Experiences of Renal Stone Fragmentation with the Use of the Ultrasound-Guided Mini-Percutaneous Nephrolithotipsy (Mini-PCNL) in 1200 Patients

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ABSTRACT

Objective: **This study assesses the results of treatment using the mini-percutaneous nephrolithotipsy (PCNL) procedure, on renal stone patients in a lateral position under ultrasound guidance, performed at the Ha Noi Hospital of Post and Telecommunications in Viet Nam.**

Object and Method: **The study was conducted with 1200 kidney stone patients who were treated using the ultrasound-guided mini-PCNL procedure in a lateral position, at the Ha Noi Hospital of Post and Telecommunications in Viet Nam, over the period from March 2018 to March2020.**

Result: **For the 1200 patients: the mean age was 40.3 ± 7.4 (from 21 to 91 years old); the mean size of stones: 18.7 ± 1.3 mm (from 12 mm to 65 mm); the mean operative time: 44.3 minutes (from 35 to 90 minutes); the mean period of hospitalisation: 3.8 days (from 3 to 12 days); the mean stone-free rate (SFR): 91.5%; the rate of second mini-PCNL: 3.8%; haemorrhage complication: 0.7%; urinary tract infections (UTIs):7.8%; septicaemia: 0.9% and septic shock: 0.3%.**

Conclusion: **Renal stone fragmentation using the mini-PCNL procedure, performed on patients placed in a lateral position under ultrasound guidance, is a method that is effective, beneficial and safe for patients with renal and upper ureteral stones.**

KEY WORDS

renal stone, mini-PCNL, ultrasound-guided

INTRODUCTION

Kidney stones are a common disease, accounted for 5-10% of the population. Moreover, the relapse rate of the disease is high, possibly up to 50%. Therefore, it badly affects the economy and decreases living standards.

Medical advances have improved the treatment of kidney stones. The minimally invasive methods of treating renal stones, such as extracorporeal shock wave lithotripsy (ESWL), retrograde intrarenal surgery (RIRS) and percutaneous nephrolithotomy (PCNL) have steadily increased as a replacement for open surgery.

The PCNL method was first performed and introduced by Fernstrom and Johans on in 1976, and has since been further studied and developed[1]. Standard-PCNL has steadily replaced other methods of treating renal stones, however, with big access tracts required, measuring from 26 to 30 Fr, it still causes many injuries to the kidneys and affects patients' rehabilitation.

To reduce the negative effects or injury caused by the standard-PCNL, the instrument has been improved in the form of "minimally evasive PCNL" or "mini-PCNL", with smaller access tracts. Helal and associates reported a mini-PCNL operation performed on a baby girl at the age of 2, in which an access tract measuring up to 16 Fr was used; since then the mini-PCNL with access tracts measuring from 12-20 Fr has been performed and developed around the world[2]. This allows more choices for the localization of stone and surgery positions, resulting in less post-operative pain, less bleeding, less potential renal failure and other kind of complications; it also is more effective for the patients. Cheng conducted a comparative study divided into two groups: mini-PCNL and PCNL and concluded that the mini-PCNL had a higher stone-free rate (85.2% compared with 70.0%, respectively) and a lower complication rate[3]. In 2013, Zeng examined and summarised 10,000 cases treated with the mini-PCNL; the results showed that the stone-free rate in respect of simple caliceal stones was 77.6%, and for complex stones, it was 66.4%[4]. Thakur performed the mini-PCNL on 60 patients with simple renal stones; showing the results that the stone-free rate after four weeks was 88.3% without considerable surgical accidents and complications; the patients' living quality was greatly increased[5].

In Vietnam, the mini-PCNL was first performed in 2012, and has since been carried out in a large number of health facilities. There have been reports and assessments on the efficiency and safety scale of this procedure. Do T.T reported the efficiency of the mini-PCNL treatment for 250 cases at the Vietnamese-Germany Friendship Hospital, with the stone-free rate of 80.7%[6]. In order to reduce complications caused by the procedure, we performed the operation in the lateral position, which has advantages of less effect on the respiration and circulation; this allows it to be carried out on kyphosis sufferers obese patients, and surgical accidents can be dealt with quickly. Using ultrasound guidance to locate the stone helps the procedure to be carried out simply, and avoids the adverse effects of X-ray location on a fluorescent screen.

