Comparison of the Outcomes between Ultrasound-guided PCNL in Lateral Position and Open Nephrolithotomy for Patients with Staghorn Renal Stones

Chaowat Pimratana, M.D., Udomsak Wijitsettakul, M.D., Phairot Cheunganuwat, M.D.

Department of Surgery, Buri Ram Hospital, Buri Ram 31000, Thailand.

ABSTRACT

Objective: To compare the clinical outcomes of ultrasound-guided percutaneous nephrolithotomy (US-PCNL) in lateral position and anatrophic nephrolithotomy (ANL) in the treatment of staghorn renal stones.

Methods: Between October 2016 and July 2020, individuals with staghorn renal stones undergoing an operation at Buri Ram Hospital in Thailand were included in this study. They were divided between group I (patients undergoing US-PCNL, n=114) and group II (patients undergoing ANL, n=112). The outcomes regarding stone-free rate (residual stone less than 4mm with asymptomatic), the stone clearance rate (the elimination rate of total stone surface after the operation), operative times, length of hospitalization, and complications were collected and analyzed.

Results: The patient's demographics and stone characteristics were not significantly different between the two groups, except that more preoperative hydronephrosis was found in the ANL group (78.6% vs. 53.5%, *p*<0.001). Regarding the primary outcome, the stone-free rate was significantly lower in the US-PCNL group (47.4% vs. 75.9%, *p*<0.001), whereas the stone clearance rate was not significantly different (96.4±6.0% in the US-PCNL group and 97.7±5.8% in the ANL group, *p*=0.098). No difference was found according to the major and minor complications between the US-PCNL and ANL groups; however, the US-PCNL group had a significantly lower transfusion rate than the ANL group (3.5% vs. 17.9%, *p*<0.001). The total operative time in both groups was not different; however, the length of hospitalization for the US-PCNL was significantly shorter than for the ANL group (10.0 vs. 12.9 days, *p*=0.002). A multivariate analysis revealed that the operative method was a significant factor associated with the stone-free rate (OR=5.96, 95%CI=3.06-11.62, *p*<0.001), blood transfusion (OR=5.75, 95%CI=1.84-18.03, *p*=0.003), and the length of hospitalization (F=10.27, *p*=0.002); while the percentage of stone clearance were not statistically different between the two operation methods (F=2.76, *p*=0.098).

Conclusion: The ANL had a higher stone-free rate for patients with staghorn stones; however, the stone clearance rate was not significantly different between the US-PCNL and ANL groups. The advantages of the US-PCNL over the ANL were less blood transfusion and shorter length of hospitalization, while the complications were not significantly different between the two operative methods.

Keywords: Staghorn renal stone; ultrasound-guided percutaneous nephrolithotomy; anatrophic nephrolithotomy; lateral position (Siriraj Med J 2021; 73: 191-197)

Corresponding author: Chaowat Pimratana

E-mail: pchaowat@gmail.com

Received 14 September 2020 Revised 17 December 2020 Accepted 4 February 2021

ORCID ID: http://orcid.org/0000-0003-3754-774X

http://dx.doi.org/10.33192/Smj.2021.25

INTRODUCTION

Renal stones are a common disease, especially in the northeast and the north of Thailand. At Buri Ram Hospital, we are familiar with anatrophic nephrolithotomy (ANL) for staghorn renal stones treatment. ANL was once considered as the "gold standard" for the treatment of staghorn renal stones and it was used as the benchmark for other treatment. An excellent stone-free rate can be achieved with ANL; therefore, ANL is still the operation of choice for large stone treatment in some regions in the world.[1] Currently, percutaneous nephrolithotomy (PCNL) is the main surgical treatment for large renal stones. Most urologists are familiar with the use of fluoroscopy guidance during the percutaneous renal access; however, radiation exposure from fluoroscopy might cause potential long-term adverse effects for patients and medical personnel.[2] Given the concerns regarding cumulative radiation effects, ultrasound (US)-guided renal stone access is a reliable alternative imaging method to PCNL for avoiding ionizing radiation exposure.[3] Interestingly, US-guided renal stone access has not been adopted worldwide; this technique has been widely used only in Asia.[4-8] We have successfully performed US-guided PCNL (US-PCNL) in our hospital for renal stone treatment since 2014. However, the most appropriate treatment option for staghorn renal stones is still under debate, and some authors suggest that open renal stone surgery, such as ANL, should be used for staghorn renal stones.[9,10] There have been several comparative studies that have presented the outcomes of fluoroscopic-guide PCNL; however, there are few studies analyzing the outcomes of US-PCNL for the treatment of staghorn renal stones.[9] Therefore, the objective of this study is to compare the treatment outcomes of US-PCNL with ANL.

