Evaluating the results of kidney stone treatment by ultrasound-guided percutaneous nephrolithotomy without preoperative indwelling ureteral catheter

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Abstracts

Objectives: Percutaneous nephrolithotomy (PCNL) is currently considered the gold standard surgery for most patients with staghorn kidney stones and kidney stones greater than 20 mm. The objective of this study is to evaluate the results of ultrasound-guided percutaneous nephrolithotomy without preoperative indwelling ureteral catheter. **Subjects and Methods:** A prospective descriptive study was conducted on 37 cases of ultrasound-guided percutaneous nephrolithotomy without preoperative indwelling ureteral catheterization at the Department of Urology, Hue Central Hospital from January 2023 to March 2024. **Results:** The average age of the patients was 54.6 ± 13.9 years (33 - 81). Most stones were classified as Guy II (59.4%). The level of hydronephrosis before surgery is mainly of grade II and grade III with a rate of 78.4%, and the grade I hydronephrosis accounts for 21.6%. The success rate of kidney puncture was 100%, punctured mainly the middle calyx (70.2%), the average puncture time was 141.6 ± 136 seconds, in which the group with grade III hydronephrosis had the puncture time the shortest at 45 ± 43 seconds. The average surgical time was 70.3 ± 38.2 minutes. No significant complications were noted, and immediate stone clearance rate post-surgery was 83.7%, rising to 89.1% after one month. **Conclusion:**Ultrasound-guided percutaneous nephrolithotomy without preoperative indwelling ureteral catheter is a safe and effective method for treating kidney stones with hydronephrosis. This technique has several advantages such as high stone clearance rates, reduced surgery time and hospital stay, and minimal complications.

Keywords: *PCNL: Percutaneous nephrolithotomy, ureteral catheter.*

1. INTRODUCTION

Urinary stones have been known since very early in the history of human development. This is a common disease, accounting for the highest rate of urinary tract diseases. The general incidence of the disease generally ranges from 2% to 12% of the population, of which the majority are kidney stones with approximately 40% of cases [1].

There has been a shift in kidney stone treatment from classic open surgery to minimally invasive surgery [2]. Percutaneous nephrolithotomy (PCNL) was first reported in 1976(3). Since then, open surgery to remove stones has gradually been replaced by percutaneous nephrolithotomy due to its economic efficiency, shorter surgery time, and lower postoperative complications [2].

Currently, percutaneous nephrolithotomy is considered the gold standard surgery for most patients with staghorn kidney stones and kidney stones larger than 20 mm [4], [5]. The technical process of classic percutaneous nephrolithotomy includes two basic stages, one of which is cystoscopy in the lithotomy position, followed by the retrograde placement of a ureteral catheter into the pelvicalyceal system. Second, change to the prone or lateral position and then perform a puncture in the renal calyces, tunnel dilation, stone fragmentation, and removal [6].

Initially, PCNL was performed under fluoroscopic guidance. However, this method revealed some disadvantages such as the impact of radiation and the risk of organ damage during surgery, so gradually, ultrasound guided PCNL is being applied by many authors due to its many advantages such as limiting organ damage, assessing kidney parenchyma, kidney vessels, and adjacent organs during surgery without radiation exposure, and thus ultrasound-guided percutaneous nephrolithotomy has been widely applied [7]. Many studies have shown similar effectiveness and safety between ultrasound and radiographic guidance [8], [9]. In PCNL, the placement of a ureteral catheter has the main purpose of creating artificial hydronephrosis in the renal pelvis system or injecting contrast material to help determine the shape of the renal calyx pelvis, thus helping to improve the success rate of surgery [10]. However, in cases

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where the kidneys already have hydronephrosis due to stones, especially cases of large and complete hydronephrosis, the necessity of ureteral catheterization becomes debatable, because this step has many disadvantages, such as wasting time for ureteral catheter placement and having to change the position of patient which can increase surgical time, also can cause ureteral damage related to the placement of the urinary catheter and the risk of retrograde infection [10]. Furthermore, older patients, mostly with chronic diseases, long surgical times, and excessive surgical stimulation, may increase the risk of related complications.

Artificial hydronephrosis through an indwelling ureteral catheter is still a matter of concern. Some studies worldwide, including those by Telma Zahirian Moghadam et al. (2021), and Xicai Zang et al. (2022), have investigated percutaneous nephrolithotomy without preoperative ureteral catheterization, demonstrating its safety, efficacy, and reduced surgical durations [7], [10]. Therefore, we conducted the research with title: "*Evaluating the results of kidney stone treatment by ultrasound-guided percutaneous nephrolithotomy without preoperative indwelling ureteral catheter*".

