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Suctioning versus traditional minimally invasive percutaneous nephrolithotomy to treat renal staghorn calculi: A case-matched comparative study

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ABSTRACT

Background: Staghorn calculi remain a treatment challenge for urologists. The aim of the study was to compare the treatment outcomes of suctioning minimally invasive percutaneous nephrolithotomy (MPCNL) and traditional MPCNL for renal staghorn stones.

Materials and methods: Between April 2018 and June 2019, we included patients suffering from renal staghorn stones who were treated with modified MPCNL with a suctioning system. The outcomes of these patients were compared with those of a cohort of patients undergoing traditional MPCNL (between January 2017 and March 2018) using a 1:1 scenario matched-pair analysis. Cases were matched sequentially according to stone burden, stone branches, and stone hardness as well as age and sex.

Results: A total of 512 patients were included in this study (256 patients in each group). The baseline characteristics were equally distributed between the two groups. The suctioning MPCNL group achieved a significantly higher stone-free rate (SFR) (78.5% vs 69.1%; $P = 0.016$) after a single procedure and had a significantly shorter operative time (106.2 ± 18.4 vs. 132.1 ± 22.2 min; $P < 0.001$) than the traditional MPCNL group. The traditional MPCNL group experienced a significantly higher rate of overall complications than the suctioning MPCNL group (27.3% vs. 16.8%; $P = 0.004$). Regarding individual complications, a significantly higher rate of fever (13.7% vs. 7.4%; $P = 0.021$) and urosepsis requiring only additional antibiotics (8.2% vs. 3.5%; $P = 0.024$) was observed in the traditional MPCNL group than in the suctioning MPCNL group; there was a trend that the suctioning MPCNL group conferred a decreased risk of urosepsis shock (1.2% vs. 2.3%), but this trend failed to achieve statistical significance ($P = 0.313$). There was no significant difference between the two groups regarding the incidence of severe hemorrhage, the mean number of tracts used during a single procedure and the postoperative hospital stay.

Conclusions: The use of suctioning MPCNL for staghorn calculi had advantages over the use of traditional MPCNL in terms of a higher SFR after a single procedure and fewer postoperative infectious complications. Further well-designed studies are needed to confirm the results.

1. Introduction

Staghorn calculi are large stones with multiple branches occupying part or all of the renal pelvis and renal calyces, and they account for 10–20% of all urinary stones [1]. Owing to effective management, the incidence of staghorn calculi is currently reduced in developed countries, but staghorn calculi are still common urological diseases in developing countries such as China [2]. If managed conservatively, staghorn calculi would deteriorate kidney function and cause life-threatening urosepsis [3].

Percutaneous nephrolithotomy (PCNL) has been recommended as the first-line choice for renal stones more than 2 cm in diameter [4]. However, standard PCNL and minimally invasive percutaneous nephrolithotomy (MPCNL) have advantages and disadvantages in terms of the treatment of staghorn calculi [5]. A recent comparative study showed that the stone-free rate (SFR) was lower with MPCNL than with standard PCNL (89.9% vs. 96%), whereas postoperative complications were significantly higher with standard PCNL than with MPCNL (20.5% vs. 7.9%) for renal stones, and the significant differences were associated with the presence of multiple stones and > 2-cm stones [6].

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Additionally, previous studies reported that standard PCNL was associated with an increased risk of serious treatment morbidity, such as severe bleeding with the need for embolization and even kidney loss due to the thick renal parenchyma typical of patients with staghorn calculi [7]. MPCNL had the advantages of less bleeding, but the system cleared stone fragments away high-pressure perfusion, thus increasing the risk of urosepsis secondary to the absorption of bacterial endotoxins and stone-colonizing bacteria under high-pressure irrigation [8,9], and the long lithotripsy time may also contribute to urosepsis risk [10,11].

