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Original Article

Minimally Invasive Percutaneous Nephrolithotomy for Staghorn Calculus – A Single-Center Study

Ram Sagar Shah*, Kartikesh Mishra, Sachidanand Sah, Abhishek Poudel

Department of Urology, Nobel Medical College and Teaching Hospital, Biratnagar, Nepal

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Abstract

Background

Staghorn calculi, either partial or complete, present a significant urological challenge. Mini-percutaneous nephrolithotomy (mPCNL) has become a less invasive alternative to standard PCNL (sPCNL). This study evaluates the efficacy and safety of mPCNL in treating staghorn calculi.

Materials and Methods

A retrospective observational study was conducted on 26 patients at Nobel Medical College Teaching Hospital for one year. Outcomes included stone-free rate (SFR), operative time, complications, and recovery.

Results

The SFR was 84.6% (22/26), with failed cases associated with larger stones (mean 42.5 ± 3.2 mm) and higher Guy's Scores. Mean operative time was 61.2 ± 12.4 minutes, increasing with stone size ($p < 0.001$). Complication rates were low, supporting mPCNL's safety.

Conclusion

mPCNL is effective for moderate-sized staghorn stones, offering high stone clearance with minimal morbidity

Keywords: *Staghorn calculus, operative time, urolithiasis*

***Corresponding Author:**
Dr. Ram Sagar Shah
Associate Professor
Email: ramsagarshahsurgeon@gmail.com
ORCID: https://orcid.org/0000-0001-6896-463X

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Introduction

Staghorn calculi are large, branching kidney stones that fill the renal pelvis and calyces, posing a significant challenge in urological practice [1]. These stones are typically composed of struvite, which forms due to urease-producing bacteria, and are often associated with urinary tract infections [2]. However, recent studies show a broader range of compositions, not solely related to infections. Left untreated, staghorn calculi can lead to serious complications, including recurrent infections, renal dysfunction, and even death [3].

The management of staghorn calculi has evolved, with Percutaneous Nephrolithotomy (PCNL) now being the gold standard. However, traditional PCNL has higher morbidity, while the advent of Mini-PCNL (mPCNL), which uses smaller tract sizes (12–20 Fr), has reduced complications and improved patient outcomes [4, 5]. Despite its advantages, the effectiveness of mPCNL for larger or more complex stones remains a topic of debate [6].

This study aims to evaluate the effectiveness of mPCNL in treating staghorn calculi. It will focus on key metrics such as stone-free rates, operative time, and complication rates. The prospective observational study conducted at Nobel Medical College Teaching Hospital, seeks to contribute to the evidence supporting mPCNL as a viable treatment option, particularly for moderate-sized stones and favorable renal anatomy.

Materials and Methods

This prospective observational study was conducted at Nobel Medical College Teaching Hospital from December 2023 to November 2024, with ethical approval obtained from the Institutional Review Committee (IRC) of the hospital. This study employed census sampling including all 26 patients who underwent Mini-PCNL (mPCNL) during this period for staghorn calculi in the study after providing written informed consent. The inclusion criteria consisted of patients diagnosed with partial or complete staghorn calculi, confirmed by CT urography, and negative preoperative urine culture and sensitivity results. Exclusion criteria included patients with uncorrected bleeding disorders or severe comorbidities that made them unfit for surgery.

Preoperative imaging included CT urography for precise stone mapping, and laboratory tests such as urine culture, serum creatinine levels, complete blood count (CBC), and coagulation profile were conducted. Culture-directed antibiotic prophylaxis was administered to minimize infection risk. The procedure was performed under fluoroscopy guidance, with an 18G needle used for the initial puncture. The tract was dilated up to 18 Fr, and stone fragmentation was achieved using a pneumatic lithotripter. Postoperative care included monitoring for hemodynamic stability and the placement of a Double-J (DJ) stent in all cases, with a nephrostomy tube inserted selectively.

Descriptive statistics were used to summarize patient demographics and clinical outcomes, with continuous variables expressed as mean ± standard deviation (SD) and categorical variables presented as percentages. A comparative analysis was performed using the independent t-test for continuous variables (e.g., operative time) and the Chi-square test for categorical variables (e.g., stone-free rate). A p-value of less than 0.05 was considered statistically significant, and all analyses were performed using SPSS version 26.

Results

Total 26 patinets enrolled in this study, the majority of patients were male, accounting for 69.2% (18 patients), while females made up 30.8% (8 patients). The average age of the patients was 45.5 years, with a standard deviation of 12.2 years, and the age range spanned from 20 to 72 years. Regarding the site distribution, 53.8% of cases (14 patients) involved the right side, and 46.2% (12 patients) involved the left side.

table 1 shows demographic characteristics of patients

Table 1: demographic characteristics

Category	Value
Total Patients	26
Sex	Male: 18 (69.2%)
	Female: 8 (30.8%)
Age (years)	Mean: 45.5 ± 12.2
	Range: 20–72
Site	Right: 14 (53.8%)
	Left: 12 (46.2%)

Table 2 summarizes key findings regarding stone characteristics and their clinical outcomes.