2. SUBJECTS AND METHODS

2.1. Subjects

We conducted a study on 37 patients undergoing ultrasound-guided percutaneous nephrolithotomy without preoperative indwelling ureteral catheter at Hue Central Hospital from January 2023 to March 2024.

2.1.1. Inclusion Criteria

The inclusion criteria were as follows:

- Patients diagnosed with kidney stones on the intervention side ≥ 2 cm or ureteral-pelvic junction stones ≥ 1.5 cm

- The kidney must have hydronephrosis of grade 1 or higher.

- The kidney on the intervention side is still functional.

2.1.2. Exclusion criteria

The inclusion criteria comprised:

- Complete staghorn stones (Grade 4 stone classification according to Guy's stone score).

- Pathological kidney stones or anatomical abnormalities such as horseshoe kidney, transplanted kidney, polycystic kidney, double kidney pelvis, urinary tract tuberculosis, kidney tumor...

- Severe coagulation dysfunction or severe cardiopulmonary failure, ASA score ≥ 3 points.

- Incomplete medical records and research information for patients.

2.2. Methods

This was a descriptive and prospective study.

2.3. Technical procedure

2.3.1. Preparing the patient

- Treatment of urinary tract infections before surgery, if present, pre-operative testing, assessing STONE score [11]. and planned surgical preparation steps.

- Psychological preparation by explaining the surgery and possible complications to the patient.

- Administration of prophylactic intravenous antibiotics before surgery.

- Preoperative preparation tools included a laparoscopic endoscopy system, nephroscope, laser lithotripsy machine, ultrasound machine along with a specialized needle, guide wire, tunnel dilator, stone pincer, etc.

2.3.2. Technique [10]*:*

- Anesthesia technique: Endotracheal anesthesia

- Positioning: Insertion of a urinary catheter and placing the patient in a lateral position.

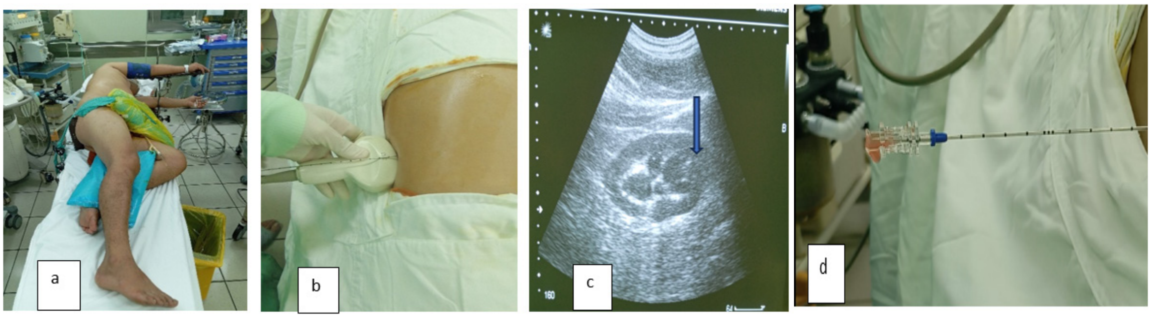

Figure 1. Steps for ultrasound-guided puncture of renal calyces without indwelling ureteral catheter

a) Setting up the patient in a lateral position.

b) and **c):** Determing the location of puncture and puncturing the renal calyx under ultrasound guidance (the green arrow shows that the needle has entered the middle calyx of the kidney).

d) Successful puncture evidenced by urine flow through the needle barrel

- Main surgical steps:

+ Step 1: Determining the location and puncture the appropriate renal calyces under ultrasound guidance (**Figure 1**).

+ Step 2: Dilating the tunnel to 18 Fr (Mini - PCNL), then placing the Amplatz sheath (Sheath).

+ Step 3: Inserting the nephroscope to examine the stones and the reanl calyx pelvic system, using a laser fragment the stones, and then remove the stone fragments.

+ Step 4: Check the renal pelvis and place a JJ ureteral catheter antegrade.

+ Step 5: Placement and fixation the nephrostomy tube.

2.4. Data processing

Data were processed using medical statistics methods, with data entry and processing performed using Excel and SPSS 22.0 software.

