

Safety and efficacy of ambulatory tubeless mini-percutaneous nephrolithotomy in the management of 10–25-mm renal calculi: A retrospective study

Parsa Nikoufar¹, Amr Hodhod², Ruba Abdul Hadi¹, Loay Abbas¹, Sai K. Vangala¹, Ahmed S. Zakaria¹, Maher Gawish³, Amer Alaref⁴, Radu Rozenberg⁴, Hazem Elmansy¹

¹Department of Urology, Thunder Bay Regional Health Sciences Centre, Northern Ontario School of Medicine, Thunder Bay, ON, Canada; ²Urology Department, King Abdulaziz Medical City, National Guard Hospitals Affairs, Riyadh, Saudi Arabia; ³Urology Department, Alazhar University, Assiut Branch, Assiut, Egypt; ⁴Department of Radiology, Thunder Bay Regional Health Sciences Centre, Northern Ontario School of Medicine, Thunder Bay, ON, Canada

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Corresponding author: Dr. Hazem Elmansy, Thunder Bay Regional Health Sciences Centre, Northern Ontario School of Medicine, Thunder Bay, ON, Canada; hazem.mansy@rocketmail.com

ABSTRACT

Introduction: This study aimed to assess the safety and efficacy of ambulatory mini-percutaneous nephrolithotomy (mini-PCNL) in a totally tubeless exit (without a nephrostomy tube or an internal stent) and tubeless exit (without a nephrostomy tube but with an internal stent) for the treatment of renal calculi 10–25 mm in size.

Methods: We conducted a retrospective analysis of patients who underwent mini-PCNL at our institution between September 2018 and September 2022. The study included a cohort of 95 patients diagnosed with renal calculi measuring 10–25 mm. All patients underwent a computed tomography (CT) renal colic scan preoperatively, on postoperative day one (POD 1), and at three-month followup. Patient demographics and outcome parameters were recorded, including stone characteristics, operative time, hospital stay, stone-free rate (SFR), complication rates, and subsequent emergency room (ER) visits. Patients were considered stone-free if they had no fragments or residual fragments measuring <4 mm.

Results: The median maximum stone diameter was 16 mm (10–25 mm). Twenty-nine patients (30.5%) had multiple renal calculi. The median operative time was 64 (38–135) minutes. Eighty-six patients (90.5%) underwent a totally tubeless procedure, without a nephrostomy tube or an internal stent. All patients were discharged home on the same operative day with a median hospitalization time of six hours. Seven (7.4%) postoperative ER visits were recorded, and two (2.1%) led to hospital readmission. The frequency of grade I, II, and III Clavien-Dindo complications were 18 (18.9%), one (1.1%), and one (1.1%), respectively. The SFR on POD 1 and three-month followup was 73.7% and 92.6%, respectively. None of the patients in the study required retreatment.

Conclusions: Ambulatory tubeless mini-PCNL is a safe and effective treatment option for 10–25 mm renal stones. Experienced institutions can safely adopt ambulatory mini-PCNL as a treatment option without an increased risk of postoperative complications, ER visits, or hospital readmissions.

INTRODUCTION

Percutaneous nephrolithotomy (PCNL) remains the preferred treatment option for renal stones >20mm due to its higher success rate; however, it is associated with increased complication rates^{1,2}. Traditionally, patients were admitted for observation following PCNL to monitor for signs and symptoms of complications². The concept of miniaturized percutaneous nephrolithotomy was introduced in 1998 and has evolved in recent years due to advancements in technology and the use of smaller instruments³⁻⁶.

The most widely adopted and extensively studied miniaturized PCNL technique is mini-PCNL. It provides a stone-free rate (SFR) comparable to standard PCNL while reducing the intraoperative and postoperative complications⁶⁻¹⁷. Mini-PCNL also increases the likelihood of achieving a totally tubeless exit (without a nephrostomy tube or an internal stent) compared to standard PCNL¹⁴⁻¹⁷.

Historically, the rationale for overnight observation was to monitor the risk of hemorrhage and sepsis. Nevertheless, systematic reviews and large case series have demonstrated low complication rates following PCNL, particularly in high-volume centers^{18,19}. Numerous studies from high-volume institutions have explored the feasibility of ambulatory PCNL, reporting safe and successful implementation. However, widespread adoption has not followed, likely due to regional differences in practice patterns and surgical techniques, which make it harder to generalize their findings²⁰⁻²⁵.

