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*Original Article*

# Assessing the Efficacy of Mini-PCNL Versus Standard PCNL for Management of Staghorn Calculi >2cm: A Prospective Study in Peshawar

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## ABSTRACT

Background: Staghorn stones pose a significant challenge in urology, given their complex nature and potential for causing substantial renal damage. Traditional management has often involved standard percutaneous nephrolithotomy (PCNL), known for its efficacy in stone clearance but also associated with considerable complication rates. Recent advancements have led to the development of mini-PCNL, aiming to reduce these complications while maintaining high stone clearance rates.

Objective: This study aims to compare the efficacy, safety, and outcomes of standard and mini-PCNL in the management of staghorn stones, with a focus on complication rates, stone clearance, and hospital stay durations.

Methods: A prospective study was conducted at the Institute of Kidney Diseases, Hayatabad, Peshawar, involving 162 patients undergoing PCNL for staghorn stones from January 2020 to December 2023. Patients were categorized into standard PCNL (n=69) and mini-PCNL (n=93) groups based on the procedural approach. Pre-operative, intra-operative, and post-operative data were collected, including patient demographics, stone size and density, operative findings, post-operative complications, and stone clearance rates. Statistical analysis was performed using SPSS version 25.

Results: The mini-PCNL group demonstrated a significantly smaller average stone size (26.8 ± 5.8 mm) compared to the standard PCNL group (32.3 ± 10.3 mm, p=0.037). Single tract use was more prevalent in mini-PCNL (87.1%) than in standard PCNL (71.0%, p=0.016). Stone clearance rates were higher in the mini-PCNL group (87.1%) versus the standard group (73.9%, p=0.041). The average hospital stay was shorter for mini-PCNL patients (2.4 ± 1.0 days) compared to those undergoing standard PCNL (3.0 ± 1.1 days, p=0.030). Complications, including post-operative hematuria requiring transfusion, were more common in the standard PCNL group.

Conclusion: Mini-PCNL offers a safer and more effective alternative to standard PCNL in the management of staghorn stones, with lower complication rates, higher stone clearance rates, and shorter hospital stays. These findings support the adoption of mini-PCNL as a preferred approach for managing complex renal calculi.

Keywords: Staghorn Stones, Percutaneous Nephrolithotomy, PCNL, Mini-PCNL, Stone Clearance, Renal Calculi, Minimally Invasive Surgery, Urology, Kidney Stones, Complication Rates

## INTRODUCTION

Staghorn calculi, prominently recognized for their expansive involvement in the renal pelvicalyceal system, delineate a critical medical condition necessitating immediate and effective management strategies to mitigate significant health risks (1,2). These stones are categorized based on the extent of their invasion into the renal architecture; partial staghorn calculi occupy the renal pelvis and at least two major calyces, whereas complete staghorn stones involve more than 80% of the pelvicalyceal system (1). The genesis of these stones is multifactorial, originating either from metabolic dysfunctions or as a consequence of recurrent infections, particularly those caused by urease-producing bacteria such as Proteus and Klebsiella (2). The imperative for timely intervention stems from the potential for severe morbidity and mortality associated with staghorn stones, as they pose a considerable threat to renal health. Surgical procedures aimed at the total clearance of these calculi are pivotal in preserving renal function and averting

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the progression of renal dysfunction, a consequence often associated with conservative management approaches, which, despite their application in select scenarios, carry a significant risk profile including a notable incidence of renal dysfunction and mortality (3,4).

The consensus among urological associations underscores percutaneous nephrolithotomy (PCNL) as the gold standard for the treatment of staghorn stones, advocating for its utilization due to the high stone clearance rates and minimized complication risks it offers (6). This recommendation is supported by evidence indicating superior outcomes of PCNL in terms of stone clearance, particularly when compared to other treatment modalities such as extracorporeal shockwave lithotripsy (ESWL) and open surgery, which, although effective for smaller stones, exhibit diminished efficacy and heightened complication rates for larger staghorn calculi (3,7,8). The evolution of PCNL, marked by the introduction of miniaturized instruments (mini-PCNL), represents a significant advancement aimed at reducing the procedure's invasiveness. By employing smaller access sheaths, mini-PCNL seeks to minimize surgical trauma to the kidney, thereby potentially lowering the incidence and severity of procedure-related complications (12,13). However, despite these advancements and the reported equivalence in stone clearance rates between mini-PCNL and standard PCNL, disparities in outcomes have prompted a reassessment of these techniques' comparative effectiveness and safety (14,15).