To manage the challenges between mini-invasions to reduce serious bleeding and enough sheath tract size to maintain a safe intrarenal pressure, a modified sheath with a suctioning system may discard the drawbacks of both MPCNL and standard PCNL but may adopt their advantages. Previous case series have reported that suctioning MPCNL for staghorn calculi has the advantages of improving the SFR after one session and reducing intrapelvic pressure [2]. Additionally, suctioning MPCNL has been reported to be safe and efficient for treating renal stones in patients with a urinary tract infection (UTI) [12]. Despite the potential benefits of suctioning PCNL in urological clinical practice, few well-designed studies with a control group have been performed to compare suctioning MPCNL and traditional MPCNL for the treatment of staghorn calculi. Therefore, the current case-matched comparative study was performed to evaluate suctioning MPCNL compared to traditional MPCNL on the basis of safety and feasibility.

2. Materials and methods

2.1. Patients

From April 2018, when suctioning MPCNL was introduced, to June 2019, 982 consecutive patients were treated with suctioning MPCNL in our institution, and the data from patients with renal staghorn stones undergoing suctioning MPCNL were retrospectively identified. The inclusion criteria were as follows: (1) the calculi were located in the renal pelvis with branches reaching at least 2 calyces; and (2) patient age ≥ 18 years old. The following patients were excluded from the study: (1) patients in whom lithotripsy was aborted because of pyonephrosis found in the renal collecting system; (2) patients with anomalous kidneys or a history of open interventions in the ipsilateral kidney; and (3) patients undergoing bilateral MPCNL or MPCNL simultaneously combined with other surgery. Afterwards, we selected patients with renal staghorn calculi from 1274 consecutive patients who successfully received traditional MPCNL between January 2017 and March 2018 to serve as the control group. The traditional MPCNL group was retrospectively matched to the suctioning MPCNL group at a 1:1 ratio with respect to stone burden, stone branches, and stone hardness as well as age and sex in sequential order.

All patients routinely received a plain X-ray of the kidney-ureter-bladder (KUB) and an abdominal noncontrast computed tomography (CT) scan preoperatively. Further routine preoperative assessments included baseline serum parameters and cultures of clean-catch midstream urine specimens. Appropriate antibiotics were administered preoperatively according to the antibiotic susceptibility tests for patients with positive urine cultures, and well-controlled UTIs were confirmed by urine culture or urinary microscopy prior to endoscopic interventions. Intraoperative prophylactic antibiotics were administered for all patients for at least 3 days postoperatively.

All procedures were conducted in accordance with the Declaration of Helsinki, and the study was approved by the Local Ethics Committee. Due to the retrospective nature and the lack of identified individual information, the need for informed consent was waived. The current study was reported in line with the STROCSS criteria [13].