In our hospital, the standard-PCNL is well performed. In addition, we have been performing the mini-PCNL since 2017. With a view to assessing the efficiency and safety scale of the method, we have conducted this study and reported the results of the ultrasound-guided mini-PCNL performed in a lateral position, at the Ha Noi Hospital of Post and Telecommunications.

OBJECT AND METHOD

We conducted a prospective, cross-sectional study on 1200 patients, who were treated using the mini-PCNL in a lateral position under ultra-

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sound guidance, which took place at the Ha Noi Hospital of Post and Telecommunications in Viet Nam from March 2018 to March 2020. The following criteria were used for selecting patients: Size of stone > 2 cm, located at the renal pelvis or calyx of kidney; upper ureteral stones; patients who had undergone a prior failed ESWL, or did not agree to be treated with ESWL. Patients with urinary tract infections (UTIs) were cured with antibiotics, and patients with serious illnesses were excluded before performing the procedure. All the patients were given clear information and agreed to participate in the study. Patients were given basic preoperative tests to assess the location and size of stones, the shape of the calyx and pelvis, as well as other overall tests such as haematology and serum biochemistry. One month after the surgery, all the patients underwent a radiography or ultrasound scan and were re-examined.

Operation techniques: First, the patient was general anesthesia, placed in the obstetric position where a performed ureteroscopy, and intubated 7 Fr ureter catheters into the renal pelvis. The patient was then turned 90 ⁻ to the lateral position, and the stones location was identified. A needle measuring 20 cm was punctured through the calyx of kidney or renal pelvis to the stone: The target signal was a urine flow through the needle or injected sterile saline through ureter catheter and the water flowed through the needle afterward, the feeling of needle touched into the stones. Placed PCNL guide wires through the exploration needle. An incision of 6-7 mm in length was made, and then the tunnel was dilated by the access tracts from 8 to 18 Fr. An Amplatz sheath was introduced into the calyx of kidney - renal pelvis. We examine the calyx of kidney and renal pelvis via the Amplatz sheath, to determine the location of the stone. The stone fragmentation was performed by laser, at an 80W power setting. The stone fragment removal was carried out via the Amplatz. Having checked the calyx of kidney and renal pelvis, a double-J stent was placed between the renal pelvis - ureter. A plastic tract of 16Fr was then inserted for kidney drainage.

Criteria for assessing stone-free status: According to the 2015 Guidelines of the European Association of Urology (EAU), the stone-free status was defined as when no residual stones were detected on plain X-ray photographs of the urinary system after the surgery, or there were residual stone fragments of less than 4 mm in size. "Residue of stone" status refers to cases where one or more stone fragments of more than 4mm in size were detected, and the patient continued to be treated in association with other methods[7]. In this study, we assessed the stone-free status based on the postoperative tests, including an ultrasound scan and radiography.

Data handling and collection: The data were collected and processed by SPSS 20.0, using a statistical algorithm. The T-test and Fisher test were used to verify the difference. A comparative value was considered statistically different when $p < 0.05$.

Table 1: Patients' pre-operative indicators (n = 1200)

Indicators		Number of patients	%
Mean age (years old)		40.3 ± 7.4[21-91]	
Mean size of stone (mm)		18.7 ± 1.3[12-65]	
Underwent an open renal surgery		29	2.4
Single kidney		8	0.7
Location of stone	Upper ureteral stones	181	15.1
	Renal pelvis stone	375	31.2
	Calyx of kidney stone	349	29.1
	Staghorn stone	195	16.3
	Multi-position stone	100	8.3
Hydronephrosis	Non-hydronephrosis	178	14.8
	Degree 1	372	31
	Degree 2	512	42.7
	Degree 3	138	11.5
Total	1200	100	

STUDY RESULT

The results achieved by the study on 1200 patients treated with the ultrasound-guided mini-PCNL in the lateral position are shown in table 1:

The mean age of the study group was 40.3 ± 7.4 [21-91], of whom the eldest patient was 91 years old. The mean size of the stone was 18.7 ± 1.3 [12-65] mm, of which the biggest was 65 mm. Most of the cases were a single stone of the renal pelvis, accounting for 31.2%; the rate of calyx of kidney stone was 29.1%; and the rate of multi-position stone accounted for 8.3%; the rate of staghorn stone was 16.3%. Among those treated with this procedure, there were 8 patients (0.7%) who had a single kidney only and 29 patients (2.4%) who had undergone previous surgery for renal stone removal.