3. RESULTS

3.1. Characteristics of the demographics of the participant

Table 1. Characteristics of the demographics of the participant

Variable	N = 37
Age (years)	54.6 ± 13.9 (33 - 81)
21 - 40	7 (18.9%)
41 - 60	18 (48.7%)
> 60	12 (32.4%)
Gender	
Male	17 (46%)
Female	20 (54%)
BMI index (kg/m²)	23.1 ± 3.1 (17,7 - 32,4)
Underweight (BMI < 18.5)	3 (8.1%)
Normal range (18,5 ≤ BMI ≤ 22.9)	14 (37.8%)
Overweight (BMI ≥ 23)	20 (54.1%)

The average age is 54.6 ± 13.9 years, the oldest age is 81 years, youngest age is 33 years. The age group with the largest proportion is 41 - 60 years with 58.7%.

3.2. Clinical and paraclinical characteristics

Table 2. Clinical and paraclinical characteristics

Variable	N = 37
ASA score	
1	8 (21.6%)
2	25 (67.6%)
3	4 (10.8%)
Reason for hospitalization	
Flank pain	29 (78.4%)
Re-examination	4 (10.8%)
Accidental discovery	3 (8.1%)
Others	1 (2.7%)
The preoperative Glomerular Filtration Rate (ml/min)	105.4 ± 16.2
The preoperative hemoglobine concentration (mg/dl)	12.3 ± 3.1 (10.2 - 14.3)

The main reason for hospitalization is flank pain, which is 78.4%.

3.3. Calculi-related characteristics of patients.

Table 3. Calculi-related characteristics of patients.

Variable	N = 37
Hydronephrosis	
Grade 1	8 (21.6%)
Grade 2	18 (48.6%)
Grade 3	11 (29.8%)

Stone location	
Pelvic-ureteral junction stone	10 (27.0%)
Pelvic stone	5 (13.5%)
Calyx stone	10 (27.0%)
Pelvicalyceal stone	12 (32.4%)
Number of stones	
One	15 (40.5%)
Multiple	22 (59.5%)
Guy's Stone Score	
Guy I	10 (27.0%)
Guy II	22 (59.5%)
Guy III	5 (13.5%)
Stone surface area (SSA) (mm^2)	
< 400	32 (86.5%)
400 - < 800	5 (13.5%)
800 - < 1600	0 (0.0%)
S.T.O.N.E (points)	
5 - 7: Low risk	27 (72.9)
8 - 10: Mediate risk	9 (24.3)
11 - 13: High risk	1 (0.8%)

Pelvic ureteral junction stones account for 27.0% in 10 patients, and renal pelvic stones account for 32.4% in 12 patients, of which the number of patients with multiple stones accounts for 59.5% in 22 cases. Stones classification according to Guy's Stone Score, grade II accounts for the highest proportion with 59.4%, followed by Guy I with 27.1% and Guy III accounts for the lowest proportion with 13.5%.

3.4. Surgical results

Table 4. Surgical results

Variable	N = 37	P value
Puncture location	37 (100%)	
Upper calyx	3 (8.1%)	
Middle calyx	26 (70,2%)	0.01
Lower calyx	8 (21.6%)	
Mean puncture time for each degree of hydronephrosis (second)	141.6 ± 136 (15 - 420)	
Grade-1 hydronephrosis	270 ± 130	
Grade-2 hydronephrosis	122 ± 118	0.04
Grade-3 hydronephrosis	45 ± 43	
Mean tunnel dilation time for each degree of hydronephrosis (second)	136.7 ± 34.5	
Grade-1 hydronephrosis		0.022
Grade-2 hydronephrosis	152.5 + 42.1	(Between 1 and 3 group)
Grade-3 hydronephrosis	145.0 ± 38.6	
	106.1 ± 34.5	
Mean operative time (min) according to SSA	70.3 ± 38.2	
< 400 mm^2	68.5 ± 32.2	
400 - 800 mm^2	82.3 ± 38.2	0.045
800 - 1600 mm^2	(None)	

