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Comparison of Upper versus Lower Calyceal Puncture Technique in Percutaneous Nephrolithotomy for Complex Renal Calculi

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ABSTRACT

Objective: To compare upper and lower calyceal puncture techniques during percutaneous nephrolithotomy (PCNL) for complex renal calculi regarding stone clearance, operative time and postoperative complications.

Study Design: Quasi-experimental study.

Place and Duration of Study: Department of Urology, Armed Forces Institute of Urology, Rawalpindi Pakistan, from Jan 2026 to Apr 2026.

Methodology: A total of 210 patients aged 18-60 years with complex renal calculi were enrolled by consecutive non-probability sampling and allocated using a computer-generated randomization sequence into Group-A (upper calyceal puncture) and Group-B (lower calyceal puncture). Patients with bleeding disorders, solitary functioning kidney, pregnancy, active untreated urinary tract infection or previous ipsilateral renal surgery were excluded. PCNL was performed under general anesthesia using fluoroscopic guidance.

Results: Mean age was 38.8±10.0 years. Male to female ratio was 127:83, (approximately 1.5:1.), Complete stone clearance was higher in Group-A than Group-B (91.4% versus 77.1%; *p*=0.006), while residual stones were lower (8.6% versus 22.9%; *p*=0.006). Mean operative time was shorter in Group-A (78.5±12.4 versus 85.2±14.1 minutes). Bleeding, fever, second puncture and hospital stay >3 days were more frequent in Group-B but not statistically significant.

Conclusion: Upper calyceal puncture achieved better clearance and shorter operative time than lower calyceal puncture, with comparable early postoperative safety.

Keywords: Renal Calculi, Nephrolithotomy, Postoperative Complications, Treatment Outcome.

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INTRODUCTION

Renal calculi are a recurrent urological disease that can cause renal colic, hematuria, obstruction, infection and hospital admissions. The Global Burden of Disease 2021 estimates reported a substantial worldwide burden of urolithiasis, and Asia remains within the recognised stone belt. Regional data show wide variation in prevalence across West, South and Southeast Asia, while Pakistani data also indicate a meaningful stone burden in local populations.[1-3]

Percutaneous nephrolithotomy (PCNL) is the recommended treatment for large renal stones, staghorn calculi and other complex stone burdens because it achieves higher stone-free rates than shock wave lithotripsy or retrograde intrarenal surgery. Contemporary guidelines emphasize that treatment success depends on stone burden, pelvicalyceal anatomy, imaging, surgeon experience, tract size and the choice of the access calyx.[4-8]

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Selection of the access calyx is a key technical decision during PCNL. Upper calyceal access provides a straighter working tract to the renal pelvis, ureteropelvic junction and branching calyces, but supracostal access may increase thoracic complications including pleural injury, hydrothorax and pneumothorax. Lower calyceal access is familiar and may reduce thoracic risk, although its acute working angle may restrict maneuverability and increase residual fragments in complex stones.[8]

Although several international studies and a recent meta-analysis have compared upper and lower calyceal access during PCNL, their findings remain inconsistent, particularly regarding stone clearance and perioperative complications. Furthermore, prospective evidence from Pakistan evaluating the optimal choice of access calyx is limited. Generating local evidence is important because patient characteristics, stone burden and surgical expertise may influence outcomes. Therefore, this study was conducted to compare upper versus lower calyceal puncture during PCNL for complex renal calculi with

respect to stone clearance, operative time and early postoperative complications.

METHODOLOGY

This quasi-experimental study was conducted at the Department of Urology, Armed Forces Institute of Urology Rawalpindi Pakistan from Jan, 2026 to April, 2026 after approval of the synopsis by the College of Physicians and Surgeons Pakistan. The study duration was three months after approval. Ethical approval was obtained from the institutional ethics/review committee vide Uro-Trg-1/IRB/2025/33, dated 29 August 2025. Written informed consent was obtained from each patient after explaining the purpose, potential benefits and risks of the procedure.

The sample size was calculated with the OpenEpi web-based calculator using a reported success rate of 90.70% for upper calyceal puncture and 76.47% for lower calyceal puncture, with 80% power and 95% confidence level.9 The required sample size was 210 patients, with 105 patients in each group. Consecutive non-probability sampling was used. Patients were allocated into Group-A and Group-B; Group-A underwent upper calyceal puncture and Group-B underwent lower calyceal puncture. The phase-wise flow of patients through the study is shown in Figure.