Table 2: Puncture process (n = 1200)

Indicators	Variables	Number of cases	Rate (%)
Positions	Upper calyx of kidney	70	5.7
	Middle calyx of kidney	740	60
	Lower calyx of kidney	422	34.3
Signals the exploration needle was in the calyx of kidney	Needle touching the stone	867	70.4
	Inject sterile saline through ureter catheters	249	20.2
	Suck the water through exploration needle	116	9.4
Numbers of tunnels created/patients	One tunnel	1172	97.7
	Two tunnels	24	2
	Three tunnels	4	0.3
Surgical accidents	Surgical bleeding	19	1.6
	Failed to place double-J stent	14	1.2
	Other accidents	0	0
Time	Mean operative time	44.3 [35-90] minutes	

Hydronephrosis degree 1 accounted for 31%. We saw a large number of patients with hydronephrosis degree 2 (42.7%), while patients with non-hydronephrosis accounted for 14.8%.

The middle calyx of kidney was the most common renal puncture site, accounting for 60%; the lower calyx of kidney accounted for 34.3%, and the upper calyx of kidney 5.7% only, including cases that needed multi-punture times for more than one tunnels.

The signs of definitely determining that the needle had entered the calyx of kidney or renal pelvis were: when it touched the stones (70.4%), and pumping water via the ureter catheters (20.2%).

Most of the patients needed only one tunnel for the procedure (97.7%). There were 2% patients who needed two tunnels for the procedure and 4 patients (0.3%) needed 3 tunnels.

In the study, we saw a large number of bleeding accidents: in 19 patients, accounting for 1.6%. Besides, there were 1.2% of cases, who failed to place a double-J stent. The mean operative time was 44.3[35-90] minutes: the shortest case was 35 minutes, and the longest was 90 minutes.

There were 8 patients, bleeding that needed vascular interventional therapy after the procedure, and well discharged. The most common complications were urinary infection, accounting for 7.8%; and septicaemia found in 11 patients (0.9%), who were then given a test for blood culture and treated with antibiotics according to the treatment regimen. Septic shock was found in 4 patients (0.3%) who needed intensive care.

The mean time for kidney drainage removal was 3.5 [2-10] days. The mean period of hospitalisation was 3.8 [3-12] days. The longest period was 12 days, seen in the patient with septic shock.

The upper ureteral stone and single renal pelvic stone accounted for a high stone-free rate, 99.4% and 98.9%, respectively. A simple calyx of kidney stone had a relatively high stone-free rate of 95.4%. For multiple

Table 3: Post-operative care (n = 1200)

Indicators	Variables	Patients	Rate (%)
Post-operative complications	Bleeding that needed vascular interventional therapy after the procedure	8	0.7
	Fever, urinary infection	94	7.7
	Fever, septicaemia	11	0.9
	Septic shock	4	0.3
	Total	117	9.7
Post-operative care	Time for kidney drainage removal	3.5 [2-10] days	
	Mean period of hospitalisation	3.8 [3-12] days	

Table 4: Stone-free rate (n = 1200)

Stone location	Total number of patients	Stone-free	Rate (%)
Upper ureteral stones	181	180	99.4
Renal pelvis stone	375	371	98.9
Calyx of kidney stone	349	333	95.4
Staghorn stone	195	167	85.6
Multi-position stone	100	47	47
Total	1200	1098	91.5

stone renal pelvis and calyx of kidney, the stone-free rate was very low (47%). There were 45 patients (3.8%) who were administered a second mini-PCNL, 25 patients then had recourse to ESWL, accounting for 2.1%. The difference was statistically significant at $p < 0.05$.

