ORIGINAL ARTICLE

A Modified Ultra-Mini-Percutaneous Nephrolithotomy (mUMP) Can Achieve Renal Stone-Free Rates Comparable to Conventional Tubeless Percutaneous Nephrolithotomy (tPCNL) for Certain Stone Sizes and Characteristics†

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Objective: To compare stone free rate results from modified ultra-mini-percutaneous nephrolithotomy (mUMP) and conventional tubeless percutaneous nephrolithotomy (tPCNL).

Materials and Methods: The present study was a retrospective cohort study in renal stone patients admitted at Sunpasitthiprasong Hospital, Thailand, between 2013 and 2021 by excluding patients with pregnancy, uncorrectable coagulopathy, and active urinary tract infection. Data was collected from 317 patients that matched criteria of patient characteristics, stone characteristics, intraoperative data, and surgical outcomes. The primary and secondary outcome were analyzed by assessing the stone-free rate immediately post-operative, within 24 hours, and at four weeks follow-up. This included perioperative data and subgroup analysis based on stone size of 20 mm or less and more than 20 mm.

Results: The group was separated into tPCNL with 184 patients and mUMP with 133 patients. The results of primary and secondary outcome of stone-free rates immediately post-operative and at follow up in tPCNL was 74.5% and 75% and in mUMP was 85% and 86.5%. When comparing stone size in subgroups of 20 mm or less, it was 100% in tPCNL and 95.5% in mUMP, however in the group of more than 20 mm stone, tPCNL was 71.3% and mUMP was 68.9%.

Conclusion: The mUMP is a safe and effective treatment compared to conventional tPCNL for stones of 20 mm or less. Furthermore, the mUMP group patients experienced less post-operative pain, shorter hospital stays, reduction of blood transfusions needs, lower irrigation volume required, and less postoperative urinary tract infection.

Keywords: Endoscopes; Kidney; Kidney calculi; Percutaneous lithotripsy; Percutaneous nephrostomy; Nephrolithotomy

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Renal stones are a common urological disease. Percutaneous nephrolithotomy (PCNL) is a standard treatment with stone clearance rates of at least 75% for renal stones larger than 2 cm and over 95% for stones between 1 and 2 cm. However, PCNL carries a risk of complications. To minimize these risks, smaller diameter instruments have been developed, leading to mini-PCNL and ultra-mini percutaneous nephrolithotomy (UMP). Conventional PCNL uses 24 to 30 Fr instruments, mini-PCNL uses 14 to 22 Fr, and UMP uses 11 to 13 Fr.

Desai & Solanki (2013)[1] performed UMP on 62 patients with moderate-sized renal stones of 20 mm or smaller and achieved an 88.9% stone-free rate after one day, indicating that UMP is safe and efficacious for these stones. Similarly, Datta et al. (2015)[2] and Agrawal et al. (2016)[3] performed UMP on patients with stones of 20 mm or smaller, with 94 and 120 patients, respectively, and reported stone clearance rates of 81% and 95% at 1-month follow-up.

In July 2020, Ahmadmusa[4] of the Division of Urology, Department of Surgery, at Yala Hospital conducted a retrospective study on modified mini-PCNL. Using a 22 Fr Amplatz sheath and at Sunpasitthiprasong Hospital, recognizing the need for more energy and lower pressure than the

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conventional UMP, as per Desai & Solanki, 2013[1], the authors performed modified UMP (mUMP) to enhance stone clearance. The authors' modifications included a released ultra-mini PCNL sheath for outer sheath from nephroscope for inner sheath body to apply larger LASER fiber between inner and outer sheath for the advantages of more energy applied and lower intrarenal pressure (Figure 1). Then a normal saline irrigation (NSS) was flushing via U-catheter and finally, a three ways stop cock adapted as a valve to irrigation fluid (Figure 2).

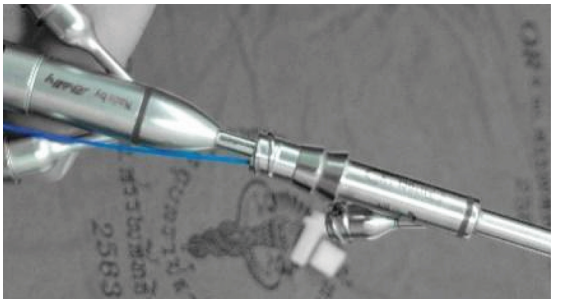

Figure 1. LASER fiber applied between inner and outer sheath for more energy.