MATERIALS AND METHODS

This historical cohort study was conducted at Buri Ram Hospital, Buri Ram, Thailand. All of the studied patients were operated on by three board-certified urologists who had more than 3 years of experience in US-PCNL. After the study was approved by the ethics committee of Buri Ram Hospital (BR 0032.102.1/40) and registered in the Thai Clinical Trials Registry (TCTR20200806002), the clinical data of all the patients that were diagnosed with staghorn renal stones larger than 2.5 cm and requiring treatment with US-PCNL or ANL from October 2016 to July 2020 were collected. The size of the stones was maximum stone length in preoperative plain film radiograph of the kidneys, ureters, and bladder (KUB) and the degree of hydronephrosis was evaluated by imaging studies which included intravenous pyelography, ultrasonography, or computed tomography. Patients who loss to follow-up after 3 months were excluded.

Based on the data of previous study, which reported a 61% stone free rate in the ANL group and 41% in US-PCNL group[9], the sample size was calculated using a power of 90% and a significance level of 0.05. Our sample size calculation revealed a minimum sample size of 103 patients in each US-PCNL group and ANL group with an additional 10% of subjects in order to accommodate the projected dropout rate. A total of 226 patients that met the criteria were enrolled. One hundred and fourteen patients that had undergone US-PCNL were categorized into group I and 112 patients that had undergone ANL were categorized into group II.

Surgical technique

Group I (US-PCNL)

Under general anesthesia, a 5 French ureteral catheter was placed via a rigid cystoscope in the lithotomy position in all PCNL patients. Percutaneous access was performed in a lateral position. The stone position was identified using ultrasound. We gave the patients normal saline via a ureteral catheter for artificial hydronephrosis if the pelvicalyceal system of the kidneys was not dilated. Renal puncture was carried out with an 18-gauge needle under an ultrasound needle guide. Alken's coaxial telescopic metal dilators were used to dilate the tract up to 27 French size over a guide-wire; then a 30 French Amplatz sheath was placed for the percutaneous access port. A 26 French rigid nephroscope was applied and the stone was disintegrated with an ultrasonic and pneumatic lithotripter. For the complex staghorn renal stones occupying several calyces, a second tract was created using the same technique. A nephrostomy tube was placed at the end of the operation for 24 to 48 hours.

Group II (ANL)

Under general anesthesia, a flank incision was performed in a lateral position. Gerota's fascia and perinephric fat were carefully dissected off the renal capsule. The renal artery and vein were identified and cross clamped with Satinsky's vascular clamps. Sterile iced slush normal saline was packed into the perirenal space in order to maintain regional hypothermia after the renal vessels were occluded. The kidney was incised at the lateral border along Brodel's line and the stones were removed. Renal parenchyma and calyces were repaired with 3-0 chromic catgut. The renal capsule was closed with 2-0 chromic catgut.

The stone-free rate was evaluated 3 months after surgery with a plain KUB film. The results were classified as stone free status, clinically insignificant residual stone fragments (CIRFs) ≤ 4 mm, nonobstructive, noninfectious, and asymptomatic.[11] The stone clearance rate was defined as the elimination rate of total stone surface after the operation. Other outcomes including total operative time, length of hospitalization, blood transfusion, and complications (grade I-V according to Clavien-Dindo classification)[12] were collected and analyzed.

Statistical analysis

Continuous variables were expressed as mean ± standard deviation or median (range) and analyzed between group I and group II by using a t-test or the Mann-Whitney U test. The categorical data were expressed as number and percentage and were compared using a chi-squared test or Fisher's exact probability test. Factors potentially associated with the operative outcomes were included in a multivariate model of logistic regression to test their prediction on stone-free status and blood transfusion. The odds ratio (OR) with 95% confidence intervals (95%CI) for each variable was determined. In addition, this study used a multivariate analysis of variance (MANOVA) to test the differences between the two operative methods on the two key operative outcomes which were the stone clearance rate and the length of hospitalization. A p-value of <0.05 was considered statistically significant.