The mean stone size was 35.9 mm (range 23-56.8 mm), with stones exceeding 40 mm were associated with a twofold increased need for nephrostomy tube placement ($p<0.01$) and each 10 mm increase in size added 12 minutes to operative time ($p<0.001$). 34.6% of stones occupied a single calyx while 65.4% involved multiple calyces. Multi-caliceal stones demon-

strated more complex characteristics, requiring 18 additional operative minutes (p=0.003).
there was right-side predominance (53.8% right vs 46.2% left), though this anatomical difference did not translate to significant variations in clinical outcomes (p>0.05). Guy's stone complexity scoring showed most cases were grade 2 (38.5%) or 3 (46.2%), with higher scores (≥3) correlating with poorer outcomes.

Table 2: Stone Characteristics and Clinical Outcomes

Parameter	Statistics	Clinical Correlations
Size (mm)	Mean: 35.9 ± 8.3 Range: 23–56.8	• >40 mm: 2x higher tube placement risk (p<0.01) • +10 mm increase: +12 min OT (p<0.001)
Location	Single calyx: 34.6% Multi-caliceal: 65.4%	• Multi-caliceal stones associated with: +18 min OT (p=0.003) - 2x higher Guy's Score (p=0.02)
Laterality	Right: 53.8% Left: 46.2%	No significant outcome differences (p>0.05)
Guy's Score	2: 38.5% 3: 46.2% 4: 11.5%	• Score =3 predicted

Table 3: this table shows overall stone-free rate (SFR) which was 84.6%, with success in 22 out of 26 cases, while the failure rate was 15.4%. Larger stones (>35 mm) accounted for 75% of failures and showed a significant association with unsuccessful outcomes (p=0.02). Stones located in multiple calyces had a 2.1 times higher risk of failure compared to single-caliceal stones (p=0.04).

Table 3: stone free rate

Parameter	Statistics	Clinical Correlations
Stone-Free Rate	Success: 84.6% (22/26) Failure: 15.4% (4/26)	• Failure predictors: - Stones >35mm (75% of failures, p=0.02) - Multi-caliceal location (RR=2.1, p=0.04)

Table 4 describe about complication rates based on the Clavien-Dindo classification as follows: 38.5% of cases had no complications (Grade 0), 42.3% had minor complications requiring no intervention (Grade 1), and 19.2% required pharmacological treatment (Grade 2). Tube placement was associated with a 2.4 times higher risk of complications (RR=2.4, p=0.03), while multi-caliceal stones had 2.8 times higher odds of complications (OR=2.8, 95% CI 1.3–6.1). The mean hemoglobin drop was 1.5 ± 0.9 g/dL, ranging from 0.5 to 4.5 g/dL. Stones larger than 40 mm were associated with an additional 0.8 g/dL hemoglobin drop (β=0.8, p=0.01), and operations lasting more than 60 minutes carried a 2.1 times higher bleeding risk (RR=2.1, 95% CI 1.2–3.7).
Angioembolization was required in 3.8% of cases (1/26). This single case involved a 36 mm stone, a Grade 2 complication, and a right-sided stone with a Guy's Score of 3 indicating moderate complexity.

Table 4: complications

Complications	Grade 0: 38.5%	• Risk factors:
(Clavien-Dindo)	Grade 1: 42.3% Grade 2: 19.2%	- Tube placement (RR=2.4, p=0.03) - Multi-caliceal stones (OR=2.8, 95%CI 1.3-6.1)
Hemoglobin Drop	Mean: 1.5 ± 0.9 g/dL Range: 0.5-4.5 g/dL	- OT >60min (aOR=1.9, 95%CI 1.1-3.3) • Significant bleeding predictors: - Stone size >40mm (â=0.8, p=0.01) - OT >60min (RR=2.1, 95%CI 1.2-3.7)
Angioembolization	Required: 3.8% (1/26)	• - 36mm stone with Grade 2 complication - Right-sided, Guy's score 3

Table 5: table 5 describes the mean operation time which was 61.2 ± 12.4 minutes, ranging from 45 to 85 minutes. The factors significantly increased operation time were higher stone complexity (Guy's Score ≥3) added 18 minutes (p<0.001), multi-caliceal stones increased time by 15 minutes (p=0.003), and larger stone size (>40 mm) extended operations by 12 minutes (p=0.01).

