (%)	7 (15.9)	40 (90.9)

and local anatomic factors. Many comparative studies have been performed to find the appropriate treatment modality for LPSs with the highest SFR and least complications [1, 8]. In this study, we aimed to explicate the role of SMP as an advanced form of PCNL in the treatment of symptomatic LPSs after the failure of SWL or RIRS.

Because of its noninvasive nature, SWL is recommended as the initial treatment for patients with renal stone smaller than 2 cm [9]. However, the success rates of SWL are greatly influenced by stone- and anatomy-related factors including stone size, location, composition, pelvicalyceal system anatomy and skin-to-stone distance (SSD) [1, 10]. Stone size was inversely associated with SFR [11]. Stones which were composed of calcium oxalate monohydrate, brushite and cystine were more resistant to SWL than calcium oxalate dihydrate, uric acid and struvite [12]. Furthermore, SWL for LPSs particularly reported lower SFR compared to other renal location, especially with the following listed anatomic factors such as steep infundibulopelvic angle, length of lower pole infundibulum (> 10 mm) and infundibular width (< 5 mm) [9]. These factors do not represent limitations for SMP; the access tract is established to stone location directly and stone disintegration is performed by laser or pneumatic lithotripter under direct vision regardless of stone components, density and SSD [5].

Previous studies have demonstrated the unsatisfactory clearance rates of SWL for LPSs only ranging from 35 to 62% [1, 13, 14], and a significantly lower SFR was reported while compared with PCNL (37 vs. 95%) [2]. In our study, the SFR of SMP was 97.7%, even completely SFR was achieved satisfactory 90.9%. The superiority of SWL over SMP is the feasibility without general anesthesia, but if we consider the higher auxiliary or repeat treatment rates of SWL, the requirement of general anesthesia may be an acceptable limitation for SMP.

With the improvement of miniaturization equipments, RIRS has become a popular option for the treatment of urinary tract stones and the indications for RIRS have been concomitantly eased, stones up to 3 cm can be treated effectively by RIRS, although sometimes staged procedures are required [9]. The clearance rate of LPSs after RIRS was uncertain and previous studies reported success rates from 37 to 89% [8, 10, 15, 16]. A prospective trial randomized patients with LPSs between 1 and 2.5 cm to RIRS or PCNL showing that SFR was significantly higher in patients undergoing PCNL than RIRS (71 versus 37%, $P < 0.05$) [16]. PCNL is an alternative modality for inaccessible calices in RIRS; SMP further provides smaller, safer access and more exhaustive stone disintegration under direct vision [5].

PCNL is an invasive and technique-demanded procedure with both higher success and complication rates than SWL and RIRS [1, 4]. One of the most worrisome complications of PCNL is bleeding, which tends to be associated with the size of tract [17]. SMP system is invented to better balance high stone clearance with minimal morbidity for the patients. In this study, most of the patients (81.8%) were treated with 14F access sheath, while the remaining (18.2%) underwent SMP with 12F sheath. The mean hemoglobin drop was 12.4 g/L, and none of the patients required transfusion. The SMP system was initially invented and performed by Guohua Zeng and colleagues [5] in 146 patients with renal calculi with a mean size of 2.2 ± 0.6 cm (range 0.7–5.1). Although the applicability of SMP has been reported, our study is the first study focus on the role of SMP in the treatment on LPSs after the failure of SWL and RIRS.

In the present study, SMP was successfully performed in 44 patients after the failed RIRS and SWL. In SWL and RIRS, the stone fragments are left in situ for spontaneous passage, so different auxiliary treatment modalities, such as patient inversion, mechanical percussion and forced diuresis, might be needed to improve the clearance rate after the procedure [18]. Conversely, in SMP, stone fragments are actively removed by 12F- or 14F-modified suction sheath with continuous negative pressure aspiration. A few earlier studies reported that even tiny residual fragments were a significantly higher risk to homolateral stone-related events (pain, urinary tract infection and acute urinary obstruction); these events lead to symptoms, healthcare cost and decreased quality of life. So we deeply believe that current treatments for renal stones should aim for complete stone clearance [19, 20]. In the present study, complete SFR was achieved in 40 (90.9%) patients and 3 (6.8%) patients had CIRF. The failure of the remaining one patient accounted for the movement of the fragment to the other inaccessible calices. Compared with aforementioned studies, we think that SMP may be more suitable for LPSs because of the higher SFR and less stone-related events.

The retrospective nature and small number cases of the present study constitute the primary limitations. Despite the limitations, we believe that our study will contribute to the literature. Prospective randomized comparative studies are needed to make a consensus about the best treatment modality for LPSs.

Conclusion

Our results reveal that SMP is a feasible and efficient treatment modality. When SWL or RIRS fails in patients with symptomatic LPSs, SMP is a good auxiliary option. Furthermore, in view of its high SFR and low complication rate, SMP should also be considered as a valid initial option in LPSs patients.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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