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COMPARISON OF EFFICACY OF MINI VERSUS CONVENTIONAL PERCUTANEOUS NEPHROLITHOTOMY FOR COMPLETE STAGHORN STONES

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Abstract

Staghorn calculi represent a complex and challenging form of renal stone disease requiring effective surgical management. Both mini-percutaneous nephrolithotomy (mPCNL) and conventional percutaneous nephrolithotomy (cPCNL) are widely used techniques; however, their comparative efficacy in the management of complete staghorn stones remains under investigation. To compare the stone-free rates and outcomes of mPCNL versus cPCNL in patients with complete staghorn renal calculi. A randomized controlled trial was conducted at the Department of Urology, Institute of Kidney Diseases, Peshawar, from May 8, 2023, to November 7, 2023. A total of 112 patients with complete staghorn calculi were enrolled and randomized into two equal groups (56 patients each): Group A underwent mPCNL, and Group B underwent cPCNL. Patient demographics, stone characteristics, and surgical outcomes were recorded. The primary endpoint was stone-free status, assessed one month postoperatively via non-contrast CT KUB. Data was analyzed using SPSS v25.0, with a significance threshold of $p < 0.05$. The mean age was 39.05 ± 11.07 years in the mPCNL group and 40.02 ± 12.87 years in the cPCNL group ($p = 0.672$). No significant differences were observed in gender distribution, stone laterality, or mean stone size between groups. Complete stone clearance was achieved in 85.7% of patients in the mPCNL group and 91.1% in the cPCNL group ($p = 0.378$). Stratified analyses based on age, gender, stone side, and stone size showed no statistically significant differences in efficacy across subgroups. Both mPCNL and cPCNL demonstrated comparable efficacy in the management of complete staghorn stones, with high stone-free rates and no significant differences in clinical or demographic variables. Further large-scale, multicenter studies with long-term follow-up are warranted to validate these results.

INTRODUCTION

Staghorn calculi, characterized by complex, branching renal stones, presents significant therapeutic challenges. These calculi have been categorized using various classification systems; particularly, the Guy's Stone Score classifies partial staghorn calculi as Score III and complete staghorn calculi as Score IV [1]. Current major urological guidelines recommend standard percutaneous

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nephrolithotomy (PCNL) as the first-line treatment modality for staghorn stones, typically involving access tracts ranging from 24 to 30 French (Fr) in diameter [2]. However, achieving complete stone clearance often necessitates multiple percutaneous tracts, which substantially increase the risk of procedure-related complications [3] Among these, hemorrhage requiring blood transfusion or angiographic embolization represents the most serious adverse event [4]. These complications are primarily attributed to the number and size of the tracts employed. To mitigate such risks, miniaturized PCNL techniques, including mini-, super-mini-, ultra-mini-, and micro-PCNL have emerged as potential alternatives to the conventional approach [5]. Multiple studies have demonstrated that mini-percutaneous nephrolithotomy (mini-PCNL) is comparable in efficacy to standard PCNL for the management of small to medium-sized, non-complex renal stones [6]. In a comparative study by Khadgi et al., involving 153 patients with staghorn calculi, both conventional-PCNL and mini-PCNL achieved similar stone-free rates (SFR) with monotherapy (88.6% for standard PCNL vs. 83% for mini-PCNL). However, mini-PCNL was associated with significantly lower complication rates (12% vs. 24.3%) and reduced severity of adverse events.[11] Similarly, Zhong et al. evaluated 54 patients with staghorn stones and reported a higher SFR with mini-PCNL (89.7% vs. 68%) compared to standard PCNL, while the overall complication rates were comparable between the two groups (37.9% vs. 52%, $p = 0.300$) [7]. Therefore, the current study is designed to determine the efficacy of mini-percutaneous nephrolithotomy (mini-PCNL) and conventional percutaneous nephrolithotomy (conventional-PCNL) in the management of complete staghorn renal calculi.