Recent findings indicate a satisfactory safety record and high overall patient satisfaction and a significant reduction of the total cost and enhances the hospital's operating margin when opting for the ambulatory approach^{26,27}. This study's primary objective was to evaluate the safety and efficacy of ambulatory tubeless mini-PCNL in managing 10-25 mm renal stones. The secondary objective was to determine the factors affecting SFR in our study population.

METHODS

After obtaining Research Ethics Board approval, we conducted a retrospective study of computed tomography (CT) scan-confirmed 10-25 mm renal stones managed with mini-PCNL from September 2018 to September 2022. Upon reviewing the medical records of enrolled patients, we verified the completeness of perioperative data and the presence of postoperative CT scans for evaluating residual stones on postoperative day one (POD 1) and 3-month follow-up, along with information regarding stone composition.

Preoperative CT scans were reviewed, and stone characteristics, including stone number, stone site (upper pole, middle pole, lower pole, and renal pelvis), three-dimensional stone size [width (w), length (l), and height (h)], and stone density were recorded. Stone volume was calculated using the formula $(\pi * l * w * d * 0.167)^{28}$. The presence of hydronephrosis and use of preoperative ureteral stents were also documented.

All procedures were conducted by a single surgeon. At our institution, mini-PCNL cases are typically scheduled as outpatient procedures, with the primary goal of achieving a totally tubeless procedure (no nephrostomy tube or internal stent) unless there is an intraoperative indication for stent insertion (tubeless) or nephrostomy tube placement. The maximum stone size for mini-PCNL at our center is restricted to 30 mm. Patients with preoperative factors such as unfit medical conditions (e.g., cognitive disorders and uncontrolled cardiovascular disease) were excluded from early discharge. Individuals residing beyond city limits and those without a caregiver were also excluded. All patients had negative urine cultures before the procedure.

Operative time was recorded as the duration from the insertion of the cystoscope to skin closure. A prophylactic preoperative IV cefazoline was given to all patients. The procedure was performed under general anesthesia, starting in the lithotomy position with the insertion of a ureteric catheter under fluoroscopy. Subsequently, the patient's position was transitioned to the prone position. Access to the kidney was achieved using the triangulation technique or, occasionally, the bull's eye technique.

Mini-PCNL was performed using a 16.5/17.5 Fr dilators and sheath with a 12 Fr nephroscope (Storz, Germany). Laser lithotripsy was carried out with a 100W Holmium:yttrium-aluminum-garnet (Ho:YAG) laser and a PowerFlex 200-micron laser fiber until December 2020. Subsequently, we adopted the MOSESTM technology P120 H laser system (Lumenis®Pulse) and a 200-micron laser fiber until September 2022.

Laser techniques (fragmentation, dusting, or both) were also recorded. Stone extraction was accomplished through a vacuum cleaner effect and/or a 1.5 F retrieval basket. Using flexible ureteroscopy in an antegrade fashion, all calyces were visually inspected for sizable residual stones.

The surgeon recovered the obtainable calculus fragments, sending some for chemical analysis. The attending urologist's decision for a totally tubeless exit or a tubeless exit (without a nephrostomy tube but with antegrade insertion of a ureteral stent) and the reason for stent insertion were recorded at the end of the procedure. Additionally, a gelatin matrix hemostatic sealant was injected into the tract followed by an intraoperative intravenous dose of Ketorolac.

After transferring the patient to the recovery room, they were asked to provide a pain score on a scale of 1 to 10. In cases where opioids were administered, we recorded the number and quantity administered. All patients were discharged from the hospital on the same operative day, and their length of hospital stay was recorded in hours. A complete blood count (CBC) was performed both before and after the procedure, and the difference between the two counts was documented. Predetermined discharge criteria included: whether the patient was deemed medically fit, had a caregiver; and met post-anesthesia care unit (PACU) discharge criteria²⁹. Before discharge, patients were also required to have acceptable laboratory results, tolerate a diet, and be ambulating independently. Discharge instructions were explained to patients, including light activities for one week, avoiding lifting heavy objects for 2 weeks, and seeking medical advice in case of increasing pain or developed fever.

A postoperative Low-dose CT scan was performed on POD 1 as an outpatient and at the three-month follow-up. A next-day CT scan was done to assess SFR and detect postoperative complications during our initial experience. The results were reviewed by both a radiologist and a urologist to assess for any residual stones, with the size and locations of any remaining stones recorded. The SFR was determined using two criteria^{30,31}: no visual remnants (zero fragments) and fragments <4 mm (3 mm or less).