DISCUSSION

Urinary stones are a common disease throughout the world; according to the European Association of Urology (EAU) in 2015, the risk of an individual developing a kidney stone during their life is about 5% - 10%. Among patients with urinary stones, kidney stones account for about 70% - 75% at the age of 30 to 60. In our study, the mean age of patients was 40.3 ± 7.4[21 1] years old (Table 1). A couple of other studies have given the same results, for instance: in Do T.T 's study, it is 47.13 ± 24.31 (22-85) years old; in Akbulut's study: 44.4 ± 12.6 years old[6,8].

The mean size of stone in our study was 18.7 ± 1.3 [12 - 65] mm (Table 1). According to the European Association of Urology (EAU, 2015), the mini-PCNL is recommended as a choice of treatment for big stones (> 20 mm) and smaller stones (10-20 mm),where treatment failed in ESWL or ESWL was contraindicated[7].

The common location of stones in our study was renal pelvic stones, accounting for 31.2%; simple calyx of kidney stone: 29.1%; staghorn stones: 16.3% and multiple stones renal pelvis and calyx of kidney accounted for : 8.3%. We indicated the mini-PCNL procedure for patients with large upper ureteral stones (> 15 mm) or who had undergone a failed ESWL, this group accounted for 15.1% (Table 1). Abdelhafez conducted a study in 2012, recording 61.4% of complex stones and 38.6% of single stones[9].

Hydronephrosis degrees 1, 2 and 3 for the patients in our study group were 31%, 42.7% and 11.5%, respectively (Table 1). In Samad Zare's study, the respective degrees of hydronephrosis were 23.2%, 16.8% and 7.2%[10].

In the mini-PCNL procedure, we chose the lateral position under the ultrasound guidance, in accordance with clinical facts and previous studies. In a comparative study by Zhu on three groups of patients using ultrasound guidance, fluoroscopic guidance and a combination of ultrasound and fluoroscopic guidance, gave the same result but affirmed that the ultrasound guidance helped to avoid radiation[11]. Wang's study reported on 3019 patients, 1574 of whom were operated using ultrasound guidance and 1445 under fluoroscopic guidance; it concluded that apart from the X-ray exposure, the patients under ultrasound guidance had a reduced blood loss rate, a reduced rate of complications, a shorter time of tunnel creation and a higher stone-free rate[12]. Knoll indicated that because the ultrasound guidance helped to easily observe internal organs, therefore damage to the large intestine, liver or spleen could be avoided[13]. Pan *et al*. studied 100 patients, divided into two groups, the prone and lateral positions. They concluded that both positions affected the circulation and arterial blood gas; however, the lateral position saw smaller changes in blood gas and haemodynamics[14]. The lateral position was familiar, allowing the surgeon to quickly deal with intra-operative complications.

The localisation of the puncture site is of importance when performing the mini-PCNL procedure, as it ensures better control and stone clearance, as well as a reduced risk of complications. The localisation of the puncture site depends on the location and size of stones, and also the complexion of the urinary system. The most appropriate puncture line is that which least damages the veins and internal organs; it is the perpendicular line to the back side outside the kidney, into Brodel's bloodless line. This puncture line will approach mainly the middle and lower calyxes. In our study, the middle calyx of kidney puncture accounted for 60%; the lower calyx of kidney puncture accounted for 34.3%, and the upper calyx of kidney puncture accounted for 5.7%, including the cases that needed two or three tunnels (Table 2). The advantage of the middle calyx of kidney puncture is that it helps to effectively monitor the calyx of kidney and renal pelvis. In Akbulut's study, the middle calyx of kidney puncture accounted for 9.1%, the lower calyx of kidney puncture 90.1%; there were no cases for upper calyx of kidney puncture[8]. In 2012, Abdelhafez reported on 83 patients treated with the mini-PCNL, in which the upper calyx of kidney puncture accounted for 4.8%, the middle calyx of kidney puncture 10.8%, and the rest was the lower calyx of kidney[9]. For simple stones, the puncture into the calyx of kidney, renal pelvis to directly approach the stones is the best way to the stone fragmentation, and to limit damage and complications. In our study, there were 70.4% of cases directly approached to calyx of kidney and renal pelvis ,determined by the feeling/sign that the needle touched the stone. Derek B. H studied 32 cases treated using the mini-PCNL, which consisted of 21.8% of lower calyx of kidney stones, 9.3% of middle calyx of kidney stones, 9.3% of upper calyx of kidney stones and 56.25% of real pelvic stones. There were 75% of cases punctured at the lower calyx of kidney, 12.5% at the middle calyx of kidney and 12.5% the upper calyx of kidney[15].