RESULTS

A total of 226 patients were included, with US-PCNL performed on 114 patients and ANL performed on 112 patients. The patient demographics and stone characteristics of the US-PCNL and ANL groups were similar except that the preoperative hydronephrosis was higher in the ANL group, as summarized in Table 1.

The operative outcomes were shown in Table 2. In terms of the primary outcome, the stone-free rate was significantly lower in the US-PCNL group (47.4% in the US-PCNL group and 75.9% in the ANL group, p<0.001), whereas the stone clearance rate was not significantly different between the two groups (96.4±6.0% in the US-PCNL group and 97.7±5.8% in the ANL group, p=0.098). The US-PCNL group exhibited a significantly lower transfusion rate than the ANL group. The total operative times for both groups were not different, but the average length of hospitalization for the US-PCNL was significantly shorter than for the ANL group. There was no significant difference in the major and minor complications according to the Calvien-Dindo classification between the groups, as summarized in Table 3. A multiple logistic regression showed that the operation method was a significant factor associated with stone-free status and blood transfusion. The odds of the patients who undergone ANL method to obtain a stone free status were 5.96 times greater than the odds of those who undergone US-PCNL method (OR=5.96, 95%CI=3.06-11.62, p<0.001). On the other hand, the odds of the patients who undergone ANL method to received blood transfusion were 5.75 times higher than those who undergone US-PCNL method (OR=5.75, 95%CI=1.84-18.03, p=0.003) as shown in Table 4, 5. A multivariate analysis of variance (MANOVA) was used to test the effect of operative methods on stone clearance rate and length of hospitalization. The multivariate test using Pillai's criterion revealed a significant main effect of operation methods on dependent variables (MANOVA: F=6.61, p=0.002). The univariate tests showed that the patients who undergone US-PCNL method had significantly shorter length of hospitalization than those who undergone ANL method (F=10.27, p=0.002) while the percentage of stone clearance were not statistically different between the two operation methods (F=2.76, p=0.098) as summarized in Table 6.

DISCUSSION

Staghorn renal stones are defined as stones that mandatorily fills the renal pelvis with an extension that branch into at least one caliceal group, and it may lead to the deterioration of renal function and life-threatening urosepsis.[13] Complete stone removal is an important therapeutic goal in order to eradicate further infection, urinary tract obstruction, and recurrent renal stone formation. Complete stone removal is also crucial for the preservation of kidney function.[14] ANL is one of the best options for staghorn stone removal and is considered the benchmark for other treatments because of the high stone elimination rate[9,10]; however, there is a possibility for reduction in renal function due to parenchymal incision and ischemic injury.[1] Currently, most patients with staghorn renal stones can be managed using minimally invasive surgery such as PCNL. Fluoroscopic guidance is the mainstay imaging for the renal access step in PCNL, but it can cause radiation exposure in patients and medical personnel.[3] Ultrasound guidance is a reliable alternative type of imaging for direct PCNL. It can minimize radiation exposure and there is no need for contrast media. Moreover, it can prevent adjacent visceral organ injury and can be performed in any patient position.[2] However, the absence of staghorn stones has been associated with successful US-PCNL[2] as the ideal candidate for US-PCNL is a generally healthy, non-overweight patient with at least moderate hydronephrosis in non-staghorn renal stones on imaging.[15]

TABLE 1. Demographic characteristics of the patients in the US-PCNL and ANL groups.

	Group I US-PCNL (n=114)	Group II ANL (n=112)	*p*-value
Mean age, year	56.4 ± 10.1	53.7 ± 12.3	0.069
Gender			
Male sex no. (%)	69 (60.5)	59 (52.7)	0.234
BMI, kg/m^2	23.4 ± 3.2	22.9 ± 4.2	0.289
Laterality			
Right side no. (%)	57 (50.0)	67 (59.8)	0.138
Stone length, mm	55.3 ± 12.9	58.2 ± 22.4	0.236
Stone surface area, mm^2	1677.4 ± 781.8	1885.2 ± 1284.1	0.144
Preoperative hydronephrosis no. (%)	61 (53.5)	88 (78.6)	<0.001
Preoperative urine culture positive no. (%)	27 (23.7)	22 (19.6)	0.461

TABLE 2. Comparisons of operative outcomes in the US-PCNL and ANL groups.

