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Updated evidence of the safety and efficacy of the miniaturized percutaneous nephrolithotomy with holmium laser lithotripsy for the treatment of recurrent nephrolithiasis

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Abstract. – OBJECTIVE: The objective of the present communication is to report the safety and efficacy of applying miniaturized percutaneous nephrolithotomy (mini-PCNL) in Vietnamese patients with recurrent kidney stones using a miniature nephroscope through a 18F metal access sheath.

PATIENTS AND METHODS: We performed a retrospective cohort study of patients who were diagnosed with recurrent nephrolithiasis and underwent mini-PCNL after previous treatments between 2017 and 2020. Clinical profile, preoperative characteristics, intraoperative events, and postoperative outcomes were obtained from the hospital database. Descriptive statistics were used for the whole analysis.

RESULTS: Of 89 eligible patients, 54 were male. The mean age was 53.4 years. Mean stone size was 24.9 mm. 37 patients had right side stone, 39 had left side stone, and 13 had stone on both sides. Pain in the flanks and back was the most symptom in our patients (n = 87, 97.8%), followed by hematuria (n = 13, 14.6%), dysuria (n = 8, 8.9%), fever (n = 7, 7.9%), acute renal colic (n = 5, 5.6%), and pyuria in 2 patients. 27 had complex stones, and the remaining stone position included renal pelvis (21, 23.6%), upper calyx (15, 16.9%), lower calyx (14, 15.7%), and middle calyx (12, 13.5%). 35 of them had grade I, 27 grade II, 8 grade III and 2 grade IV of hydronephrosis. Renal failure was documented in 12 patients (13.5%). 18 patients were performed with 2-times punctures (20.2%) and 13 with 3-times punctures (14.6%). We used one percutaneous tract in 79 patients and the remaining 10 were performed with two tracts. The upper, middle, and lower calyx was the site of puncture access in 6 (6.7%), 73 (82.0%), and 10 (11.3%) cases, respectively. 3 patients had bleeding requiring intraoperative blood transfusion and 2 were converted to open surgery. Intraoperative parameters recorded percutaneous puncture duration of 20.9 minutes (5-50), and total operative duration of 112.9 minutes (40-240). 7 patients developed secondary bleeding after surgery, besides 5 cases of fever, 2 cases of septic shock and one case of drainage failure. Early stone-free rate was 89.9% and this rate was 94.4% for patients after one month of mini-PCNL. Mean duration of ureteral catheter circulation was 2.7 days (2-20), mean length of postoperative hospitalization was 6.6 days (4-25) and mean total hospital stay was 12.9 days (7-28).

CONCLUSIONS: Present results show the safety of mini-PCNL with respect to recurrent nephrolithiasis. Our updated evidence may provide appropriate modified approaches that aim at reducing the risk of recurrent kidney stone development.

Key Words:
Recurrent kidney stones, Recurrent nephrolithiasis, Miniaturized percutaneous nephrolithotomy, Mini-PCNL.

Introduction

Up to around 15% of the population is affected by kidney stone diseases[1]. The increasing trend in the incidence of kidney stones was documented[2-4] over the past two decades, both in adults and pediatric population, which could also visualize a tendency towards recurrent kidney stones. Approximately 50% of adult patients can have a recurrent

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stone within a follow-up period of 5-10 years after the first kidney stone[5]. The stone recurrence rate was similar or greater in children compared to adult[5]. In Safarinejad's study[6], the average cumulative recurrence of kidney stones after 1 year, 5 years and 10 years was 16%, 33% and 53%, respectively.