Materials and Methods

This study was designed as a randomized controlled trial conducted at the Department of Urology, Institute of Kidney Diseases, Hayatabad, Peshawar, over a period of six months, from May 8, 2023, to November 7, 2023. A total of 112 patients diagnosed with complete staghorn calculi were enrolled and randomly allocated into two equal groups of 56 patients each, with one group undergoing conventional percutaneous nephrolithotomy (PCNL) and the other receiving mini-PCNL. The sample size was calculated using the OpenEpi sample size calculator, assuming a level of significance of 5%, a power of 80%, an efficacy of 68% for conventional PCNL, and 89.7% for mini-PCNL, as reported in previous literature [8]. In the current study patients of either gender aged 18 to 60 years or having a negative urine culture prior to the procedure were included. Rest of all patients which have done surgery either minor or major, and also have infection were Excluded.

Data Collection Procedure

The current research study was conducted in the Department of Urology, Institute of Kidney Diseases (IKD), and Peshawar, following ethical approval from the Institutional Ethical Review Board and the College of Physicians and Surgeons Pakistan (CPSP). All patients diagnosed with complete staghorn calculi and scheduled for percutaneous nephrolithotomy (PCNL) were prospectively enrolled, adhering strictly to predefined inclusion and exclusion criteria to minimize confounding variables and reduce bias. Preoperative assessment included a comprehensive medical history, physical examination, and standard laboratory investigations, such as complete blood count, serum creatinine, blood glucose, serum calcium, uric acid, blood grouping, urinalysis, and urine culture. Radiological evaluations included plain abdominal radiography (KUB), ultrasonography, and non-contrast computed tomography (NCCT) of the kidneys, ureters, and bladder (KUB). Participants were randomized into two groups using block randomization. Group A underwent mini-PCNL, while Group B received conventional PCNL. All surgical procedures were performed under general anesthesia in the prone position by a fellow of CPSP with expertise in endourology. The efficacy of the intervention, defined as the stone-free rate, was assessed for one month postoperatively using NCCT-KUB. All imaging assessments were performed by a single experienced radiologist, also a fellow of CPSP, to ensure consistency and reduce inter-observer variability. Patients lost to follow-up were replaced with new participants using the same sampling criteria and method.

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Data Analysis

Data was analyzed using IBM SPSS Statistics version 25.0. Continuous variables such as age and stone size were expressed as mean ± standard deviation (SD), while categorical variables including gender, stone laterality, and treatment efficacy were presented as frequencies and percentages. To assess the impact of potential effect modifiers, stratification was performed for age, gender, stone size, and stone side. Post-stratification comparisons within groups were made using the Chi-square test, with a p-value < 0.05 considered statistically significant. Comparative efficacy between mini-PCNL and conventional PCNL groups was also evaluated using the Chi-square test. Results were summarized and presented through appropriate tables and graphs.

Results

A total of 112 patients were collected in the current study. The study was randomly assigned into two equal groups: mini-PCNL (mPCNL) and conventional-PCNL (cPCNL), with 56 patients in each group. The mean age of patients in the mPCNL group was 39.05 ± 11.07 years, while in the cPCNL group it was 40.02 ± 12.87 years. The difference in mean age between the two groups was not statistically significant (p = 0.672), as shown in Table 1.

Table 1. Comparison of patients' age between the groups

Group	Number	Age (years)		p-value
		Mean	Std. Deviation	
mPCNL	56	39.05	11.07	0.672
cPCNL	56	40.02	12.87	
Total	112	39.94	11.96	

With respect to gender distribution, the mPCNL group consisted of 31 males (55.4%) and 25 females (44.6%), whereas the cPCNL group included 37 males (66.1%) and 19 females (33.9%). The gender distribution was comparable between the two groups, showing no statistically significant difference (p = 0.246) as shown in Table 2.

Table 2. Comparison of patients' gender between the groups

Gender	Group		p-value
	mPCNL f (%)	cPCNL f (%)	
Male	31 (55.4%)	37 (66.1%)	0.246
Female	25 (44.6%)	19 (33.9%)	
Total	56 (100.0%)	56 (100.0%)	

Analysis of stone laterality revealed that in the mPCNL group, 30 patients (53.6%) had right-sided stones and 26 patients (46.4%) had left-sided stones. In the cPCNL group, 25 patients (44.6%) had right-sided stones and 31 patients (55.4%) had left-sided stones. The distribution of stone laterality did not differ significantly between the groups (p = 0.345) as shown in Table 3.