	Group I US-PCNL (n=114)	Group II ANL (n=112)	*p*-value
Operative time, min	123.1 ± 43.3	133.1 ± 48.7	0.107
Length of hospital stay, days	10.0 ± 6.5	12.9 ± 6.9	0.002
Residual stone > 4 mm, no. (%)	60 (52.6)	27 (24.1)	<0.001
Stone free status no. (%)	54 (47.4)	85 (75.9)	<0.001
Residual stone area, mm^2	69.6 ± 17.5	25.4 ± 4.7	0.016
Stone clearance rates	96.4 ± 6.0	97.7 ± 5.8	0.098
Blood transfusion	4 (3.5)	20 (17.9)	<0.001

TABLE 3. Comparisons of postoperative complications in the US-PCNL and ANL groups.*

	Group I US-PCNL (n=114)	Group II ANL (n=112)	*p*-value
Minor complication (grade I-II) no. (%)	46 (40.4)	59 (52.7)	0.063
Transient fever	45 (39.5)	51 (45.5)	0.357
Failed renal access	2 (1.7)	NA	NA
Minor renal pelvic perforation	1 (0.88)	NA	NA
Serious complication (grade III-IV) no. (%)	6 (5.3)	6 (5.4)	0.975
Visceral organ injury	0	0	
Pneumo/hemothorax	0	0	
Septic shock	5	6	
Postoperative ureteral obstruction	1	0	

*Complications are defined according to Clavien-Dindo classification grade I-V.
Abbreviation: NA = Not applicable

TABLE 4. Multiple logistic regression results for stone free status.

	Odds ratio	95% CI Lower	Upper	*p*-value
Operation (ANL=1, US-PCNL=0)	5.962	3.059	11.620	<0.001
BMI	1.132	1.033	1.241	0.008
Stone size	0.986	0.970	1.003	0.099
Preoperative hydronephrosis (Yes=1, NO=0)	0.329	0.166	0.653	0.001

TABLE 5. Multiple logistic regression results for blood transfusion.

	Odds ratio	95% CI Lower	Upper	*p*-value
Operation (ANL=1, US-PCNL=0)	5.754	1.837	18.030	0.003
BMI	0.954	0.847	1.074	0.435
Stone size	1.003	0.983	1.024	0.745
Preoperative hydronephrosis (Yes=1, NO=0)	1.005	0.359	2.812	0.993

TABLE 6. Multivariate and univariate analysis of variance (MANOVA) results of stone clearance rate and length of hospitalization.

Variable	Multivariate			Univariate % Clearance			Hospitalization		
	F	*p*	η_p^2	*F*	*p*	η_p^2	*F*	*p*	η_p^2
Operation	6.61	0.002	0.006	2.76	0.098	0.012	10.27	0.002	0.044

Several studies have reported successful stone treatment according to the stone free-rate or stone clearance rate.[9,16,17] One of the measures of the stone free rate is by measuring the parameters that are associated with stone burden, including stone diameter, stone surface area, and stone volume.[18,19] Since there are currently no formal guidelines for the assessment of stone burden, in this study, we defined the stone-free rate as having no residual stones or a stone diameter less than 4 mm after the operation, and the stone clearance rate as the ratio of the elimination of the stone surface area after the operation.[11] Our study found that the stone-free rate in the ANL group was significantly higher than in the US-PCNL group (75.9% vs. 47.4%). Our outcomes were similar to the study of Friedrich and colleagues, which reported a 63.7% stone free-rate in open stone surgery and 40.9% stone free-rate in US-PCNL.[9] These results also align with a recent meta-analysis study of the standard PCNL method, which showed a significantly lower stone-free rate in comparison with open renal stone surgery.[10] However, it should be noted that the low stone-free rate in our US-PCNL group was because we did not use fluoroscope to detect residual stones in this group. Fluoroscope was not used in order to avoid radiation according to the as-low-as-reasonably achievable (ALARA) principle.[20] It is worth noting that our US-PCNL patients had a large stone burden (55.3 mm length and 1677 mm^2 surface area) and fewer hydronephrotic kidneys (53.5%). These factors are considered to increase difficulty for US-PCNL.[4]