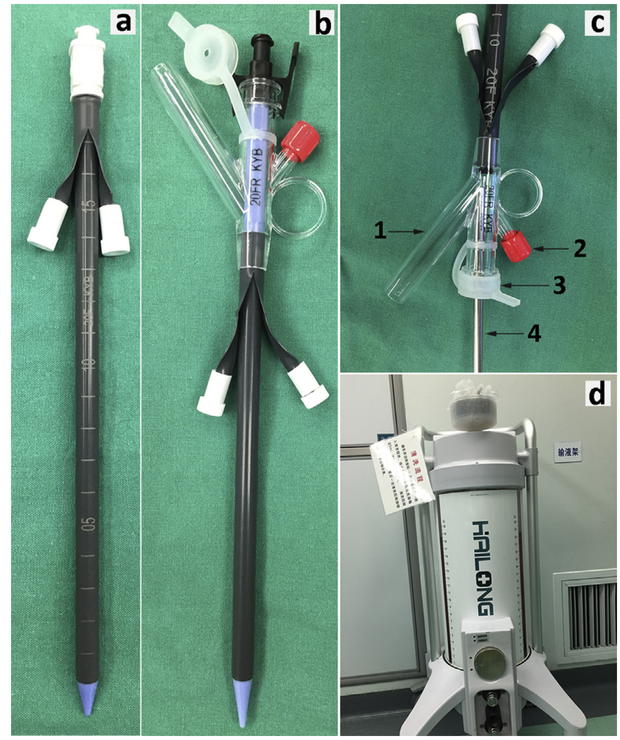

Fig. 1. (a) A traditional 20Fr peel-away sheath. (b) A suctioning 20Fr peel-away sheath. (c) Tail of the suctioning sheath: 1- a side channel for vacuum suction; 2- a side channel covered by a red cap was used as an air valve to regulate the pressure of the suctioning system; 3- elastic rubber cap with a hole; 4- a 12Fr nephroscope. (d) The vacuum device. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

2.2. Surgical technique

2.2.1. Traditional MPCNL group

After the induction of general anesthesia, the patient was placed in the lithotomy position. A 4F ureteral catheter was inserted into the renal pelvis under direct vision of a 9.8 Fr semirigid ureteroscope (Karl Storz, Germany). Then, the patient was turned to achieve the prone position. Under the guidance of sonography, an 18 gauge puncture needle (Kang Yi Bo, China) was placed into the appropriate calix, and a safe guidewire (Kang Yi Bo, China) was inserted. With the guidance of the guidewire, the percutaneous track was formed using serial fascial dilators until a 20F peel-away sheath (Kang Yi Bo, China; Fig. 1a) was secured in the tract. Then, the perfusion flow was set to 400–600 mL/min (30–40 cmH_2O). With the direction view of a 12Fr nephroscope (Karl Storz, Germany), lithotripsy was performed using a holmium:yttrium-aluminum-garnet laser (Ho:YAG) with a 400-μm fiber at an energy level of 50–60 W and a frequency level of 16–24 Hz. Stone fragments were washed away with the help of saline perfusion.

2.2.2. Suctioning MPCNL group

The suctioning system included a modified peel-away sheath (Fig. 1b) and a negative vacuum aspiration machine (Fig. 1d). On the tail end of the modified sheath (Fig. 1c), a side channel was designed to achieve a suctioning effect via connection with the suction device, and another side channel covered by a red adjusting cap was used as an air valve to manually regulate the negative pressure of the suctioning system. Additionally, on the tail end of the sheath, an elastic rubber cap with a hole through which the nephroscope passed was designed to achieve an airproof system during the PCNL procedure.

The anesthesia method, the patient's position and the establishment of a percutaneous track were in accordance with the traditional MPCNL

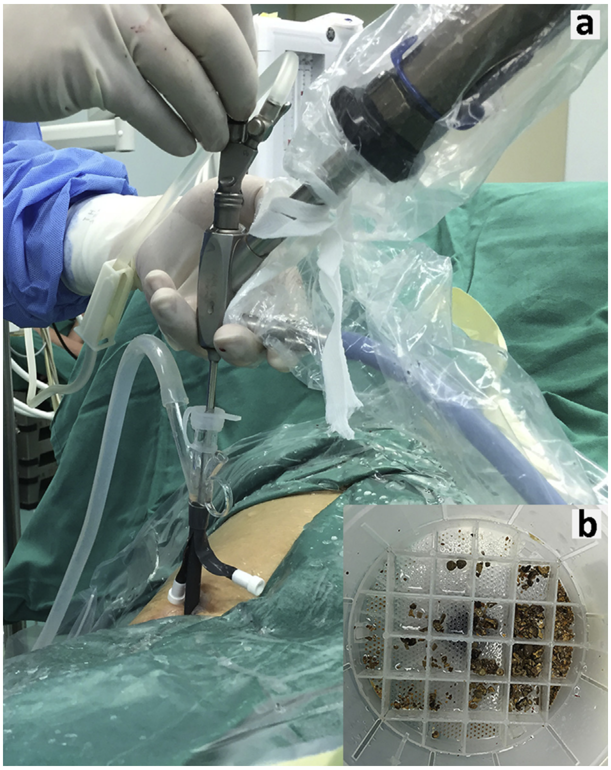

Fig. 2. (a) Application of the suctioning peel-away sheath during percutaneous nephrolithotomy. (b) Stone fragments sucked out by the suctioning system.