Figure 2. Three ways stop cock adapted as a valve to irrigation fluid.

Objective

The present study aimed to compare stone free rate between mUMP and conventional tubeless PCNL (tPCNL).

Materials and Methods

The present study was a retrospective cohort study conducted at Sunpasitthiprasong Hospital, Thailand, between 2013 and 2021. It included renal stone patients admitted for either mUMP or conventional tPCNL. Staff surgeons performed the operations, and patient selection was based on surgeon preference. Exclusion criteria were pregnancy, uncorrectable coagulopathy, the need for multiple procedures in the same operation, and active urinary tract infection (UTI).

Patient characteristics such as gender, age, height, weight, body mass index, and underlying diseases and stone characteristics such as size, area, number, location, presence of diverticulum or hydronephrosis, and previous stone operations were recorded. The primary outcome was the stone-free rate at immediate post-operative, or within 24 hours and at 4-week follow-up. Secondary outcomes included operative time, intraoperative blood loss, intraoperative NSS use, post-operative pain, length of stay, re-operation rate, post-operative UTI, and Clavien-Dindo classification. The subgroup analysis was performed based on stone size of 20 mm or less and more than 20 mm.

The IBM SPSS Statistics, version 25.0 (IBM Corp., Armonk, NY, USA) were used to calculate the required sample size for the present case-control study. The calculation was based on the following assumptions. In the control group (tPCNL), an expected stone-free rate of 98%, derived from the study by Jung et al., 2022[5], which compared PCNL, extracorporeal shock wave (ESWL), and flexible ureterorenoscopy. In the intervention group (mUMP), the expected stone-free rate was 88.9%, based on Desai & Solanki (2013)[1] as Alpha 0.05 and Beta 0.20. By using these parameters, the calculation determined a minimum sample size of 102 patients per group, for a total of 204 patients. Statistical analysis was performed using IBM SPSS, version 25.0 . Data were analyzed using independent t-test to calculate mean ± standard deviation (SD), Mann-Whitney U test to calculate median and interquartile range (IQR), chi-square test or Fisher's exact test to express results in percentages (%) and univariable/multivariable logistic regression to calculate odds ratios (OR) with 95% confidence intervals (CI). A p-value of less than 0.05 was statistically significant.

Three hundred seventeen patients were identified from electronic medical records at Sunpasitthiprasong Hospital and met the inclusion criteria for the present study. These patients were divided into two groups, with 133 that underwent mUMP and 184 that underwent conventional tPCNL. Stone size was determined using preoperative kidney-ureter-bladder

Table 1. Demographics data

	mUMP (n=133)	tPCNL (n=184)	p-value
Sex; n (%)			0.302
Female	53 (39.8)	79 (42.9)	
Male	80 (60.2)	105 (57.1)	
Age (year); mena±SD	58.83±12.83	57.31±12.44	0.292
BMI; mena±SD	24.41±5.35	23.69±3.66	0.155
Patient height (cm); mena±SD	158.34±10.81	158.90±11.17	0.656
Kidney stone side; n (%)			0.584
Left	60 (45.1)	91 (49.5)	
Right	73 (54.9)	93 (50.5)	
Number of stone; n (%)			0.090
1	90 (67.7)	121 (65.8)	
2	25 (18.8)	19 (10.3)	
3	6 (4.5)	16 (8.7)	
4	4 (3.0)	12 (6.5)	
5	3 (2.3)	3 (1.6)	
≥6	5 (3.8)	13 (7.1)	
Size of stone sum of diameter (mm); median (IQR)	16 (10, 25)	34 (25, 47)	<0.001*
≤20; n (%)	88 (66.2)	24 (13.0)	<0.001*
Size area (mm^2); median (IQR)	99 (38, 231)	431 (258.5, 698)	<0.001*
Location; n (%)			<0.001*
Lower pole	69 (51.9)	47 (25.5)	
Middle	9 (6.8)	1 (0.5)	
Multiple	18 (13.5)	46 (25.0)	
Pelvis	23 (17.3)	81 (44.0)	
Upper pole	14 (10.5)	9 (4.9)	
Stone in diverticulum; n (%)	9 (6.8)	3 (1.6)	0.018*
Staghorn stone; n (%)	8 (6.0)	31 (16.8)	0.014*
Hydronephrosis; n (%)	37 (27.8)	129 (70.1)	<0.001*
DM; n (%)	21 (15.8)	22 (12.0)	0.967
HT; n (%)	32 (24.1)	51 (27.7)	0.534
Dyslipidemia; n (%)	17 (12.8)	19 (10.3)	0.463
CKD stage; n (%)			0.105
No	38 (28.6)	46 (25.0)	
Stage1	31 (23.3)	44 (23.9)	
Stage2	30 (22.6)	50 (27.2)	
Stage3	23 (17.3)	26 (14.1)	
Stage4	10 (7.5)	7 (3.8)	
Stage5	1 (0.8)	11 (6.0)	
Previous stone operation; n (%)			<0.001*
ANL	0 (0.0)	3 (1.6)	
ESWL	86 (64.7)	24 (13.0)	
PCNL	0 (0.0)	2 (1.1)	
None	47 (35.3)	155 (84.2)	