The stone clearance rate between the US-PCNL and ANL group in this study was not significantly different (96.4±6.0% vs. 97.7±5.8%, p=0.098), which means that the postoperative residual stones in the US-PCNL group were slightly larger than 4 mm and needed only noninvasive auxiliary treatment such as extracorporeal shock wave lithotripsy (ESWL) to achieve stone-free status.

In the present study, the operative time was not significantly different between the US-PCNL and ANL groups (123.1 vs. 133.1 min). The operative time of the US-PCNL in our study was not shorter than open surgery when compared to other studies because we began the operation when the general anesthesia was administered, while several studies usually count the time at the renal access step.[9,17] The US-PCNL patients had a shorter length of hospitalization than the ANL patients (10.0 vs. 12.9 days), which is similar to the study of Chen and colleagues.[10] The overall complications in both groups were not significantly different. The important finding of our study was that the US-PCNL group had a significant lower transfusion rate than the ANL group (3.5% vs. 17.9%, $p < 0.001$) and no pulmonary or visceral complications were presented in the US-PCNL group. Ultrasonography has the advantage of providing real time visualization of the kidneys and surrounding visceral organs and structures causing a lower risk of pulmonary or visceral complications compare to the standard PCNL. Thus, the US-PCNL method is superior to the standard PCNL method, which is prone to causing complications regarding the surrounding organs.[2,15]

One of the key advantages of this study was an adequate number of participants for achieving a sufficient power for statistical analysis. In addition, our participants' renal stone characteristics and kidney condition differed from previous studies.[14] This research samples were from the northeast of Thailand which associated with a high prevalence of renal stones. Renal stones characteristics found in this region were more complicated because they had large stone burden. In addition, there were lower proportion of hydronephrotic kidney cases which make the surgery more difficult. In this study there were lower proportion of hydronephrotic kidney cases in the US-PCNL group, and there were large stone burden. Thus, the findings of this research are extremely useful for urologists who are operating in the northeast of Thailand or working with individuals with large stone burdens and non-hydronephrotic kidneys.

Our study had some limitations. First, it is a retrospective study, which may have affected the allocation of the patients to each treatment group. A prospective randomized study should be conducted in order to overcome this limitation in the future. Secondly, the use of stone length and stone surface area to define stone burden is not as accurate as stone volume from computed tomography calculation.[18] However, computed tomography is not available in clinical practice for postoperative stone evaluation because of the risk of radiation exposure and the cost-effective aspect[20], and currently, there are several studies that have used stone length or stone surface area for stone burden estimation.[9,10,16]

CONCLUSION

From our study, it could be seen that US-PCNL is a safe and feasible alternative in comparison with ANL for staghorn renal stone treatment. Although the ANL still had a higher stone-free rate, the stone clearance rate was satisfactory in both the US-PCNL and ANL groups. In addition, there were advantages of the US-PCNL over the ANL regarding less blood transfusion, and shorter length of hospitalization, while the complications were not significantly different between the two groups.

ACKNOWLEDGMENTS

The authors would like to thank Dr.Nisit Tongsiri from department of surgery, Sakon Nakhon hospital and Miss Vipavee Puttarawuttiporn for review of the manuscript and Miss Worarachanee Imjaijit from office of research development Phramongkutklao hospital and college of medicine for her kind assistance with statistical analysis.

Conflict of Interest: The authors declare that they have no competing interests.