group. After a 20F-modified peel-away sheath (Kang Yi Bo, China) was successfully fixed in the targeted tract, a 12Fr nephroscope (Karl Storz, Germany) was passed through the work channel, and a side suction channel was connected to the vacuum device (HAILONG, China) (Fig. 2a). The perfusion flow and the suctioning pressure were then set at 600–800 mL/min (30 cmH_2O) and 10–20 KPa, respectively, to maintain an intrarenal pressure of less than 20 cmH_2O. The negative pressure of the suctioning system was dynamically controlled by manually regulating the air valve on the tail of the suctioning sheath. Stones were fragmented with Ho:YAG, and the settings were consistent with those of the traditional MPCNL group. Small fragments were mainly aspirated by the suctioning system during lithotripsy; the nephroscope was backed up to the tail of the sheath to facilitate aspiration of the debris larger than the gap between the nephroscope and the sheath but smaller than the caliber of the sheath (Fig. 2b).

In both groups, if pyonephrosis was found in the collecting system intraoperatively, first-stage lithotripsy was replaced with simple nephrostomy drainage. If multiple nephrostomy tracts were necessary, the same procedure was performed for each of the tracts. After confirming the clearance of calculi inside the upper ureter, renal pelvis, and accessible renal calices, a 6F double-J stent (KYB, China) was routinely placed, and the front end of a 16F Foley catheter was placed in the collecting system as a nephrostomy tube. The operative time was calculated from the time of insertion of the ureteroscope for placing a ureteral catheter to the successful placement of the nephrostomy tube.

MPCNL procedures in both groups were performed by 3 experienced surgeons. All patients routinely received KUB or noncontrast CT examination if necessary 3–5 days postoperatively. The nephrostomy tube was removed later if a second PCNL was not needed and if no symptoms of flank pain or fever were observed. At 1 month postoperatively, KUB or noncontrast CT examination if necessary was performed to confirm whether a complementary procedure was needed, and the DJ stent was removed under local anesthesia in the outpatient clinic.

2.3. Data collection

The epidemiological and clinical data (age, sex, body mass index (BMI), hydronephrosis, solitary kidney, comorbidities, the American Anesthesiology Association (ASA) scores, characteristics of the calculi (stone burden, stone hardness (measured in Hounsfield units, HU), and stone composition), SFR for one session, intraoperative and postoperative complications, operative time, the length of postoperative hospital stay and other clinical data were identified.

The degree of hydronephrosis was assessed according to the Society of Fetal Urology grading system [14]. Intraoperative and postoperative complications were evaluated according to the Clavien system classification [15]; septic shock was defined according to the third international consensus definitions for sepsis and septic shock (Sepsis-3) [16]. Stone burden was calculated by the formula ($0.785 \times length_{max} \times width_{max}$) according to CROES [17]; the burden of multiple stones was calculated by summing the burden of each stone. The stone-free status was defined as no radiological residue fragments > 3 mm. Additionally, medical images of all patients were read by one radiologist and one urologist independently to measure the stone burden determined by CT and to assess the postoperative stone-free status determined by CT or KUB; if a discrepancy was found, it was resolved by consulting a third author.

2.4. Statistical methods

Chi-squared or Fisher's exact tests, as appropriate, were used to analyze the proportions of categorical variables; Student's t-test was used to analyze numerical variables with normal distribution. A two-sided p value less than or equal to 0.05 was considered statistically significant. Statistical analysis was performed using the Statistical Package for the Social Sciences 22.0 (SPSS for Windows, Chicago, IL, USA).