In addition, postoperative complications were closely monitored over 90 days and recorded, including emergency room (ER) visits, complaints during follow-up visits, and imaging results that indicated a complication. The complications were categorized and reported according to the Clavien-Dindo scale. Study participants were provided with the option to utilize Seamless MD (www.seamless.md), a comprehensive digital care platform. This platform enables remote monitoring and personalized guidance. Patient progress was systematically tracked, and our team performed postoperative follow-up phone calls. During these calls, we discussed postoperative CT scan results on post-operative day one and diligently monitored patients for any complaints, including hematuria or renal colic.

Continuous variables were represented by their median values and ranges, while categorical variables were characterized through frequencies and percentages. Statistical analysis was performed utilizing the Statistical Package for the Social Sciences (SPSS®) version 23.0

(IBM® Corp, USA). Multivariate logistic regression models were employed to explore potential independent factors that may predict the stone-free status.

RESULTS

A total of 95 patients, after exclusion of 3 patients, who underwent scheduled mini-PCNL day-surgery were included in the study. Two patients were excluded due to residing beyond city limits, and one patient because of uncontrolled cardiovascular condition. Patient demographic data, stone characteristics, and preoperative variables are listed in Table 1. The median stone size was 16 mm (10–25 mm). Sixty-six cases (69.5%) involved a solitary stone, while 29 patients (30.5%) presented with multiple stones.

Intraoperative and perioperative data are included in Table 2. The median operative time was 64 minutes (38-135 minutes), and the median hemoglobin drop (intraoperative blood loss) was 14 g/L (4-45 g/L). One patient had a hemoglobin drop of 45 g/L. He was monitored for an extra 4 hours and was vitally stable. CBC was repeated twice, once before discharge and another one when came for the next-day CT scan, and both showed stable hemoglobin. He didn't receive a blood transfusion because his hemoglobin level was 121 g/L, and blood transfusion is not indicated according to our institution's protocol for blood transfusion. The median hospital stay was 6 hours (4-7 hours), and none of the patients required an overnight hospital admission.

Eighty-six patients (90.5%) were discharged home totally tubeless, without the need for a nephrostomy tube or intraoperative stent insertion. In contrast, nine cases (9.5%) required intraoperative stent insertion at the conclusion of the procedure. The reasons for intraoperative stent insertion are outlined in Table 2. All stents were removed at 2-4 weeks postoperatively.

A total of 7 ER visits were documented, with three related to hematuria, two to renal colic, and two to postoperative fever. The 90-day complication rates were recorded according to the Clavien-Dindo classification system of surgical complications.

Clavien I complications were observed in 18 cases, accounting for 18.9% of the total cases. These complications included one instance of hematuria with clot passage, 13 cases of prolonged hematuria without clot passage, and 4 cases of renal colic, with one of them requiring the insertion of an intraoperative stent. Thirteen of the 20 patients who experienced postoperative complications opted not to visit the ER; instead, they were provided reassurance via a phone call from a member of urology team.

All cases were managed expectantly. A Clavien II complication included one patient who presented with a low-grade fever with mild hydronephrosis (without detected stone fragments) and was treated with oral antibiotics. Clavien III complications included a case of moderate-grade fever postoperatively due to urosepsis that was treated with stent insertion under general anesthesia (Clavien IIIa). The readmission rate was 2.1% due to postoperative fever.

On POD 1, the SFR, defined as the absence of residual fragments measuring 0 mm, was 56.8%. In contrast, an SFR of 73.7% was achieved when a cut-off of <4 mm was utilized. At the 3-month postoperative CT assessment, the SFR remained favorable at 87.4% with a cut-off of 0

mm, and it increased to 92.6% when a cut-off of <4 mm was applied. Notably, only 2 patients (2.1%) required flexible ureteroscopy (F-URS) for the management of residual stones. Multivariate logistic regression analysis indicated that no factors significantly impacted the presence of residual stones on POD 1.

DISCUSSION

Due to the constraints on hospital resources and healthcare accessibility brought about by the COVID-19 pandemic, we initiated measures to enhance the quality of care. The unprecedented experience underscored the significance of efficiently utilizing healthcare resources, improving patient care and satisfaction while simultaneously decreasing medical expenditures. One of the essential aspects of cost reduction in PCNL is lowering the average length of hospital stay. With recent technological advancements in PCNL, there has been a notable increase in the adoption of ambulatory PCNL, allowing patients to be discharged within 24 hours^{23,24,27,32,33}. The adoption of an ambulatory PCNL program may not be feasible for all institutions, urologists, or patients. It is crucial that the attending surgeon possesses the necessary skills and receives training in managing a high volume of cases. Moreover, an experienced healthcare team ensures that the perioperative process aligns with the complexity and unique aspects of PCNL. Establishing precise inclusion and exclusion criteria is imperative to guarantee the highest level of patient safety.