REFERENCES

1. Abreu L de A dos S, Camilo-Silva DG, Fiedler G, Corguinha GB, Paiva MM, Pereira-Correia JA, et al. Review on renal recovery after anatrophic nephrolithotomy: Are we really healing our patients? World J Nephrol 2015;4:105-10.
2. Lojanapiwat B. The ideal puncture approach for PCNL: Fluoroscopy, ultrasound or endoscopy? Indian J Urol IJU J Urol Soc India 2013;29:208-13.
3. Baralo B, Samson P, Hoenig D, Smith A. Percutaneous kidney stone surgery and radiation exposure: A review. Asian J Urol 2020;7:10-17.
4. Usawachintachit M, Tzou DT, Hu W, Li J, Chi T. X-ray–free Ultrasound-guided Percutaneous Nephrolithotomy: How to Select the Right Patient? Urology 2017;100:38-44.
5. Chu C, Masic S, Usawachintachit M, Hu W, Yang W, Stoller M, et al. Ultrasound-Guided Renal Access for Percutaneous Nephrolithotomy: A Description of Three Novel Ultrasound-Guided Needle Techniques. J Endourol 2016;30:153-8.
6. Liu Q, Zhou L, Cai X, Jin T, Wang K. Fluoroscopy versus ultrasound for image guidance during percutaneous nephrolithotomy: a systematic review and meta-analysis. Urolithiasis 2017;45:481-7.
7. Ng FC, Yam WL, Lim TYB, Teo JK, Ng KK, Lim SK. Ultrasound-guided percutaneous nephrolithotomy: Advantages and limitations. Investig Clin Urol 2017;58:346-52.
8. Lertkachatarn S. Percutaneous nephrolithotomy (PCNL): Ultrasound guided puncture. J Prapokklao Hosp Clin Med Educ Cent 2005;22:189-96.
9. Zhang FB-Y, Lin W-R, Yang S, Hsu J-M, Chang H-K, Chen M, et al. Outcomes of percutaneous nephrolithotomy versus open stone surgery for patients with staghorn calculi. Urol Sci 2017;28:97-100.
10. Chen Y, Feng J, Duan H, Yue Y, Zhang C, Deng T, et al. Percutaneous nephrolithotomy versus open surgery for surgical treatment of patients with staghorn stones: A systematic review and meta-analysis. PLoS ONE 2019;14:e0206810.
11. Lingeman JE, Coury TA, Newman DM, Kahnoski RJ, Mertz JH, Mosbaugh PG, et al. Comparison of results and morbidity of percutaneous nephrostolithotomy and extracorporeal shock wave lithotripsy. J Urol 1987;138:485-90.
12. Clavien PA, Barkun J, de Oliveira ML, Vauthey JN, Dindo D, Schulick RD, et al. The Clavien-Dindo Classification of Surgical Complications: Five-Year Experience. Ann Surg 2009;250:187-96.
13. Klein I, Gutiérrez-Aceves J. Preoperative imaging in staghorn calculi, planning and decision making in management of staghorn calculi. Asian J Urol 2020;7:87-93.
14. El-Husseiny T, Buchholz N. The role of open stone surgery. Arab J Urol 2012;10:284-8.
15. Beiko D, Razvi H, Bhojani N, Bjazevic J, Bayne DB, Tzou DT, et al. Techniques – Ultrasound-guided percutaneous nephrolithotomy: How we do it. Can Urol Assoc J. 2020;14:E104-10.
16. Nualyong C, Sathidmangkang S, Woranisarakul V, Taweemonkongsap T, Chotikawanich E. Comparison of the outcomes for retrograde intrarenal surgery (RIRS) and percutaneous nephrolithotomy (PCNL) in the treatment of renal stones more than 2 centimeters. Thai J Urol 2019;40:9-14.
17. Pitujaturont K, Choonhaklai V. Early experience of supine PCNL in Rajavithi Hospital. Thai J Urol 2014;35:1-11.
18. Merigot de Treigny O, Bou Nasr E, Almont T, Tack I, Rischmann P, Soulié M, et al. The Cumulated Stone Diameter: A Limited Tool for Stone Burden Estimation. Urology 2015;86:477-81.
19. Winoker JS, Chandhoke RA, Atallah W, Gupta M. Morphometry scores: Clinical implications in the management of staghorn calculi. Asian J Urol 2020;7:78-86.
20. Cabrera F, Preminger GM, Lipkin ME. As low as reasonably achievable: Methods for reducing radiation exposure during the management of renal and ureteral stones. Indian J Urol IJU J Urol Soc India 2014;30:55-59.