mUMP=modified ultra-mini-percutaneous nephrolithotomy; tPCNL=tubeless percutaneous nephrolithotomy; BMI=body mass index; DM=diabetes mellitus; HT=hypertension; CKD=chronic kidney disease; ANL=anatrophic; ESWL=extracorporeal shock wave lithotripsy; PCNL=percutaneous nephrolithotomy; SD=standard deviation; IQR=interquartile range

Independent t-test or Mann-Whitney U test and chi-square test or Fisher's exact test, * $p<0.05$ is considered statistical significance

(KUB) X-rays. The longest diameter on the X-ray was measured for each patient. Patients with stones measuring less than 4 mm on KUB were classified as stone-free. Ethics approval of the present research was given by Institutional Review Board (IRB) of Sunpasitthiprasong Hospital (020/65 R).

Results

The present study included 317 patients with 133 in the UMP group and 184 in the tPCNL group. Patient demographic data (Table 1) were comparable across both groups. However, significant differences were noted in stone characteristics (Table 1). The

Table 2. Primary outcome

	mUMP (n=133); n (%)	tPCNL (n=184); n (%)	p-value
Stone clear postoperative	113 (85.0)	137 (74.5)	0.024*
Stone clear at 4 weeks	115 (86.5)	138 (75.0)	0.012*

mUMP=modified ultra-mini-percutaneous nephrolithotomy; tPCNL=tubeless percutaneous nephrolithotomy
Chi-square test, * p<0.05 is considered statistical significance

Table 3. Secondary outcome

	mUMP (n=133)	tPCNL (n=184)	p-value
Operative time; median (IQR)	100 (80, 140)	90 (60, 120)	<0.001*
Estimate blood loss (mL); median (IQR)	50 (10, 100)	100 (50, 200)	<0.001*
Blood loss (hematocrit change); median (IQR)	−0.4 (−3, 0.3)	−2 (−3, 0.3)	0.586
PRC transfusion; n (%)	0 (0.0)	2 (1.1)	0.179
Length of stay (day); median (IQR)	3 (3, 4)	4 (4, 5)	<0.001*
Total saline use intraoperative (mL); median (IQR)	3,000 (2,000, 4,000)	14,500 (10,000, 22,000)	<0.001*
Wound infection; n (%)	0 (0.0)	0 (0.0)	N/A
Postoperative UTI; n (%)	11 (8.3)	68 (37.0)	<0.001*
Postoperative fever (°C); median (IQR)	37.43 ± 0.59	37.53 ± 0.53	0.646
Postoperative re-drainage; n (%)	0 (0.0)	0 (0.0)	N/A
Pain score day 1; median (IQR)	4 (3, 5)	5 (4, 7)	<0.001*
Pain score day 2; median (IQR)	0 (0, 0)	0 (0, 3)	<0.001*
Postoperative pain (total morphine) (mg); median (IQR)	3 (0, 6)	8 (3, 12)	<0.001*
Patient weight (kg); mean±SD	61.35±14.02	60.15±11.43	0.400
Morphine/weight (mg/kg); median (IQR)	0.05 (0, 0.1)	0.12 (0.05, 0.22)	<0.001*
Perioperative mortality; n (%)	0 (0.0)	0 (0.0)	N/A
Postoperative AKI; n (%)	0 (0.0)	3 (1.6)	0.139
Postoperative CKD; n (%)	0 (0.0)	1 (0.5)	0.394
Postoperative ESRD in 3 months; n (%)	0 (0.0)	1 (0.5)	0.394
Postoperative ICD; n (%)	0 (0.0)	0 (0.0)	N/A
Clavien-Dindo; n (%)			<0.001*
0	100 (75.2)	106 (57.6)	
1	11 (8.3)	46 (25.0)	
2	22 (16.5)	32 (17.4)	