3. Results

A total of 512 patients were included in this study (256 patients in each group). The baseline characteristics of the patients, as well as the characteristics of the calculi, were comparable in both groups (Table 1). Additionally, the constituent ratio of patients treated by the 3 surgeons was similar (P = 0.184) between the suctioning MPCNL group (number of cases: 112, 55, and 89) and the traditional MPCNL group (number of cases: 101, 73, and 82).

After a single procedure in both groups, patients in the traditional MPCNL group (169/256; 66.0%) and patients in the suctioning MPCNL group (188/256; 73.4%) received CT (P = 0.068), and the remaining patients in both groups received KUB. The SFR of the suctioning MPCNL group (201/256; 78.5%) was superior to that of the traditional MPCNL group (177/256; 69.1%; P = 0.016). Additionally, regarding those patients with residual stones, 34 patients (34/55; 61.8%) and 61 patients (61/79; 77.2%) received complementary lithotripsy in the suctioning and traditional MPCNL groups, respectively (P = 0.054), and the remaining patients in both groups received conservative treatment.

The traditional MPCNL group experienced a significantly higher rate of overall complications than the suctioning MPCNL group (27.3% vs. 16.8%; P = 0.004). The traditional MPCNL group was associated with a higher incidence of fever (13.7% vs. 7.4%; P = 0.021) and urosepsis requiring only additional antibiotics (8.2% vs. 3.5%; P = 0.024) than the suctioning MPCNL group. Additionally, the traditional MPCNL group experienced a higher rate of septic shock than the suctioning MPCNL group (2.3% vs. 1.2%; P = 0.313), but it did not reach statistical significance. No significant difference was noted between the two groups in terms of severe hemorrhage requiring blood transfusion (P = 0.559) or angioembolization treatment (P = 1.0). Prolonged urine leakage was observed in 1 (0.4%) and 1 (0.4%) patients in the traditional and suctioning MPCNL groups, respectively (P = 1.0), and this

Table 1
Baseline characteristics of the included patients.

Parameters	Suctioning MPCNL (256)	Traditional MPCNL (256)	P value
Age (years), mean ± SD	56.8 ± 15.2	55.2 ± 14.1	0.206
Sex (male/female)	159/97	159/97	–
BMI (kg/m^2), mean ± SD	24.6 ± 4.7	24.2 ± 3.5	0.346
ASA score, mean ± SD	1.60 ± 0.74	1.51 ± 0.69	0.122
Positive urine culture, n (%)	71 (27.7%)	62 (24.2%)	0.364
Solitary kidney, n (%)	19 (7.4%)	26 (10.2%)	0.275
Stone characteristics			
Stone laterality (L/R), n	119/136	130/126	0.331
Complete staghorn calculi[a], n (%)	97 (37.9%)	95 (37.1%)	0.855
Stone burden (mm^2), mean ± SD	1523 ± 667	1487 ± 632	0.468
Stone hardness (HU), mean ± SD	1163 ± 236	1133 ± 243	0.159
Degree of hydronephrosis, n, %			0.385
None or mild	184 (71.9%)	175 (68.4%)	
Moderate or severe	72 (28.1%)	81 (31.6%)	
Comorbidities, n (%)			0.571
Diabetes mellitus	32 (12.5%)	37 (14.5%)	
Hypertension	65 (25.4%)	55 (21.5%)	
Renal insufficiency	17 (6.6%)	13 (5.1%)	

[a] Complete staghorn calculi were defined as calculi with ≥5 branches. ASA = American Society of Anesthesiologists; BMI = body mass index; HU = Hounsfield unit; MPCNL = minimally invasive percutaneous nephrolithotomy; SD = standard deviation.

leakage was managed by removing and re-siting the DJ stent. One patient in the suctioning MPCNL group (0.4%) developed chest tightness 2 days after surgery, which was diagnosed as mild bilateral hydrothorax according to a chest X-ray, and it was successfully managed with conservative treatment. In both groups, no patients experienced other complications, such as acute renal failure or intestinal injury.