Following the recent survey[7] result of VOV – the Vietnamese national radio broadcaster – the prevalence of urinary tract stones in Vietnam was estimated to be 2-12% of the population, of which the prevalence was 40% for kidney stones. Comparing this data with previous international reports, Vietnam can be considered as one of the countries with the highest incidence of kidney stones in the world. To the best of our knowledge, although some studies[1,2] evaluated systematic reviews of the incidence of kidney stones, as well as urinary tract stones in various countries, it is still not available a study on the overall prevalence of kidney stones in Vietnam. The rate of recurrent kidney stones, depending on Vietnamese hospital and health facilities, is unknown. In recent years, through decreasing the size of the access sheath tract, miniaturization of percutaneous nephrolithotomy (PCNL) has been more flexibly applied in Vietnam with the reduction of perioperative comorbidities in those with urinary calculi[8]. Yet, it is not an available clinical evaluation of the events and outcomes of miniaturized percutaneous nephrolithotomy (mini-PCNL) for particular patients who were diagnosed with recurrent nephrolithiasis. Hence, the objective of the present communication is to report the safety and efficacy of applying mini-PCNL in Vietnamese patients with recurrent kidney stones using a miniature nephroscope through a 18 Fr metal access sheath. This updated evidence may result in finding appropriate approaches that reduce the risk of the development of recurrent kidney stones. The present approach experience of ours are helpful to health care providers for the prevention of incident and recurrent kidney stones.

Patients and Methods

Study Design and Patients

The study was reviewed and approved by the Institutional Review Board of Hanoi Medical University and informed consent was obtained from the patients. This is a retrospective population-based review of perioperative and postoperative outcomes of patients who were diagnosed with recurrent nephrolithiasis and underwent mini-PCNL after previous treatments. Herein recurrent nephrolithiasis was documented following previous treatment with retroperitoneal laparoscopy, extracorporeal shock wave lithotripsy (ESWL), open or laparoscopic surgical removal of a stone or previous mini-PCNL procedures. All study patients received the recurrence treatment with mini-PCNL by urologists at Hanoi Medical University Hospital (Hanoi, Vietnam). All patients with recurrent nephrolithiasis underwent mini-PCNL with a high pulsed Ho:YaG laser (Lumenis 80 W, Lumenis India Pvt. Ltd., Gurugram, Haryana, India) at Hanoi Medical University Hospital from January 2017 to September 2020. We excluded individuals with specific conditions including severe urinary tract infections, uncontrolled diabetes, bleeding disorders, pregnancy, abdominal aortic aneurysm, renal artery stenosis/aneurysm, congenital anomalies of kidney and urinary tract, ureteral structures, ureteropelvic junction obstructions. The clinical profile, preoperative characteristics, intraoperative events, and postoperative outcomes were abstracted from the database of our center.

Mini-PCNL Surgical Procedure

Stage 1: Preparing Conditions for Mini-PCNL

Under general anesthesia, the patient was placed in the supine decubitus position. A ureteral catheter was placed upstream from the bladder to the kidney to partially evaluate the position and shape of the kidney stone compared to the renal calyx, the morphology of the renal calyx, urinary tract malformations, and ureteral circulation. After that, a physiological saline injection was used to dilate the renal calyces, aiming at facilitating the process of puncture, dilation and lithotripsy. The urethral Foley catheter was inserted after placing the J-J stent, and the J-J stent was fixed with the urethral Foley catheter. The sonde was attached to the water pump wire. The patient was changed to lateral decubitus position. The surgeon stands on the side of the operating kidney, facing the screen of the endoscope and ultrasound machine.

Stage 2: Performing Mini-PCNL

Sonography was applied to detect stones in renal pelvis in combination with lower calyces, stones in renal pelvis in combination with middle calyces or the junction of the bladder to the ureter, and stones in renal pelvis in combination with all three calyces. Puncture position and line