mUMP=modified ultra-mini-percutaneous nephrolithotomy; tPCNL=tubeless percutaneous nephrolithotomy; PRC=; UTI=urinary tract infection; AKI=acute kidney injury; CKD=chronic kidney disease; ESRD=end-stage renal disease; SD=standard deviation; IQR=interquartile range; N/A=not available
Independent t-test or Mann-Whitney U test and chi-square test or Fisher's exact test, * p<0.05 is considered statistical significance

difference between these two groups was due to the mean stone size. In the mUMP group, the mean stone size was smaller at 16 (10, 25) mm compared to tPCNL at 34 (25, 47) mm. Additionally, the lower pole stones and stone in diverticulum were more common in the mUMP group because in the mUMP group, the patients failed from ESWL, while the tPCNL group had more stones within the renal pelvis. Finally, hydronephrosis was more prevalent in the tPCNL group. The primary outcome (Table 2) was significantly different in stone-free rates between the tPCNL and the mUMP groups at either immediately post-operative with 74.5% versus 85% or 4-week follow-up with 75% versus 86.5%. In the secondary outcomes (Table 3), the operative time of mUMP was longer at 100 (80, 140) minutes compared to tPCNL at 90 (60, 120) minutes. The average blood loss in mUMP was lower at 50 (10, 100) mL than tPCNL at 100 (50, 200) mL. The average length of stay in the mUMP patients was shorter at 3 (3, 4) days than tPCNL at 4 (4, 5) days. The use of NSS in the mUMP group was significantly less at 3,000 (2,000, 4,000) mL than in the tPCNL group at 14,500 (10,000, 22,000) mL. The post-operative UTI rate was lower in the mUMP group at 8.3% compared to the tPCNL group at 37.0%. Finally, the mUMP patients had lower pain scores on day 1 at 4 (3, 5 versus 5 (4, 7) and on day 2 at 0 (0, 0) versus 0 (0, 3) compared to tPCNL

Table 4. Univariable and multivariable logistic regression

Operation	Univariable		Multivariable	
	OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
Stone clear postoperative				
UMP	1.94 (1.09 to 3.46)	0.025*	0.70 (0.28 to 1.73)	0.438
PCNL	Reference	1	Reference	1
Stone clear at 4 weeks				
UMP	2.13 (1.17 to 3.88)	0.013*	0.80 (0.32 to 2.01)	0.637
PCNL	Reference	1	Reference	1

UMP=ultra-mini-percutaneous nephrolithotomy; PCNL=percutaneous nephrolithotomy; OR=odds ratio; CI=confidence interval
Adjusted for number of stone, size of stone, location, diverticulum, and hydronephrosis

patients. Total morphine used was also lower in the mUMP group at 3 (0, 6) mg compared to the tPCNL group at 8 (3, 12) mg. This difference remained significant when adjusted for patient weight for mUMP at 0.05 (0, 0.1) mg/kg and for tPCNL at 0.12 (0.05, 0.22) mg/kg. In addition, complications were less severe in the mUMP group based on the Clavien-Dindo classification, although no patients in either group experienced complications greater than grade 2. The univariable/multivariable logistic regression analysis, adjusted for Number of stone, size of stone, location, diverticulum and hydronephrosis, showed a non-significant OR of 0.70 and 0.80 for stone-free rates in mUMP and tPCNL, respectively (Table 4). In the subgroup of stones of 20 mm or less (Table 5) the stone-free rates immediately post-operative were not significantly different between tPCNL at 100% and mUMP at 95.5%. In addition, in the subgroup of stones greater than 20 mm (Table 6), the stone-free rates immediately post-operative were 70.6% in tPCNL and 64.4% in mUMP with no significant differences. It is interesting to note that the largest stone successfully cleared using mUMP was 44 mm in summed diameter and 26 mm for a single stone.

Table 5. Size of stone sum of diameter ≤20 mm

	mUMP (n=88) n (%)	tPCNL (n=24) n (%)	p-value
Stone clear postoperative	84 (95.5)	24 (100)	0.287
Stone clear at 4 weeks	84 (95.5)	24 (100)	0.287

mUMP=modified ultra-mini-percutaneous nephrolithotomy; tPCNL=tubeless percutaneous nephrolithotomy
Chi-square test