In this study, we present our findings from a cohort of 95 patients who underwent planned ambulatory mini-PCNL. The median stone size measured 16 mm (10–25 mm) and the median operative time was 64 minutes (38–135 minutes). Patients had a median hospital stay of 6 hours (4–7 hours), with none requiring an overnight hospital admission. Among the patients, 86 (90.5%) were discharged home without the need for nephrostomy tube or intraoperative stent insertion, while 9 cases (9.5%) required intraoperative stent insertion at the end of the procedure.

Wu and colleagues reported the results of a retrospective data of planned day-surgery PCNL with a mean stone diameter of 33 mm. The average operative time was 64 minutes, which is similar to our data. A total of 95.4% of patients in their study were either discharged on the same day or placed under overnight observation before discharge, while 4 patients (4.6%) necessitated a full admission exceeding 24 hours²³. Contrary to our findings, it's worth noting that all patients in Wu et al.'s study received either a ureteral double-J stent or an external catheter. Tubeless procedures without a nephrostomy tube were performed in 60.5% of cases²³.

In their randomized controlled trial (RCT), Dutta et al. assessed the outcomes of ureteroscopy versus prone mini-PCNL for the management of 1-2cm renal stones. Renal drainage was favored using a 14F Foley catheter as a nephrostomy tube, a ureteral stent, or, in specific cases, a totally tubeless approach. A notable distinction between their trial and our retrospective data lies in the duration of hospitalization, as patients in their mini-PCNL group stayed overnight, whereas our study typically resulted in a 6-hour hospital stay. Additionally, their trial included postoperative CT scans conducted between postoperative days 1 and 30³².

In our cohort, 3.2% of patients required more than one tract access with a totally tubeless discharge. In Zhao et al.'s retrospective review, which used propensity score matching, 86 patients who underwent planned day-PCNL were matched to another 86 patients who required a minimum 2-day postoperative hospital stay following the same procedure. The hospital stay for day-PCNL patients averaged 13.6 hours, and double-J stents were routinely inserted. The frequency of multiple tract usage was slightly lower in the planned day-PCNL group (9.3%) compared to the admitted group (12.8%)²⁴.

The primary obstacle preventing PCNL from being conducted as outpatient surgery is the management and treatment of postoperative complications. Patients in our hospital typically receive a phone call the following day from a member of the urology team and are monitored for postoperative complications with the Seamless MD digital care platform. In our cohort, the overall complications rate was 21.1% including Clavien I (18.9%), Clavien II (1.1%), and Clavien III (1.1%). Among the 20 patients who experienced postoperative complications, 13 (65%) chose not to visit the ER and received reassurance via phone calls from the urology team. The readmission rate, attributed to postoperative fever, was 2.1%.

Jones and colleagues' systematic review evaluating the safety and efficacy of day-case PCNL surgery with a mean stone size of 20.5 mm documented an average hospital stay of 17.5 hours. The results showed an overall complication rate of 13.5%, primarily comprising Clavien I or II complications, with an associated 3% hospital readmission rate³³.

Zhao et al. reported an overall complication rate of 11.6% in the day-care mini-PCNL group, consisting of 7% Clavien I, 2.3% Clavien II, and 2.3% Clavien III complications. Notably, among the 8 (9.3%) patients who underwent multiple tracts, there was no significant increase in the complication rate. Additionally, the readmission rate for day-care mini-PCNL patients was at 2.3%²⁴.

In their RCT, Dutta and colleagues observed that the SFR on POD 1, determined using CT criteria, was greater in the mini-PCNL group when using a 2 mm cut-off (76%) compared to our cohort's use of a <4 mm cut-off (73.7%). Similarly, when applying a strict 0 mm cut-off, the SFR was also higher in their mini-PCNL group (67%) as opposed to our cohort (56.8%)³². Furthermore, the retreatment rate for residual stones was 4% in their study, whereas it was 2.1% in our cohort. Serra et al.'s retrospective study, found that the SFR, defined as the absence of residual stones confirmed by ultrasound or CT scan 3 months after the intervention, was 83%. Only one patient (3%) required retreatment with ureteroscopy²⁷.

Despite the presence of advanced laser technologies (i.e. TFL and MOSES) at our institution, many patients opt for mini-PCNL to avoid stent-related symptoms. In addition, we utilize a ureteral access sheath with stent insertion in nearly all cases of f-URS managing kidney stones >1 cm. Additionally, we believe that renal anatomy, including factors such as the infundibular–pelvic angle, infundibulum width, and length, can influence the success rate,

particularly in the lower pole calyx when f-URS is used, which represents over 50% of cases in our cohort.