were determined to access the kidney stone. We selected the puncture line to enter the avascular plane of Brodel and the needle was perpendicular to the posterior surface to limit vascular damage in the renal parenchyma. Under ultrasound guidance, the surgeons inserted the needle into the determined position, along with the assistant injected water into the JJ stent. When the needle touched the stone or sees the needle tip into the renal calyx or renal pelvis, the needle barrel was withdrawn. Then, while the assistant held the needle, the surgeon passed the guide wire through the needle, observing on the ultrasound screen to assess whether the needle and guide had reached the stone. The puncture needle was withdrawn, and the guide wire was kept. Renal tunnel dilation began with a size 8 Fr flexible catheter, when the catheter entered the renal pelvis and calyces, and withdrew, and then the tracts were dilatated to 18 Fr using a single-step dilator. Access to the renal collecting system was gained by single-step dilation and insertion of an 18 Fr, metal Amplatz sheath. After determining the size, morphology and position of the stone, the Amplatz tube was rotated close to the stone. Laser lithotripsy made the stone moderately broken, and the stones were removed with the pince and dormia basket or stone fragments followed water pressure out of the renal pelvis and calyces. All renal calyces were carefully checked to avoid missing stones. A 6-7 Fr double-J stent was placed antegradely at the end of the procedure. As checking to be sure to rule out the risks of bleeding and stone retention, we did not proceed with percutaneous renal drainage with a Foley catheter.

Statistical Analysis

A first visual inspection for coding errors, outliers, or funky distributions was performed on data. All statistical analyses were performed with Stata® 15 (StataCorp. LLC, USA). Main descriptive statistics were reported as absolute and relative (%) frequencies for categorical variables or as means with their standard deviation (SD) or median and min and max values depending on the normality of the distribution.

Results

Preoperative Characteristics

Of 89 eligible patients with recurrent stones, 54 were male and 35 females. Their mean age was 53.4 years (32 years to 83 years). Most had normal weight (69, 77.5%), 16 were overweight (18.0%) and 4 was underweight (4.5%). Mean stone size was 24.9 mm (11-57 mm). Preoperative renal imaging revealed that 37 patients had right side stone, 39 had left side stone and 13 had stone both sides. 83 patients had a history of previous renal surgery (PCNL or open nephrolithotomy), and 6 had a history of retroperitoneal endoscopy. Pain in the flanks and back was the most symptom in our patients (87, 97.8%), followed by hematuria (13, 14.6%), dysuria (8, 8.9%), fever (7, 7.9%), acute renal colic (5, 5.6%), and pyuria in 2 patients. 27 patients had complex stones, and the remaining stone position included renal pelvis (21, 23.6%), upper calyx (15, 16.9%), lower calyx (14, 15.7%), and middle calyx (12, 13.5%). 35 of them had grade I, 27 grade II, 8 grade III and 2 grade IV of hydronephrosis on preoperative imaging studies (Table I).

Preoperative laboratory findings of blood count parameters revealed the mean RBC, hematocrit, hemoglobin, white blood cells, and platelet count were 4.7 T/L, 42.9%, 142.5 g/L, 8.0, and 282.5, respectively. The mean BUN and creatinine values were 5.5 mmol/L and 84.5 μmol/L respectively. Renal failure was detected in 12 patients (13.5%). Erythrocytosis was found in 76 patients (85.4%) and leukocytosis was in 60 patients (67.4%) (Table I).

Intraoperative Characteristics

Table II shows the intraoperative events, procedures and parameters. 58 of patients were performed with only one puncture into the renal pelvis, 18 patients underwent 2-times punctures (20.2%) and 13 those with 3-times punctures (14.6%). We used one percutaneous tract in 79 patients and the remaining 10 ones were performed with two tracts. The upper, middle, and lower calyx were the site of puncture access in 6 (6.7%), 73 (82.0%), and 10 (11.3%) cases, respectively. In this case series, we encountered 5 patients occurred complications during surgery, of which 3 patients had bleeding requiring intraoperative blood transfusion and 2 patients were converted to open surgery. Intraoperative parameters recorded percutaneous puncture duration of 20.9 minutes (5-50), and total operative duration of 112.9 minutes (40-240).

Postoperative Characteristics

Table III indicated outcome and complications of mini-PCNL surgery of 89 patients who had recurrent nephrolithiasis. There were 7 patients

Table I. Preoperative characteristics of the study population.