The operative time was significantly shorter in the suctioning MPCNL group (106.2 ± 18.4 min) than in the traditional MPCNL group (132.1 ± 22.2 min; $p < 0.001$). There was no significant difference between the two groups regarding the mean number of tracts used during a single procedure (P = 0.083) or the postoperative hospital stay (p = 0.346).

Although stone analysis data were not obtained for all patients, no difference was noted in the type of calculi between the two groups (P = 0.756). The details of the perioperative and postoperative outcomes are listed in Table 2.

4. Discussion

Staghorn calculi remain a treatment challenge for urologists, especially in patients with complete staghorn stones. Achieving a complete stone removal state necessitates multiple percutaneous tracts and/or multiple sessions and a long lithotripsy duration [18,19], which may result in hemorrhage requiring transfusion and even embolization secondary to standard PCNL procedures [20] as well as postoperative fever or even life-threatening urosepsis secondary to MPCNL procedures [10]. In recent years, MPCNL with the use of a suctioning system was applied at our institution in the hope of reducing infection-related complications secondary to high intrarenal pressure and increasing the SFR after a single procedure.

In the current study, the suctioning MPCNL group achieved a significantly higher SFR (78.5%) than the traditional MPCNL group (69.1%). The satisfactory SFR was also superior to that of the traditional MPCNL group (58.82%) for staghorn calculi reported by a different study [21], although there may be inconsistent baseline characteristics among different studies. Similarly, a case series reported a 16–18 Fr pressure-measuring suctioning sheath during MPCNL for 60 patients with staghorn calculi, and it provided a satisfactory SFR (76.7%; 46/60) after one session [2]. The primary reasons for the improved SFR with the use of the suctioning system may be as follows. First, the suctioning system can aspirate small fragments directly during lithotripsy, allowing breakage of the stones and clearing fragments simultaneously; it was effective to aspirate the fragments smaller than the caliber of the sheath when the nephroscope was backed up to the tail of the sheath. Thus, the suctioning system can relieve us from repeated manual removal of fragments with perfusion and/or pliers. Moreover, with the help of vacuum aspiration, suctioning PCNL provides a clear surgical vision by immobilizing stones in the renal pelvis and calyces under high flow perfusion without increasing the irrigation pressure. Therefore, suctioning MPCNL had the advantages of high lithotripsy efficiency and a short operative time, thus leading to an improved SFR after one session (Fig. 3) since large staghorn stones always necessitate multiple sessions largely due to limiting the lithotripsy time at a given session to approximately 90–120 min [5]. Compared to the SFR (64.8%–73.4%) achieved by standard PCNL for staghorn calculi [8,10], the SFR with suctioning MPCNL is also slightly higher, which may be attributed to the fact that the small nephroscope and tract can successfully enter narrowed renal calyces and that it is also easy to

Table 2
Treatment outcomes of the suctioning MPCNL group and the traditional MPCNL group.

Parameters	Suctioning MPCNL	Traditional MPCNL	P value
SFR after one session, n (%)	201/256 (78.5%)	177/256 (69.1%)	0.016
Complementary lithotripsy, n (%)	34/55(61.8%)	61/79 (77.2%)	0.054
Total complications[a], Clavien grade classification, n (%)	43/256 (16.8%)	70/256(27.3%)	0.004
Fever (> 38 °C) (G I)	19/256(7.4%)	35/256 (13.7%)	0.021
Urosepsis requiring only additional antibiotics (G II)	9/256(3.5%)	21/256 (8.2%)	0.024
Blood transfusion (G II)	7/256 (2.7%)	5/256(2.0%)	0.559
Hydrothorax (G II)	1/256(0.4%)	0/256	1.0
Prolonged urine leakage (G III)	1/256(0.4%)	1/256(0.4%)	1.0
Selective angioembolization (G III)	3/256 (1.2%)	2/256(0.8%)	1.0
Septic shock (G IV)	3/256(1.2%)	6/256 (2.3%)	0.313
Operative time (min), mean ± SD	106.2 ± 18.4	132.1 ± 22.2	< 0.001
Number of tracts, mean ± SD (range)	2.28 ± 0.95(1–4)	2.16 ± 0.84(1–4)	0.083
Postoperative hospitalization duration (days), mean ± SD	4.32 ± 1.47	4.43 ± 1.53	0.346
Stone composition[b], n (%)			0.756
Calcium-based	151/249(60.7%)	154/238 (64.7%)	
Uric acid	31/249(12.4%)	28/238 (11.8%)	
Struvite	27/249(10.8%)	20/238 (8.4%)	
Mixed	40/249(16.1%)	36/238 (15.1%)	