Table 3. Comparison of stone side between the groups

Stone Side	Group		p-value
	mPCNL f (%)	cPCNL f (%)	
Right	30 (53.6%)	25 (44.6%)	0.345
Left	26 (46.4%)	31 (55.4%)	
Total	56 (100.0%)	56 (100.0%)	

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The mean stone size was 3.29 ± 0.50 cm in the mPCNL group and 3.23 ± 0.51 cm in the cPCNL group. This difference was not statistically significant (p = 0.537) the overall data are shown in Table 4.

Table 4. Comparison of stone size between the groups

Group	N	Stone size (cm)		p-value
		Mean	Std. Deviation	
mPCNL	56	3.29	0.50	0.537
cPCNL	56	3.23	0.51	
Total	112	3.26	0.50	

Stone-free status was achieved in 48 patients (85.7%) in the mPCNL group, while 8 patients (14.3%) had residual stones. In the cPCNL group, 51 patients (91.1%) achieved complete stone clearance, with 5 patients (8.9%) having residual stones. The difference in stone clearance efficacy between the two groups was not statistically significant (p = 0.378) as shown in Table 5.

Table 5. Comparison of efficacy between groups

Efficacy	Group		p-value
	mPCNL f (%)	cPCNL f (%)	
Yes	48 (85.7%)	51 (91.1%)	0.378
No	08 (14.3%)	05 (8.9%)	
Total	56 (100.0%)	56 (100.0%)	

Stratification Analysis

To evaluate potential effect modifiers, efficacy was stratified by age, gender, stone laterality, and stone size in both the mini-PCNL (mPCNL) and conventional-PCNL (cPCNL) groups. When stratified by age, patients under 40 years of age had an efficacy rate of 88.9% in the mPCNL group and 94.1% in the cPCNL group (p = 0.435), while patients aged above 40 years showed efficacy rates of 80.0% and 86.4%, respectively (p = 0.580). No statistically significant difference in stone-free rates was observed between the two techniques across age groups. Regarding gender, male patients had efficacy rates of 77.4% in the mPCNL group and 89.2% in the cPCNL group (p = 0.189). Among female patients, the stone-free rates were 96.0% for mPCNL and 94.7% for cPCNL (p = 0.842). Again, no statistically significant differences were observed between the groups based on gender. In terms of stone laterality, right-sided stones were cleared in 83.3% of mPCNL cases and 88.0% of cPCNL cases (p = 0.625), while left-sided stones were cleared in 88.5% and 93.5% of cases in the mPCNL and cPCNL groups, respectively (p = 0.499). These findings suggest that stone location did not significantly influence the comparative efficacy of the two procedures. When stratified by stone size, patients with stones smaller than 3 cm demonstrated clearance rates of 76.0% in the mPCNL group and 89.7% in the cPCNL group (p = 0.179). For stones larger than 3 cm, the efficacy was 93.5% in mPCNL and 92.6% in cPCNL (p = 0.866). These results indicate that stone size did not significantly affect treatment outcomes between the two groups.

Table 6. Stratification of efficacy by age, gender, stone side and stone size in both groups

Variable		Group	Efficacy		p-value
			Yes f (%)	No f (%)	
Age (years)	≤ 40	mPCNL	32 (88.9%)	04 (11.1%)	0.435
		cPCNL	32 (94.1%)	02 (5.9%)	
	> 40	mPCNL	16 (80.0%)	04 (20.0%)	0.580
		cPCNL	19 (86.4%)	03 (13.6%)	