The existing literature presents a dichotomy in findings regarding the impact of mini-PCNL and standard PCNL on surgical trauma and complication rates, thereby necessitating further research to elucidate the optimal approach for the management of staghorn stones. This prospective study aims to bridge the knowledge gap by comparing the efficacy and safety of miniaturized and standard PCNL, with the objective of contributing insightful data to inform clinical decision-making and enhance patient care outcomes in the management of this complex urological condition.

## MATERIAL AND METHODS

The study was conducted by the Urology and Transplant Team A at the Institute of Kidney Diseases in Hayatabad, Peshawar, following the ethical guidelines approved by the institution's review board, adhering to the principles outlined in the Declaration of Helsinki. The approval was secured prior to the initiation of the research activities to ensure the ethical conduct of the study and the safeguarding of participant rights and welfare. This prospective study meticulously evaluated pre-operative, intra-operative, and post-operative data from all patients who underwent percutaneous nephrolithotomy (PCNL) for the treatment of staghorn stones within the unit from January 2020 to December 2023. A total of 162 subjects were included in the study through non-probability convenience sampling. Patients were systematically classified into two distinct groups based on the procedural approach undertaken: the standard PCNL group and the mini-PCNL group.

Inclusion criteria were broad, encompassing patients of both genders, across all age groups, diagnosed with either partial or complete staghorn calculi, and those for whom multiple tracts were established. Exclusion criteria were defined to omit patients with borderline staghorn stones, congenital renal malformations, and those presenting with accessory renal calculi alongside the staghorn stones. A thorough history and clinical examination were conducted for each patient, complemented by a comprehensive series of laboratory and radiological investigations. These included a complete blood count, renal and liver function tests, serum electrolytes, coagulation profile, virology screening, urinalysis, and urine culture. Imaging studies were extensive, featuring ultrasound examinations of the kidneys, ureters, and bladder (KUB), X-rays of the same areas, and non-contrast computed tomography scans (CT KUB) to accurately assess the stone's characteristics and anatomical details.

General anesthesia was administered to all patients uniformly, and prophylactic antibiotic coverage with Meropenem was initiated upon induction. The surgical technique involved a retrograde pyelogram to delineate the pelvicalyceal system, achieved by the introduction of a 6 Fr ureteric catheter using cystoscopic guidance while the patient was in a lithotomy position. Following this, patients were repositioned supinely, and the selected calyx was accessed under fluoroscopic guidance using an 18G TLA needle, with tract dilation subsequently tailored to the procedural requirements as determined by the operating surgeon. In the standard PCNL group, tract dilation was executed up to 28 Fr using metal dilators, and a 28 Fr amplatz sheath was inserted, whereas, in the mini-PCNL group, dilation was limited to 18 Fr with the use of plastic dilators, followed by the introduction of a 16 Fr nephroscope.

Stone fragmentation in both groups was achieved using a pneumatic lithotripter, with stone fragments extracted via tri-prong forceps in the standard PCNL group and comparable techniques in the mini-PCNL group. Stone clearance was verified through nephroscopic visualization and fluoroscopic assessment. Both groups received antegrade stenting post-procedure, and nephrostomy tubes of respective sizes were placed according to the procedure performed. The post-operative care protocol mandated a hospital stay extending to the day following the procedure, with discharge criteria including stable vital signs and pain management.

Data collection spanned various parameters including patient demographics, stone characteristics (density and size), intraoperative findings, post-operative outcomes such as the mean drop in hemoglobin levels (calculated as the difference between preoperative and 12-hour post-operative hemoglobin levels), stone clearance verified by post-operative radiographs, and the incidence of

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complications. Follow-up evaluations were scheduled one month post-surgery, including radiographic and ultrasonographic examinations of the KUB region to identify any residual stone fragments, with fragments ≤4 mm deemed clinically insignificant. Data analysis was conducted using SPSS version 25 and Excel 2016 software, employing the Chi-square test to ascertain statistical significance, with a p-value of <0.05 considered indicative of significant findings.