	All Patients (n = 89)	
	Count	% of total
Gender - %		
Male	54	60.7
Female	35	39.3
Age group - %		
≤ 40 years	10	11.2
41-50 years	26	29.2
51-60 years	33	37.1
61-70 years	15	16.9
> 70 years	5	5.6
BMI classification - %		
Underweight	4	4.5
Normal weight	69	77.5
Overweight	16	18.0
Previous urologic treatment - %		
Percutaneous nephrolithotomy	1	1.1
Open nephrolithotomy	82	92.1
Retroperitoneal endoscopy	6	6.7
Clinical symptoms on admission		
Acute renal colic - %	5	5.6
Pain in the flanks and back - %	87	97.8
Dysuria - %	8	8.9
Hematuria - %	13	14.6
Pyuria - %	2	2.2
Fever - %	7	7.9
Side of kidney stones - %		
Right kidney	37	41.6
Left kidney	39	43.8
Both kidneys	13	14.8
Size of kidney stones - %		
< 2 cm	23	25.8
2-3 cm	47	52.8
> 3 cm	19	21.3
Position of kidney stones - %		
Renal pelvis	21	23.6
Upper calyx	15	16.9
Middle calyx	12	13.5
Lower calyx	14	15.7
Complex stones	27	30.3

	All Patients (n = 89)	
	Count	% of total
Position of kidney stones - %		
Lower calyx	14	15.7
Complex stones	27	30.3
Number of kidney stones -%		
1 stone	21	23.6
2 stone	18	20.2
≥ 3 stone	50	56.2
Stone surface area - %		
< 200 mm^2	32	36.0
200 mm^2 - < 300 mm^2	24	27.0
≥ 300 mm^2	33	37.1
Degree of hydronephrosis [a]		
Grade 0	17	19.1
Grade 1	35	29.3
Grade 2	27	30.3
Grade 3	8	9.0
Grade 4	2	2.2
Kidney failure - %		
No	77	86.5
Yes	12	13.5
Urinary erythrocytes - %		
Negative	13	14.6
Positive	76	85.4
Urinary leukocytes - %		
Negative	29	32.6
Positive	60	67.4
	Mean ± SD	Min - Max
Patient age (years)	53.4 ± 11.1	32 - 83
Stone size (mm)	24.9 ± 9.6	11 - 57
Stone surface area (mm^2)	343.6 ± 247.7	43 - 1119
RBC (T/l)	4.7 ± 0.5	3.2 - 6.0
Hematocrit (%)	42.9 ± 6.5	6.5 - 50
Hemoglobin (g/l)	142.5 ± 15.6	104 - 173
WBC (K/uL)	8.0 ± 3.2	4.1 - 28.3
Platelet count	282.5 ± 86.7	125 - 701
BUN (mmol/L)	5,56 ± 1.6	2.2 - 12.3
Creatinine (μmol/L)	84.5 ± 30.1	44 - 235

[a]Hydronephrosis was graded into four degrees according to Beetz et al[9]. RBC: red blood cells; WBC: white blood cells; BUN: Blood urea nitrogen. SD: standard deviation.

who showed secondary bleeding after surgery. 3 other complications occurred in several patients, including 5 cases of fever, 2 cases of septic shock and one case of drainage failure. According to the Clavien-Dindo classification, Clavien grade I complications were 11 (12.4%) and Clavien grade II complications were 2 (2.2%). We also documented several postoperative main laboratory parameters: the mean RBC, hematocrit, hemoglobin, WBC, BUN, and creatinine were 4.9 T/L, 40.2%, 134.7 g/L, 5.21 mmol/L and 82.8 μmol/L respectively.

As was also shown in Table III, the early stone-free rate was 89.9% and this rate after one month mini-PCNL was 94.4% patients. Mean duration of ureteral catheter circulation was 2.7 days (2-20), mean length of postoperative hospitalization was 6.6 days (4-25) and mean total hospital stay was 12.9 days (7-28). Postoperative outcome was observed to be convenient for the whole cohort.