[a] Some patients had simultaneous complications.
[b] Not all patients received analysis of the calculi. G = grade; SD = standard deviation.

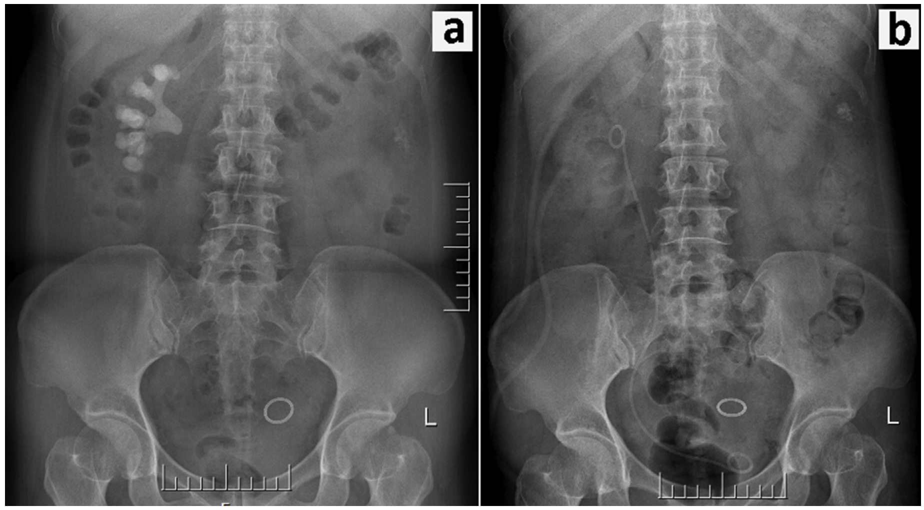

Fig. 3. (a) Preoperative KUB (a plain X-ray of the kidney-ureter-bladder) of a patient with 8.5-cm staghorn renal calculi in the right panel. (b) Postoperative KUB for the patient after 120 min suctioning MPCNL using two 20Fr percutaneous tracts.

completely remove debris and rubble in calyces with a narrow neck.

MPCNL usually requires high-pressure irrigation to push out fragments, leading to increased renal pelvic pressure [22]. Zhong et al. reported that a steady intrarenal pressure of ≥20 mmHg was associated with an increased risk of urosepsis secondary to endoscopic interventions, and most patients (83.75%; 67/80) undergoing MPCNL experienced an increased renal pelvic pressure of ≥30 mm Hg [23]. Patients with staghorn stones are more likely to have a pre-existent urinary tract infection [24] combined with the heavy burden [11]; thus, such patients undergoing MPCNL have a relatively high risk of postoperative infectious complications, which has been reported to be higher than 24% [8]. Therefore, it is always a challenge for urologists to reduce postoperative complications without compromising the SFR for staghorn calculi.