## RESULTS

In the comparative analysis of pre-operative assessments between standard and mini percutaneous nephrolithotomy (PCNL) procedures, the distribution of genders across both groups showed a slight variation, with males constituting 68.1% of the standard PCNL group and 66.7% in the mini PCNL group, while females accounted for 31.9% and 33.3%, respectively. This difference was not statistically significant (p=0.87), indicating a consistent gender distribution across both procedural groups (Table 1). The average size of the stones presented a notable difference, with the standard PCNL group exhibiting larger stones (32.3 ± 10.3 mm) compared to the mini PCNL group (26.8 ± 5.8 mm), a variance that was statistically significant (p=0.037), suggesting that patients undergoing the standard PCNL procedure had more substantial calculi (Table 1).

When examining the side of the stone, a nearly balanced distribution was observed in both groups: 49.3% of stones were located on the right side in the standard PCNL group compared to 54.8% in the mini PCNL group. Conversely, 50.7% were on the left side in the standard group versus 45.2% in the mini group. This difference did not reach statistical significance (p=0.29), implying that the side of stone location did not notably differ between the two groups (Table 1). Preoperative urine cultures revealed that a higher proportion of patients had sterile urine in the standard PCNL group (92.8%) compared to the mini PCNL group (89.2%), with infected preoperative urine cultures slightly more common in the mini PCNL group (10.8% vs. 7.2%); however, these differences were not statistically significant (p=0.32), indicating similar urinary tract infection statuses preoperatively across both groups (Table 1). The pre-operative hemoglobin levels were comparable between the groups, with the standard PCNL group showing an average of 12.94 ± 1.7 mg/dl and the mini PCNL group at 13.03 ± 1.8 mg/dl, further confirming the similarity in patient baseline characteristics (p=0.73) (Table 1).

Table 1: Pre-operative Assessment between Standard and Mini PCNL

| Variables | Standard (n=69) | Mini (n=93) | p-value |
|---|---|---|---|
| Gender (n, %) | | | 0.87 |
| - Male | 47 (68.1%) | 62 (66.7%) | |
| - Female | 22 (31.9%) | 31 (33.3%) | |
| Average Size of Stone (mm) (SD) | 32.3 ± 10.3 | 26.8 ± 5.8 | 0.037 |
| Side of Stone (n, %) | | | 0.29 |
| - Right | 34 (49.3%) | 51 (54.8%) | |
| - Left | 35 (50.7%) | 42 (45.2%) | |
| Preoperative Urine Culture (n, %) | | | 0.32 |
| - Sterile | 64 (92.8%) | 83 (89.2%) | |
| - Infected | 5 (7.2%) | 10 (10.8%) | |
| Pre-operative Hemoglobin (mg/dl) (SD) | 12.94 ± 1.7 | 13.03 ± 1.8 | 0.73 |

Note: A p-value less than 0.05 is considered statistically significant.

Table 2: Operative and Postoperative Outcomes between Standard and Mini PCNL

| Variables | Standard (n=69) | Mini (n=93) | p-value |
|---|---|---|---|
| Number of Tracts (n, %) | | | 0.016 |
| - Single | 49 (71.0%) | 81 (87.1%) | |
| - Multiple | 20 (29.0%) | 12 (12.9%) | |
| Puncture of Calyx (n, %) | | | 0.044 |
| - Upper | 7 (10.1%) | 19 (20.4%) | |
| - Middle | 15 (21.7%) | 33 (35.5%) | |
| - Lower | 28 (40.6%) | 28 (30.1%) | |
| - Upper & Middle (Maximum 2) | 5 (7.3%) | 6 (6.4%) | |
| - Middle & Lower | 9 (13.0%) | 3 (3.2%) | |

| | | | |
|---|---|---|---|
| - Upper & Lower | 6 (8.7%) | 3 (3.2%) | |
| Post-operative Hemoglobin (mg/dl) (SD) | 11.73 ± 1.5 | 11.89 ± 1.9 | 0.845 |
| Drop in Hemoglobin (mg/dl) (SD) | 1.21 ± 1.0 | 1.14 ± 1.1 | 0.336 |
| Clearance Rate (n, %) | 51 (73.9%) | 81 (87.1%) | 0.041 |
| Hospital Stay (days) (SD) | 3.0 ± 1.1 | 2.4 ± 1.0 | 0.030 |

Operative and postoperative outcomes further differentiated the two procedural approaches. A significant difference was found in the number of tracts created, with single tracts being more prevalent in the mini PCNL group (87.1%) compared to the standard PCNL group (71.0%), denoting a preference for a less invasive approach in the mini PCNL procedures (p=0.016) (Table 2). The puncture of calyx also varied significantly; the mini PCNL group had a higher percentage of upper calyx punctures (20.4%) compared to the standard group (10.1%), and similar trends were observed for middle calyx punctures, highlighting the precision in targeting specific calyces in the mini PCNL approach (p=0.044) (Table 2).