Discussion

The urological management of the patient group that did not cure the underlying cause of the kidney stones was what caused most patients to return at a later date[10,11]. There is currently a focus on how to prevent patients from the recurrence of stones after initial treatment in order to reduce the burden on the urology departments. Besides, urolithiasis is usually associated with metabolic disturbances or urinary tract infections, leading to multiple recurrences or obstructive anomalies that necessitate reconstruction along with the removal of the stone; hence, the validity of PCNL in treating such stones is clear[12].

If we consider that the physicians, for preventing the recurrence of all urinary stones, propose adequate dietary advice or medical treatment according to the stone composition (calcium stone, uric acid stone, cystine stone, struvite stone, etc.), it is unlikely that stone recurrence might be a consequence of an inappropriate medical care. We cannot exclude the possibility that patients were not compliant with physician recommendations. There is no evidence that such default of compliance may depend on the stone type. Thus, intrinsic characteristics of crystalline phases or of the stone morphology appear highly suggestive for different courses of stone diseases, according to the stone composition and morphology[13-15].

The main issue in our practice condition is that there is no primary screening system of kidney stones in the community, as well as in provincial health facilities, evident in the late detection of the kidney stone recurrence. Besides the cost and insurance coverage for the kidney stone treatment have not been one of the main barriers for the patients and their family. The available evidence in the literature was mostly reported from large institutions in developed countries[1,16-18], and no publications on the surgical events, post-mini-PCNL outcomes, as well as the efficiency and safety in the application of the mini-PCNL for kidney stones recurrence, were known in the resource-scarce conditions in clinical practice like in Vietnam. With the recent progress of the miniaturization's technology of the access sheath, the miniaturized PCNL can currently be categorized into mini-PCNL (≤ 22 Fr), Chinese mini-PCNL (14-20 Fr), super-mini-PCNL (10-14 Fr), ultra-mini-PCNL (11-13 Fr), micro-PCNL (4.8 Fr), and mini-micro-PCNL (8 Fr)[13]. All patients in our report underwent mini-PCNL with Amplatz sheath 18 Fr. Despite the innovations of new surgical approaches with the miniaturization of the access sheath, the indications for the mini-PCNL have not been standardized in the treatment of recurrent kidney stones yet.

Table II. Intraoperative characteristics.

Intraoperative variables	All Patients (n = 89) Count	% of total
Percutaneous puncture of renal pelvis - %		
1 time	58	65.2
2 times	18	20.2
3 times	13	14.6
Number of tracts - %		
1 tract	79	88.8
2 tracts	10	11.2
Positions for puncture - %		
Upper calyx	6	6.7
Middle calyx	73	82.0
Lower calyx	10	11.3
Bleeding requiring transfusion - %	3	3.4
Conversion to open surgery - %	2	2.2
	Mean ± SD	Min - Max
Percutaneous puncture duration (minutes)	20.9 ± 9.4	5 - 50
Operative duration (minutes)	112.9 ± 43.5	40 - 240

RBC: red blood cells; WBC: white blood cells; BUN: Blood urea nitrogen.
SD: standard deviation.

For our patients with a history of surgery to remove kidney stones, the perirenal fibrosis and anatomical changes of the renal calyx system after open stone removal surgery could cause difficulties in the tunneling process, as well as it could be necessary to use more tunnels in the mini-PCNL process. Although specific medical interventions depended on the stone type and identifiable factors in the urine, mini-PCNL had been given great attention in our institution towards the treatment of recurrent kidney stones. Mini-PCNL was reported to bring less complications (such as bleeding, blood transfusion needs, fever, postoperative pain, postoperative hospitalization, kidney, and another organ injury) compared with standard PCNL[14,15]. Nevertheless, operation time in mini-PCNL was more prolonged and there was not significant difference in SFR between mini-PCNL and standard PCNL.

In the present cohort of the recurrent nephrolithiasis, we documented a high stone clearance rate with acceptable complication rate after applying mini-PCNL procedure in Vietnamese patients. We considered the status of stone clearance as

Table III. Postoperative characteristics.