Mean postoperative hospitalization time (day)	3.53 ± 1.55	
Clavien - Dindo classification		
Grade 0	31 (83.8%)	
Grade I	5 (13.5%)	
Grade II	1 (2.7%)	0.001
Grade III	0	
Indwelling double-J failed	1 (2.7%)	
Post-operative fever	2 (5.4%)	
Post-operative immediate stone-free rate in each S.T.O.N.E score group	31/37 (83.7%)	
5 - 7 points	24/29 (88.9%)	
8 - 10 points	6/9 (66.7%)	
11 - 13: points	0/1 (0.0%)	0.033
1 month postoperative stone –free rate in each S.T.O.N.E score group	33/37 (89,1%)	
5 - 7: points	26/29 (89.6%)	
8 - 10: points	6/9 (66.7%)	
11 - 13: points	0/1 (0.0%)	0.026

The location of kidney puncture in our study was mainly in the middle calyx, accounting for 70.2% (26 patients). The overall average puncture time is 141.6 ± 136 seconds, of which the fastest puncture time is 15 seconds, the longest puncture time is 420 seconds.

4. DISCUSSION

Percutaneous nephrolithotomy has become one of the main treatment methods for complicated stones, but it also carries potential risks of complications such as bleeding, infection, and kidney failure [12]. Accurate puncture of target renal calyces is one of the important steps to improve the success rate of puncture, and water irrigation through an indwelling ureteral catheter can dilate the target renal calyces, so reducing injury to the renal parenchyma and perirenal vessels during puncture and reducing intraoperative bleeding. However, this procedure can prolong surgical durations, and high-pressure retrograde irrigation poses a risk of urinary tract infection [13]. Furthermore, elderly patients have many comorbidities and poor immunity, which can easily lead to postoperative complications such as sepsis [14]. Establishing artificial hydronephrosis in PCNL requires retrograde ureteral catheterization and changing the patient's position twice, which can also lead to damage to the ureteral mucosa during ureteral catheterization [15]. Furthermore, elderly patients have varying degrees of atherosclerosis, and poor self-adjustment and changes in position during surgery can cause orthostatic hypotension [16], in addition to the potential risk of injury to the limbs, head, and neck when changing positions. Several studies have indicated the safety of renal puncture without ureteral catheterization and hopefully this procedure will help overcome the limitations of artificial hydronephrosis, Yeh et al. [17] showed that in patients with a dilated renal pelvis greater than 5 mm, inducing additional artificial hydronephrosis did not reduce the success rate of puncture or increase intraoperative bleeding. Eryildirim et al. [15] demonstrated that in patients with moderate to severe hydronephrosis, the induction of artificial hydronephrosis did not reduce the puncture time (5.76 ± 2.45 minutes vs 5.28 ± 2.08 minutes, p = 0.4909). Therefore, to assess the safety and effectiveness of the percutaneous nephrolithotomy without indwelling pre-operative ureteral catheter, we conducted a study on patients undergoing the ultrasound-guided percutaneous nephrolithotomy without a preoperative indwelling ureteral catheter at the Department of Urology, Hue Central Hospital, from January 2023 to March 2024.

In our study, there were 37 patients who underwent percutaneous nephrolithotomy under ultrasound guidance without ureteral catheter prior to surgery, including 20 female (54%), 17 male (46%), with an average age of 54.6 ± 13.9 years old. The 41 - 60 age group accounts for the highest proportion with 58.7%. 74% of patients live in rural areas and 26% of patients live in urban areas.

27.0% of patients had ureteropelvic junction stones (10 patients), and 32.4% had renal pelvic stones (12 patients), with 59.5% presenting with multiple stones in a kidney unit. Stone classification according to Guy'S Stone Score revealed Grade II as the most prevalent (59.4%), followed by Grade I (27.1%), and Grade III (13.5%). Regarding stone burden according to stone surface area, in our study, mainly patients had a surface area of less than 400 mm2 with 32 patients (86.5%), there are 13.5% of patients with an average surface area of 400 - 800 mm2, no patient has a surface area greater than 800 mm2. Regarding hydronephrosis, our study exclusively focused on patients with grade I or higher, with grade I accounting for 21.6% and the remainder predominantly exhibiting severe hydronephrosis (grades II and III) at 78.4%. Regarding the evaluation of the complexity of stones according to the S.T.O.N.E score, the average S.T.O.N.E score is 7.2 ± 0.96 points, of which 27 patients are in the low-risk group of remnant stones (from 5 - 7 points), representing 72.9%, the remaining belong to the group of average risk of remnant stones (8 - 10 points) accounting for 24.3%, and only one patient (0.8%) belongs to the group of high risk of remaining stones.