For staghorn stones or multiple stones, in many cases, we needed to create more than one tunnel to approach the stones. In our study, the rate of one tunnel created were 97.7%, two tunnels: 2% and three tunnels: 0.3% for stone clearance. Zhu studied 147 patients with a simple stone rate that accounted for 90.5%, and complex stones accounted for 9.5%. Respectively, 9.5% of cases needed more than one tunnel, of which cases of two tunnels accounted for 8.7% and three tunnels accounted for 0.7%[11]. The reason for creating more than one tunnel to approach the stone in respect of staghorn or multiple stones was to ensure the highest stone-free rate.

Surgical accidents: The most common surgical accidents we observed during the performance of the procedure were haemorrhage, accounting for 1.6%; failure to place the double-J stent: 1.2%; no other types of complication. For the 1.6% of patients who bled while performing the procedure, we assessed the whole status of the patients and the stones in order to decide the next decisions: All the patients ceased the surgeries and applied medical treatment, then a second mini-PCNL were performed. For those who failed to place double-J stents, we changed the patients' position and successfully inserted the double-J stents by the RIRS procedure. When studying 250 patients, Do T.T found that haemorrhage occurred in 3.6% of cases that ceased the procedure and who were administered a second mini-PCNL; there were no cases that had recourse to open surgeries; 4.4% of cases failed to place double-J stent that required a double-J stent to be placed by the RIRS procedur[6].

For patients who were successfully punctured and had tunnels created and stones approached, the mean operative time was 44.3 [35-90] minutes, of which the longest was seen for the patients with staghorn stones (Table 2). The operative time depended on the size and location of stones and the surgeon's experience. According to Derek B. H's study on 32 patients, the mean operative time was 50 (40-82) minutes with the mean stone size of 17 mm[15]. According to Abdelhafez's study in 2012 on the mini-PCNL procedure, the average size of the stone was 36.7 ± 23.37 mm, and the mean operative time was 99.2 ± 48.3 minutes[9].

Stone-free rate: In our study group, the mean stone-free rate was 91.5%, of which patients with upper ureteral stones showed the highest stone-free rate 99.4%; the patients with a simple renal pelvic stone showed a stone-free rate of 98.9%; the patients with calyx of kidney stones showed a stone-free rate of 95.4%; those with staghorn stones

recorded a stone-free rate of 85.6%; and patients with multiple, complex stones occupying the calyx of kidney and renal pelvis showed the lowest stone-free rate of 47%. There were 25 patients who experienced residual stones and who were managed by the ESWL, accounting for 2.1%. The number of patients found with residual stones that were administered a second mini-PCNL accounted for 3.8% (Table 4).There was a difference between simple stones and complex stones (multiple stones occupying the calyces and renal pelvis, staghorn stones) ($p < 0.05$). In 2012, Abdelhafez reported that for 83 cases treated with the mini-PCNL, the stone-free rate was 78.3% at the first operation, 14 cases (16.9%) needed other methods, and 4 cases (4.8%) were administered a second mini-PCNL. There was a significant difference in the stone-free rates between simple stones and staghorn stones: 96.9% as compared with 66.7%, respectively ($p < 0.05$)[9]. For upper ureteral stones (> 15 mm), the stone-free rate was 99.4%. We chose the mini-PCNL procedure for this type of stone, instead of the RIRS, to limit the rate of residual stones. The advantages of the mini-PCNL over the RIRS in the treatment of upper ureteral stones (≥ 15 mm) were studied by Gu XJ in 2013, who found the stone-free rates of 93.3% and 41.4%, respectively[16]. According to Abdelhafez's report in 2013, the mini-PCNL seems more effective for the treatment of smaller stones (< 20 mm) as compared with bigger stones (> 20 mm), with the stone-free rates of 90.8% and 76.3%, respectively[17]. Zeng's study showed the same result, with the stone-free rate for simple stones and complex stones being 77.6% and 66.4%, respectively ($p < 0.05$). The difference gradually decreased for second mini-PCNL treatments or other interventions, showing the stone-free rates of 86.7% and 86.1% ($p > 0.05$)[4]. Zhu studied and indicated that there was a link between the stone-free rate and the complexity of stones[11]. According to Özgör, who studied 360 cases with calyx of kidney stones, the stone-free rate after mini-PCNL treatment reached 84.7%[18].