Intraoperative variables	All Patients (n = 89) Count	% of total
Bleeding - %	7	7.8
Fever - %	5	5.6
Septic shock - %	2	2.2
Drainage failure - %	1	1.1
Clavien–Dindo classification of surgical complications - %		
No complication	76	85.4
Grade I	11	12.4
Grade II	2	2.2
Ureteral catheter circulation time - %		
<3 days	71	79.8
3 – 5 days	12	13.5
>5 days	6	6.7
Stone free status three days after surgery - %		
Yes	80	89.9
No	9	10.1
Surgical outcome - %		
Good	80	89.9
Average	7	7.9
Poor	2	2.2
Stone free status one month after surgery - %		
Yes	84	94.4
No	5	5.6
	Mean ± SD	Min - Max
RBC (T/l)	4.9 ± 1.1	3.7 - 6.0
Hematocrit (%)	40.2 ± 6.1	6.1 - 51
Hemoglobin (g/l)	134.7 ± 15.1	104 - 165
BUN (mmol/L)	5.21 ± 1.2	4.2 - 9.1
Creatinine (μmol/L)	82.8 ± 17.4	62 – 127
Ureteral catheter circulation time (days)	2.75 ± 1.54	2 - 20
Length of postoperative hospitalization (days)	6.6 ± 4.2	4 - 25
Total hospital stay (days)	12.9 ± 6.3	7 - 28

RBC: red blood cells; BUN: Blood urea nitrogen.
SD: standard deviation.

there was absence of stones or stone fragments ≤ 4 mm on postoperative C-arm imaging, combined with radiography of the urinary system at the first 3 days after surgery. Although it was associated with a better complication profile, there was concern about the relative efficiency in the clearance of stones when compared with standard-PNCL, as the smaller tract may hinder the required instrumental manipulations for the stone removal especially with large-sized calculi. In general, postoperative outcome was convenient for the whole cohort. Early stone free rate after mini-PCNL was 89.9%, and mid-term rate of tone clearance was 94.4%. Our results were consistent with previous study reports[17,18]. The safety and efficacy of mini-PCNL was also revealed in retrospective case series[16-18] in various country populations, meaning in encouraging more surgeons to apply this technique for the treatment of large, complex and staghorn stones. Guohua et al[19] performed mini-PCNL with 100 patient sample and reported a stone free rate of 93% for mini-PCNL for staghorn stones, while Zhao et al[20] reported a stone free rate of 84% for two-stage multi-tract mini-PCNL for staghorn stones.

Some limitations of this report need to be noted. This is a retrospective analysis based on an available database including consecutive patients who were diagnosed with recurrent nephrolithiasis and underwent mini-PCNL after previous treatments. We acknowledged a relatively small sample size with a short follow-up duration. The system was only tested in adult patients with recurrent stones; therefore, we cannot know the effectiveness on the children population. We plan to prospectively investigate in a group of children and compare outcomes with other minimally invasive PCNL techniques for larger stones.

Conclusions

Present report raises favorable intraoperative and postoperative results in the mini-PCNL application of the treatment of recurrence of kidney stones. Besides existent limitations, we found equivalent efficacy in terms of both secondary stone-free rate and safety profile in applying mini-PCNL for the recurrence of moderately sized renal stones compared to available evidence.

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Conflict of Interest

The authors declare that they have no conflict of interests.

Data Availability

The dataset used in this article is not available publicly. However, upon a reasonable request, the data can be obtained from the authors.

Authors' Contributions

Minh-An Nguyen and Tung-Linh Phan initiated the study. The manuscript was written by Minh-An Nguyen, Tung-

Linh Phan and Hoang-Long Vo. Minh-An Nguyen and Tung-Linh Phan performed the operations. Minh-An Nguyen, Hoang-Long Vo and Nguyen-Vu Le collected, analyzed and interpreted the data. Minh-An Nguyen and Nguyen-Vu Le reviewed the manuscript.

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