Post-operative outcomes were notable for their implications on patient recovery. While the post-operative hemoglobin levels and the drop in hemoglobin did not significantly differ between the groups, indicating comparable levels of operative bleeding and trauma (p=0.845 and p=0.336, respectively), the stone clearance rate was significantly higher in the mini PCNL group (87.1%) compared to the standard PCNL group (73.9%) (p=0.041), suggesting a more effective removal of calculi in the mini PCNL procedures (Table 2). Furthermore, the hospital stay was shorter for patients undergoing mini PCNL (2.4 ± 1.0 days) compared to those who had standard PCNL (3.0 ± 1.1 days), a difference that was statistically significant (p=0.030) and indicative of a faster recovery and return to daily activities for patients treated with the miniaturized approach (Table 2).

## DISCUSSION

Staghorn stones have long been a challenge in urology, demanding effective and minimally invasive treatment strategies. Historically, the standard percutaneous nephrolithotomy (PCNL) was favored over open surgical approaches, primarily due to its superior stone clearance rates and comparatively lower complication rates (16). Despite these advantages, the incidence of complications associated with standard PCNL has remained a significant concern, especially when compared to newer, more minimally invasive techniques (17). In our study, we noted a higher incidence of complications in the standard PCNL group, with post-operative hematuria necessitating blood transfusions being the most frequently encountered complication. This outcome aligns with the established notion that larger tract sizes in standard PCNL, especially when multiple tracts are employed, contribute to greater renal parenchymal injury and subsequent hemorrhage (18).

Interestingly, none of the patients in our study required angioembolization, a procedure often necessitated in cases of significant bleeding post-standard PCNL, particularly when multiple tracts are utilized (19). This deviation from prior findings may reflect advancements in surgical technique or patient selection criteria. The study also documented other complications such as post-operative fever and sepsis, alongside isolated instances of pleural injury requiring chest intubation due to the supra-12th rib access to the calyx, emphasizing the range of potential adverse outcomes associated with both standard and mini PCNL.

The significant differentiation in stone size between groups underlines a traditional bias towards employing standard PCNL for larger stones, with mini-PCNL reserved for smaller calculi (20). However, our findings suggest that mini-PCNL can be effectively applied to larger stones as well, challenging the conventional paradigm. This approach not only reduces complication rates but also shortens hospital stays and minimizes intraoperative bleeding, without compromising stone clearance rates. The advantages of mini-PCNL extend to the utilization of continuous low-pressure irrigation, which mitigates hydrostatic trauma and decreases the risk of septic complications and extravasation (21).

Our study corroborates the findings from a research study in China, which emphasized the safety and efficacy of mini-PCNL in the treatment of staghorn stones (22). Notably, the stone clearance rates in our study favored mini-PCNL, likely due to enhanced visibility and accessibility afforded by the smaller instrumentation, which facilitates navigation to all calyces without significant hemorrhage. The choice of calyx for puncture—a critical step in the procedure—was influenced by various factors including the surgeon's expertise, renal anatomy, and the proximity of adjacent structures. Our analysis suggests that while the lower calyx is more accessible, it is susceptible to guidewire torquing and kinking, whereas punctures in the upper and middle calyces, aligned with the kidney's longitudinal axis, offer better maneuverability (25).

The strengths of our study lie in its prospective design and the comprehensive comparison between standard and mini PCNL techniques. However, limitations are present, including the non-randomized selection of patients, which could introduce selection bias, and the single-center nature of the study, potentially limiting the generalizability of the findings. Future research should aim to

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address these limitations through multicenter, randomized controlled trials to further validate the efficacy and safety of mini-PCNL in a broader population.

## CONCLUSION

In conclusion, our study reinforces the role of PCNL as a cornerstone in the treatment of staghorn stones, with mini-PCNL demonstrating superior outcomes in terms of stone clearance, reduced hospital stays, and minimized complications. These findings highlight the significant impact of minimally invasive techniques in the management of renal calculi, including complex staghorn stones, underscoring the evolution of surgical strategies towards more patient-centered care. Recommendations for future research include the exploration of long-term outcomes associated with mini-PCNL and the development of guidelines to optimize patient selection for this promising technique.

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