Table 6. Size of stone sum of diameter >20 mm

	mUMP (n=45) n (%)	tPCNL (n=160) n (%)	p-value
Stone clear postoperative	29 (64.4)	113 (70.6)	0.630
Stone clear at 4 weeks	31 (68.9)	114 (71.3)	0.095
Location			0.034*
Lower pole	18 (40.0)	39 (24.4)	
Middle	2 (4.4)	1 (0.6)	
Multiple	13 (28.9)	46 (28.7)	
Pelvis	10 (22.2)	68 (42.5)	
Upper pole	2 (4.4)	6 (3.8)	
Stone in diverticulum	3 (6.7)	1 (0.6)	0.013*
Staghorn	8 (17.8)	31 (19.4)	0.310

mUMP=modified ultra-mini-percutaneous nephrolithotomy; tPCNL=tubeless percutaneous nephrolithotomy
Chi-square test or Fisher's exact test, * $p<0.05$ is considered statistical significance

Discussion

The mUMP offers an alternative approach to stone clearance, aiming to reduce complications compared to conventional PCNL. In the present study, and without the use of nephrostomy tube, the authors define tPCNL as a procedure similar to mUMP ensuring comparable stone burdens across treatment groups.

The UMP, a newer technology utilizing smaller instruments, requires urologists to develop specific surgical skills. Early research, such as Desai & Solanki (2013)[1], suggested UMP was ideal for stones of 20 mm or less. Subsequent studies, like Agrawal et al. (2016)[3], confirmed its effectiveness for this stone size. More recently, Karakan et al. (2016)[6] conducted a randomized controlled trial (RCT) directly comparing UMP and PCNL for stones of less than 25 mm, with a mean size of 20.3±3.0 mm in the UMP group. They reported comparable stone-free rates with UMP at 88% and PCNL at 89.3%. Similarly, Adamou et al. (2022)[7] used UMP for single stones with a mean size of 20.93±3.97 mm, achieving a 92.9% stone-free rate.

Due to a selection bias at Sunpasitthiprasong Hospital, larger stones were more likely treated with tPCNL. To address this, the authors performed a subgroup analysis demonstrating that mUMP is a

viable alternative to conventional UMP and tPCNL for stones of 20 mm or less. Additionally, mUMP proved particularly effective for larger stones located in the lower pole of the kidney.

Although multivariable logistic regression indicated that tPCNL might have a slightly higher overall stone-free rate, the present study explored the limits of mUMP's capabilities. While previous literature focused on conventional UMP for stones of less than 20 mm, the authors successfully cleared stones as large as 26 mm for a single stone and 55 mm as summed diameter for multiple stones, using the mUMP technique. Furthermore, stones located in the lower pole of the kidney showed a higher likelihood of post-operative clearance.

The mUMP shows good results in less postoperative UTI complication, which is the result of lower intrarenal pressure from unlock inner-outer sheet and less irrigation fluid.

In the authors' experience, mUMP can effectively clear single stones up to 26 mm in size using medium to large laser fibers for high-energy lithotripsy. Based on this, the authors suggest that mUMP can be considered a viable alternative for stones up to 25 mm.

Conclusion

The mUMP proved to be safer and a more effective treatment compared to conventional tPCNL for stones of 20 mm or smaller. Patients in the mUMP group experienced less post-operative pain, shorter hospital stays, reduced need for blood transfusions, and lower irrigation volume requirements. Additionally, the authors' experience suggests mUMP can be considered a viable alternative for clearing stones up to 25 mm, as the authors successfully cleared a single stone as large as 26 mm.

Suggestion

A RCT is warranted to compare mUMP and conventional tPCNL for single stones sized 20 to 30 mm. The authors believe mUMP, especially when combined with a new Thulium laser and other technological advancements, has the potential to achieve stone clearance rates exceeding those of tPCNL for stones larger than 2.5 cm.

What is already known on this topic?

Based on Desai & Solanki's (2013)[1] landmark study, which demonstrated the feasibility of UMP, or ultra-mini PCNL, 11 to 13 Fr, as an alternative to conventional PCNL for stones less than 2 cm, further technological advancements have emerged. These include the development of endoscopes like retrograde intrarenal surgery (RIRS) for stone removal and the use of mini PCNL (22 Fr) by Ahmadmusa et al. (2020)[4] in Thailand, which yielded results comparable to conventional PCNL.

What does this study add?

This study demonstrates the feasibility of using larger diameter laser fibers and irrigation tubes for mUMP in treating renal stones larger than 20 mm.

The authors successfully extended the applicability of mUMP to a maximum stone burden of 26 mm, and less postoperative UTI suggesting its potential as an alternative to conventional tPCNL for selected patients.

Conflicts of interest

The authors declare no conflict of interest.

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