Complications: The post-operative complication rate of our study group was 9.7%, mostly consisting of fever caused by infections, of which urinary infection was contracted by 7.8% and blood infection was 0.9%. These patients underwent tests for blood culture, urine culture, and were given antibiotics according to the treatment regimen, resulting in a good result. There were 0.3% of patients developed septic shock and received intensive care producing good progress. There were 8 patients who experienced bleeding via urinary sonde, kidney drainage in the postoperative period; their veins were X-rayed, and venous interventions applied and were then discharged (Table 3). Derek B. H studied 32 cases given the mini-PCNL treatment and found that 3 cases (9.3%) developed complications: 1 patient contracted urinary infection (3.1%), 1 patient developed haemorrhage and received medical treatment, 1 patient developed septic shock and received intensive care[15]. When studying 250 patients, Do .T.T found that complications occurred in 5.2% of cases, including 1 case of post-operative haemorrhage that was managed by venous intervention, 8 cases of fever caused by an infection that were given antibiotics, and 3 cases of septic shock that was managed by intensive care[6]. In our study, no case of complications related to the digestive system in the postoperative period or pleural lesions were observed. This result was partly due to the experiences of the surgeon, and partly because of the position and the ultrasound guidance, which helped to reduce the related complications. Zhu studied 147 cases and found that post-operative complications occurred in 11.5%, mostly consisting of postoperative fever (4.8%), septic shock (0.7%) and haemorrhage that needed venous intervention (0.7%)[11].

In this study, we placed kidney drainage in all the patients, in accordance with experiences and previous studies. In our opinion, placing kidney drainage helps the circulation of the urinary tract; to limit complications or if any, monitor and deal with them better. We removed the kidney drainage based on the progress of the patient; the mean-time of kidney drainage removal was 3.5[2-10] days. In the study by Do T.T, all 250 patients were placed kidney drainage, and the mean-time of kidney drainage removal were 2.87 ± 1.43 days[6].

The mean length of hospitalisation of the study group was 3.8[3-12] days; the longest stay was observed for the patient with septic shock and received intensive care (Table 3).The study by Mishra indicated that the lengths of hospital stay of the mini-PCNL were 3.2 ± 0.8 days[19]. Zhu studied 147 cases given the mini-PCNL treatment and found that the mean length of hospitalisation was 5.5 ± 2.1 days[11]. The length of hospitalisation is linked with the size, location of the stones and patients complications. Thakur studied 60 cases given the mini-PCNL treatment for simple stone of < 20 mm, mean size: 14.4 (8-20 mm), and found that the mean length of hospitalisation was 58.22 (46.0-96.2) hour[5].

CONCLUSION

Through this study, we have demonstrated that the ultrasound-guided mini-percutaneous nephrolithotipsy in the lateral position is an effective and safe method, especially for upper ureteral stones (> 15 mm) and simple stones. In our study, we assessed the results based on postoperative tests. The stone-free rate of the mini-PCNL procedure increased when associated with other methods of intervention or extended intensive care time for patients experiencing residual stones. As this procedure produces the advantages of a high stone-free rate and radiation avoidance, and with fewer complications, it is highly recommended that the mini-PCNL be continued, improved and widely applied at health facilities, to bring benefits for patients.

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