Selecting the location of the puncture to create a tunnel in the kidney is an important factor that determining the success and possible complications of PCNL. According to the author Khadgi (2020) (18), the puncture in the middle calyx can access most of the pelvicalyceal system and the upper ureter segment while avoiding touching the lungs. On the other hand, a puncture of the middle calyx will make it easier to access the stone than a puncture of the lower calyx in the case of ureteropelvic junction stones or upper ureteral stones or stones in multiple locations. Our sample predominantly involves puncturing the middle calyx, accounting for 70.2% (26 patients), the rest are punctures into the upper and lower calyces. The reason for selecting the upper or lower calyx due to obstruction of the calyx neck or hydronephrosis mainly in these calyx groups. The average puncture time overall is 141.6 ± 136 seconds, with the quickest puncture completed in 15 seconds and the longest taking 420 seconds. In comparison to other studies, such as that conducted by Pham Ngoc Hung et al. (2022) [19], where the average puncture time was 264.3 ± 255.2 seconds, and by Eryildirim (2017) [15], where it was 316.8 ± 124.8 seconds, our results demonstrate notably shorter puncture times, which can be explained by the fact that our study subjects mostly had large and complete hydronephrosis, mainly grade II and III. The average puncture time according to the group with grade I, grade II, and grade III hydronephrosis is 270 ± 130 seconds; 122 ± 118 seconds; and 45 ± 43 seconds, respectively. There is a statistically significant difference in puncture time between the 3 groups ($p < 0.05$). The average tunnel dilation time is 149 ± 32 seconds, ranging from 100 to 210 seconds. There is a statistically significant difference in the average tunnel dilation time between grade I hydronephrosis and grade III hydronephrosis group ($p < 0.05$). The average operative time is 70.3 ± 38.2 minutes, shorter than in the study of Telma Zahirian Moghadam (2021) [7] (148.75 minutes) and in our previous study in 2022 [19] (114 minutes), perhaps because the patients in this study had not spent time indwelling a ureteral catheter prior to puncture, plus, most of the stones were simple, mainly Guy I and Guy II, so the operative time was shorter compared to other studies. However, the operative time depends on many factors such as stone size, degree of hydronephrosis, number of kidney calyces carrying stones, and stone density, as well as surgical experiences and equipment conditions of the medical facility [20].

In the study, we observed a case of intraoperative bleeding requiring a blood transfusion, the patient received appropriate medical management and stabilized thereafte. There were two cases of postoperative fever, probably due to the long surgery time and latent infection released during lithotripsy. In one case, the stone fell into the ureter forming a chain, failed to place the JJ catheter, required ureteroscopy to dissolve the stone, and placed the JJ catheter retrograde Although this represents a potential drawback of the technique, the lithotripsy system, coupled with continuous suction, can mitigate the risk of stone migration into the ureter. Additionally, it is necessary to place JJ early when a void is detected during lithotripsy. No cases of puncture failure, lung or pleural perforation or colon perforation, renal pelvis perforation, or post-operative septic shock have been recorded. The classification of complications according to Clavien - Dindo is mainly grade 0 and grade I, from which it can be concluded that this technique is safe, with few complications during and after surgery. The average postoperative stay is 3.8 ± 1.2 days, the average drainage time is 1.43 ± 0.7 days, shorter or equivalent compared to previous studies [19], [10] thus reducing hospital stay and reducing medical costs.

In this study, the postoperative immediate stone-free rate was 83.7% (31/37 patients) increasing to

89.1% (33/37 patients) after 1 month. Currently, numerous tools are available to assess and predict the outcomes of PCNL surgery, including the GSS, CROES nomogram, STONE score, and the Seoul National University scoring system (S-ReSC scoring system of Seoul National University). Among these, the STONE score stands out as a novel, user-friendly tool for predicting stone clearance ability [11]. In our study, there was a correlation between the S.T.O.N.E score and the stone-free rate at both immediate postoperative and one-month follow-up time, with $p < 0.05$. Compared with other studies [10], [19], the stone clearance rate in our study is higher or equivalent.

The limitation of the study is that the number of patients is not large enough; more research is needed to confirm the safety and effectiveness of this method.

5. CONCLUSION

Ultrasound-guided percutaneous nephrolithotomy without preoperative indwelling ureteral catheter in patients with hydronephrosis renal stone is a feasible, safe and effective technique. It offers notable advantages such as a high stone-free rate, reduced operative time, and shorter hospital stays, without an associated increase in perioperative or postoperative complications.

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