Limitations

This study has certain limitations. Firstly, it is a retrospective study conducted at a single center, involving a relatively small group of patients. Secondly, it lacks a control group that underwent conventional inpatient mini-PCNL, which prevents us from making comparisons regarding complications or readmission rates to the ER or hospital. Additionally, our results were achieved by a single surgeon with extensive experience with mini-PCNL and may be difficult to replicate by someone earlier in their learning curve. A definitive clinical protocol for safely assessing unplanned readmissions during the initial postoperative phase following ambulatory mini-PCNL has not been established. Moreover, it is essential to exercise meticulous perioperative management, and larger well-structured research studies are needed in this area.

CONCLUSIONS

Mini-PCNL is a safe and efficient technique for treating 10-25 mm kidney stones. Experienced institutions can safely adopt ambulatory mini-PCNL as a treatment option without an increased risk of postoperative complications, ER visits, or hospital readmissions. Most complications can be managed conservatively, with only a minimal number necessitating interventions.

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FIGURES AND TABLES

Table 1. Patient demographics		
Parameter		Values
Total number of participants n		95
Gender, n (%)	Male	60 (63.2)
	Female	35 (36.8)
Age, years, median (range)		61 (27–79)
BMI, kg/m ² , median (range)		22 (18–41)
ASA score, n (%) (functional status)	I	53 (55.8)
	II	37 (38.9)
	III	5 (5.3)
Comorbidities, n (%)	Hypertension	19 (20)
	Diabetes mellitus	15 (15.8)
Stone size, mm, median (range)		16 (10–25)
Stone density, HU, median (range)		914 (350–1417)
Laterality, n (%)	Left	42 (44.2)
	Right	53 (55.8)
Stone number, n (%)	Single	66 (69.5)
	Multiple	29 (30.5)
Stone site, n (%)	Upper pole	5 (5.3)
	Middle pole	3 (3.2)
	Lower pole	50 (52.6)
	Pelvis	37 (38.9)
Hydronephrosis, n (%)	None	64 (67.4)
	Grade I and II	22 (23.2)
	Grade III and IV	9 (9.5)
Presence of preoperative stent, n (%)		9 (9.5)

ASA: American Society of Anaesthesiologists.

Table 2. Perioperative findings		
Parameter		Values (N=95)
Operative time, min		64 (38–135)
Number of working tracts, n (%)	Single	92 (96.8)
	Multiple	3 (3.2)
Puncture technique	Triangulation	70 (73.7)
	Bull's eye	25 (26.3)
Postoperative ureteral stent insertion (by indication)	Total	9 (9.5)
	Ureteral injury	2 (2.1)
	Ureteropelvic edema	3 (3.2)
	Migrated stone	4 (4.2)

Totally tubeless, n (%)	86 (90.5)	
Intraoperative blood loss (Hg drop), g/L, median (range)	14 (4–45)	
Blood transfusion, n (%)	0 (0)	
Pain score in the recovery room, median (range)	1 (0–7)	
Use of opioids in the recovery room, n (%)	8 (8.4)	
Length of hospital stay, hours, median (range)	6 (4–7)	
Postoperative ER visit, n (%)	7 (7.4)	
Readmission, n (%)	2 (2.1)	
Retreatment, n (%)	2 (2.1)	
Perioperative complications, n (%)	Clavien–Dindo Grade I	18 (18.9)
	Clavien–Dindo Grade II	1 (1.1)
	Clavien–Dindo Grade III	1 (1.1)

ER: emergency room; Hg: hemoglobin.

Parameter		Values (N=95)	
Day 1 postoperative CT	Stone-free rate, n (%)	Cutoff 0 mm	54 (56.8)
		Cutoff <4 mm	70 (73.7)
	Presence of residual stone \geq 4 mm, n (%)	25 (26.3)	
	Residual stone size, mm, median (range)	0 (0–10)	
3-month postoperative CT	Stone-free rate, n (%)	Cutoff 0 mm	83 (87.4)
		Cutoff <4 mm	88 (92.6)
	Presence of residual stone \geq 4 mm, n (%)	7 (7.4)	
	Residual stone size, mm, median (range)	0 (0–9)	
Stone composition	Calcium oxalate monohydrate, n (%)	43 (45.3)	
	Calcium oxalate dihydrate, n (%)	32 (33.7)	
	Uric acid, n (%)	12 (12.6)	
	Calcium phosphate, n (%)	8 (8.4)	

CT: computed tomography.