Table 5: operative time summary

Operation Time	Mean: 61.2 ± 12.4 min	• Prolonged OT predictors:
	Range: 45-85 min Prolonged (>65min): 34.6%	- Guy's score =3 (+18min, p<0.001) - Multi-caliceal stones (+15min, p=0.003) - Stone size >40mm (+12min, p=0.01)

Discussion

Major urological guidelines endorse percutaneous nephrolithotomy (PCNL) as the gold standard for managing staghorn calculi [7]. However, miniaturized PCNL (M-PCNL) has introduced a paradigm shift, offering potential advantages over standard PCNL (S-PCNL) in terms of reduced complications and improved patient outcomes [8]. This discussion synthesizes findings from the reviewed studies to evaluate the efficacy, safety, and clinical implications of M-PCNL versus S-PCNL for staghorn calculi.
Our study demonstrated a stone-free rate (SFR) of 84.6% following mini-percutaneous nephrolithotomy (mPCNL). This result compares favorably with published literature on mPCNL outcomes. Khan et al. reported an 88% SFR, while Khadgi et al. showed 83% success, both closely

matching our findings [9, 10]. A meta-analysis by Yogahutama et al. reported a lower aggregate SFR of 75.3% across multiple mPCNL studies [11]. The highest reported SFR came from Sultan et al.[12] at 90.7%.

These comparisons suggest that our mPCNL outcomes are consistent with most contemporary studies, particularly those by Khan and Khadgi. The minor variation compared to Sultan et al.'s higher success rate may reflect differences in stone complexity or surgical approach. These findings challenge the historical notion that smaller tracts compromise clearance[13].

This study recorded a mean operative time of 61.2 minutes for mini-percutaneous nephrolithotomy (mPCNL), which was notably shorter than the times reported by Khan et al. at 115.69 ± 17.6 minutes and Khadgi et al. at 90 ± 32.4 minutes [9, 10]. This difference may be attributed to the selection of less complex stone cases in our series.

Comparative studies highlight that mPCNL generally offers reduced operative times compared to standard PCNL (sPCNL). A meta-analysis by Yogahutama et al. found mPCNL to be 14.06 minutes faster on average than sPCNL[11]. Sultan et al. reported a mean operative time of 80.2 minutes for mPCNL versus 105.3 minutes for sPCNL, attributing the shorter duration to fewer tract dilations and more efficient stone fragmentation with smaller instruments[12].

However, Khan et al. observed longer operative times with mPCNL (115.69 vs. 108.72 minutes for sPCNL), potentially due to the learning curve associated with the technique or the need for additional punctures in complex cases. These variations suggest that while mPCNL can streamline operative time in many scenarios, case complexity and surgeon experience remain influential factors. Our favorable operative time reinforces mPCNL as an efficient approach, particularly for appropriately selected cases.

Our study reported a 34.61% (9/26 cases) complication rate for mini-percutaneous nephrolithotomy (mPCNL), graded as Clavien-Dindo 1-3. This places our results between the higher rate observed by Khan et al. (41%) and the lower rate reported by Khadgi et al. (12%)[9, 10]. Despite this variability, our findings align with mPCNL's established safety profile, as complications were predominantly minor to moderate in severity.

Comparative studies consistently demonstrate mPCNL's superior safety compared to standard PCNL (sPCNL). Sultan et al. noted significantly fewer complications with mPCNL (13% vs. 26%, p=0.038), while Khadgi et al. reported reduced transfusion rates (2.4% vs. 12.9%, p=0.013)[10, 12]. The smaller tract size in mPCNL minimizes parenchymal injury, particularly beneficial in complex staghorn calculi requiring multiple accesses.

While postoperative fever rates were statistically similar between approaches, mPCNL showed a non-significant trend toward higher incidence (OR 1.15, 95% CI 0.80–1.67, p=0.45). This may relate to increased intrarenal pressure during irrigation through smaller tracts, emphasizing the importance of strict sterile technique and appropriate antibiotic prophylaxis.

This study demonstrates that mini-PCNL is a highly effective and safe procedure for staghorn calculi, with an SFR comparable to traditional PCNL but with reduced morbidity. These results support mini-PCNL as a safe, effective alternative for moderate staghorn stones, balancing invasiveness and success

Limitations

This study has limitations: its retrospective design, small sample size (n=26), and single-center experience may affect generalizability. Larger prospective trials comparing mPCNL and sPCNL for staghorn stones are warranted.

Conclusion

This study demonstrated that Mini-PCNL (mPCNL) is an effective treatment for staghorn calculi, achieving a high stone-free rate. Larger stones and multi-caliceal stones were significant predictors of treatment failure, and larger stones also contributed to longer operative times. The complication rate was moderate, with most cases experiencing minor complications. Risk factors for complications included larger stones, longer operative times, and multi-caliceal stones. Despite these challenges, mPCNL showed promising results with reduced morbidity compared to traditional PCNL. Overall, mPCNL is a safe and effective option for treating staghorn calculi, especially for patients with moderate-sized stones and favorable renal anatomy.

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