The current study showed that suctioning MPCNL for staghorn calculi had advantage over traditional MPCNL of reducing urosepsis and requiring only additional antibiotics. Although no significant difference was observed in urosepsis shock between the two groups, which may be largely due to the limited number of patients, there was a trend that the suctioning MPCNL group conferred a decreased risk of urosepsis shock. Similarly, Yang and coworkers applied the use of a pressure-measuring suctioning sheath in MPCNL (16–18 Fr tracts) for 60 patients with staghorn calculi [2]; renal pelvic pressure was successfully maintained at less than 2 mm Hg, and only 3 patients (5.0%) developed postoperative fever requiring only additional antibiotics; no cases of serious sepsis were observed. Moreover, Huang et al. conducted a prospective randomized study to compare MPCNL with and without a suctioning system for renal stones complicated by UTI with one surgery and found that suctioning MPCNL (16Fr) experienced a significantly lower rate of postoperative fever (11.4%(10/88) vs. 37.3%(25/67)) [25]. Xu et al. also reported a single-center experience with a suctioning MPCNL technique (20Fr) to treat renal stones in patients with UTI; they concluded that patients with UTI benefited from the modified MPCNL technique by significantly reducing postoperative infectious complications (4.9% (21/422) vs. 28.4% (27/95)) [12]. In addition to the attenuated intrarenal pressure by vacuum aspiration [2,26], a shorter operative time in the suctioning MPCNL group conferred a lower risk of infectious complications since operative time was considered an independent risk factor for developing postoperative fever or urosepsis [11,27].

In addition to infectious complications, the incidence of severe hemorrhage requiring transfusion or embolization is also a crucial parameter when assessing the safety of PCNL. The patients in the suctioning and traditional groups experienced a similar mean number of percutaneous tracts and a comparable rate of transfusion and embolization in the current study. Compared to the use of standard PCNL for staghorn calculi reported by other studies [8,10], both groups experienced a relatively lower incidence of severe hemorrhage, as expected. Therefore, combined with the results of previous similar studies [2,12,25], our results show that MPCNL with the aid of a suctioning sheath for staghorn calculi can effectively reduce postoperative infectious complications without increasing other complications.

We have to acknowledge certain limitations of the current study. First, the current matched-pair study was a retrospective design and was performed at a single center; even though the matching parameters were equally distributed in both groups, we could not eliminate the potential selection bias. Second, the matching parameters did not include the surgeon; the surgeon preference may have an influence on the results despite the similar constituent ratios of patients treated by the 3 surgeons between the two groups. Third, while all surgeons had over 10 years of experience with MPCNL, the suction group involved surgeries that occurred later in the authors' years of experience, which may impact the results. Fourth, considering the cost efficiency, we did not measure the real-time intrarenal pressure in every patient, even though previous studies revealed that the suctioning system could effectively reduce intrarenal pressure [2,26]. Last, KUB is inferior to CT for evaluating the stone clearance state, but the SFR was not assessed by noncontrast CT in all patients due to the preferences of individual patients. Considering the limitations mentioned above, future prospective randomized studies with large case sizes are required to confirm the current results.

5. Conclusions

The current study demonstrated that suctioning MPCNL for staghorn calculi had advantages over traditional MPCNL of improving the lithotripsy efficiency to enhance the SFR after a single procedure and reducing intrarenal pressure to attenuate postoperative infectious complications; thus, the modified MPCNL technique was safe and efficient for managing staghorn calculi. Nevertheless, further well-designed studies are still needed due to the retrospective observational nature of our study.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Data statement

Data will be made available on request. If required, the corresponding author can be contacted.

Ethical approval

The study was approved by the Xiangya Hospital of Central South University Ethics Committee (proof number: 201904097).

Declaration of interest

The authors declare that they have no conflict of interest.

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CRediT authorship contribution statement

Zewu Zhu: Conceptualization, Visualization, Methodology, Writing - original draft. **Yu Cui:** Validation, Data curation, Investigation. **Huimin Zeng:** Investigation, Resources. **Yongchao Li:** Investigation, Resources. **Cheng He:** Investigation, Resources. **Jinbo Chen:** Writing - review & editing. **Feng Zeng:** Investigation, Resources. **Yang Li:** Methodology, Software, Formal analysis. **Zhiyong Chen:** Methodology, Software, Formal analysis. **Hequn Chen:** Conceptualization, Project administration, Supervision.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijsu.2019.10.032.

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