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Gender	Male	mPCNL	24 (77.4%)	07 (22.6%)	0.189
		cPCNL	33 (89.2%)	04 (10.8%)	
	Female	mPCNL	24 (96.0%)	01 (4.0%)	0.842
		cPCNL	18 (94.7%)	01 (5.3%)	
Stone Side	Right	mPCNL	25 (83.3%)	05 (16.7%)	0.625
		cPCNL	22 (88.0%)	03 (12.0%)	
	Left	mPCNL	23 (88.5%)	03 (11.5%)	0.499
		cPCNL	29 (93.5%)	02 (6.5%)	
Stone size (cm)	≤ 3	mPCNL	19 (76.0%)	06 (24.0%)	0.179
		cPCNL	26 (89.7%)	03 (10.3%)	
	> 3	mPCNL	29 %93.5)	02 (6.5%)	0.866
		cPCNL	25 (92.6%)	02 (7.4%)	

Discussion

The management of staghorn calculi continues to be a significant clinical challenge due to their complex branching morphology and the associated risk of complications. This randomized controlled trial compared the efficacy and safety of mini-percutaneous nephrolithotomy (mPCNL) and conventional percutaneous nephrolithotomy (cPCNL) in patients with complete staghorn stones. In the current research study, both procedures offer comparable stone clearance rates, with no statistically significant difference observed between the two groups (p = 0.378). The overall stone-free rate (SFR) achieved was 85.7% in the mPCNL group and 91.1% in the cPCNL group, consistent with previously published studies. For instance, Khadgi et al. reported SFRs of 83% and 88.6% for mPCNL and cPCNL, respectively, while Zhong et al. observed a significantly higher SFR in the mPCNL group (89.7%) compared to cPCNL (68%) [9, 10]. The results of the current study align with these results, indicating that mPCNL can achieve high stone clearance rates comparable to cPCNL, even in patients with large stone burdens such as staghorn calculi. Importantly, stratification analysis by variables such as age, gender, stone laterality, and stone size revealed no statistically significant impact on the efficacy outcomes between the two groups. This suggests that the performance of mPCNL remains consistent across various patient demographics and clinical presentations. In particular, the comparable outcomes in patients with stones larger than 3 cm further reinforce the utility of mPCNL for managing complex calculi, despite its relatively smaller tract size. One of the key advantages of mPCNL lies in its minimally invasive nature, which is associated with reduced postoperative pain, lower bleeding risk, and shorter hospital stays, as shown in several previous investigations [11, 12]. While these parameters were not the primary outcomes in the present study, the observed efficacy supports the consideration of mPCNL as a viable alternative to conventional approaches, especially in resource-constrained settings where complication management may be challenging. In the present study, no statistically significant differences were observed in stone-free rates between the mini-PCNL (mPCNL) and conventional-PCNL (cPCNL) groups, indicating comparable efficacy of both techniques in the management of complete staghorn calculi. Furthermore, subgroup analysis based on patient age, gender, stone laterality, and stone size also revealed no significant variation in treatment outcomes between the two groups. These findings suggest that both mPCNL and cPCNL maintain consistent performance across a wide range of patient demographics and stone characteristics, reinforcing their reliability and versatility as treatment options. Despite the encouraging results, certain limitations of this study must be acknowledged. The single-center design, modest sample size, and relatively short follow-up period may limit the generalizability and long-term applicability of the findings. Additionally, while the study was prospective and randomized, the sample size may not have been sufficient to detect smaller, yet potentially clinically meaningful differences between the two techniques. These results

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contribute valuable evidence to the growing literature supporting the use of both mPCNL and cPCNL for staghorn calculi. Future studies incorporating larger, multi-center cohorts with extended follow-up periods are recommended to validate these findings and further refine clinical guidelines for the optimal management of complex renal stones.

Conclusion

In conclusion, this study comparing miniaturized percutaneous nephrolithotomy (mPCNL) and conventional percutaneous nephrolithotomy (cPCNL) in the treatment of staghorn renal calculi demonstrated comparable efficacy in achieving complete stone clearance, with both techniques yielding high success rates. No statistically significant differences were observed between the two groups in terms of patient demographics, stone characteristics, or clinical outcomes, indicating that both mPCNL and cPCNL are equally effective and feasible options for the surgical management of staghorn stones.

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