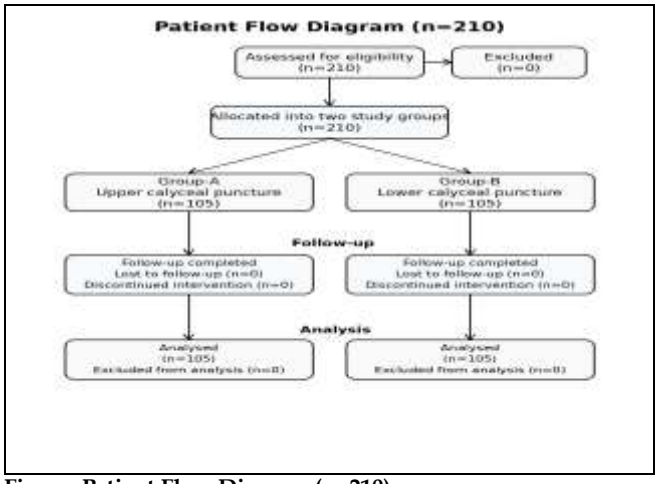

Figure: Patient Flow Diagram (n=210)

Inclusion Criteria: Male and female patients aged 18-60 years, diagnosed with complex renal calculi on radiological evaluation, fit for general anesthesia and planned for PCNL were included. Complex renal calculi were defined as renal stones involving the renal pelvis and extending into calyces, large stone burden requiring PCNL, or calculi in which complete clearance through a simple single lower calyceal route was expected to be difficult.

Exclusion Criteria: Patients with known bleeding disorder or uncorrected coagulopathy, pregnancy, solitary functioning kidney, previous renal surgery on the same side, active untreated urinary tract infection, severe uncontrolled comorbidity making general anaesthesia unsafe, or refusal to provide written informed consent were excluded.

All procedures were performed under the supervision of an experienced urologist. Cystoscopy was performed and a 4 Fr ureteric catheter was inserted. Patients were placed in prone position. Fluoroscopic guidance was used to identify the calyx that provided the most favorable access to the stone. Correct puncture was confirmed by free contrast flow, clear delineation of the collecting system and guidewire placement. Tract dilation was performed using fascial and metallic dilators. Stones were fragmented with pneumatic lithoclast and fragments removed using a rigid nephroscope. If complete stone clearance could not be achieved through the initial tract, an additional puncture was performed.

The primary outcome was successful stone clearance, defined as no residual fragments or residual fragments <4 mm on fluoroscope and Nephroscope as seen per-operatively. Secondary outcomes included residual stones, operative time, bleeding complications, postoperative fever, need for second puncture and hospital stay exceeding three days.

Data was recorded on a predesigned questionnaire. Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS), version 23. Age, Stone size and operative time were normally distributed. Normality of quantitative data was assessed using the Shapiro-Wilk test. Age, Stone size and operative time were normally distributed. Stone size and operative time were expressed as Mean±SD; age was reported as Mean±SD and additionally stratified into predefined age groups. Categorical variables were reported as frequency and percentage. Chi-square test or Fisher exact test was applied after stratification, and $p< 0.05$ was considered statistically significant.

RESULTS

A total of 210 patients were included, with 105 patients in each group. The overall mean age was 38.8±10.0 years. Mean age was comparable between Group-A and Group-B (38.6±10.2 versus 39.1±9.8 years). Most patients were aged 31-50 years. Male patients predominated in both groups, comprising 61.9% of Group-A and 59.0% of Group-B. Baseline

demographic and stone-related characteristics were comparable between the two groups, with no statistically significant differences in age, age distribution, gender, stone side, stone location or stone size (all p>0.05). Operative time was significantly longer in the lower calyceal puncture group compared to the upper calyceal puncture group (85.2±14.1 vs 78.5±12.4 minutes, p<0.001) (Table-I).

Table-I: Demographic and Clinical Characteristics of the Study Population (n=210)

Variables	Categories	Group-A: Upper puncture (n=105)	Group-B: Lower puncture (n=105)	*p*-value
Age (years)	Mean±SD	38.6±10.2	39.1±9.8	0.720
Age group (years), n(%)				
	18-30 years	28(26.7%)	25(23.8%)	0.883
	31-50 years	55(52.4%)	58(55.2%)	
	>50 years	22(21.0%)	22(21.0%)	
Gender, n(%)				
	Male	65(61.9%)	62(59.0%)	0.778
	Female	40(38.1%)	43(41.0%)	
Stone side, n(%)				
	Right	55(52.4%)	53(50.5%)	0.890
	Left	50(47.6%)	52(49.5%)	
Stone location, n(%)				
	Renal pelvis	60(57.1%)	58(55.2%)	0.889
	Renal pelvis with calyceal extension	45(42.9%)	47(44.8%)	
Stone size (cm)	Mean±SD	2.8±0.6	2.7±0.5	0.206
Operative time (min)	Mean±SD	78.5±12.4	85.2±14.1	<0.001

SD: standard deviation. Continuous variables are presented as mean ± standard deviation and compared using independent samples t test. Categorical variables are presented as frequency (percentage) and compared using Chi square test (or Fisher's exact test where appropriate). A p value ≤ 0.05 was considered statistically significant.

Right-sided stones were slightly more common in both groups. The mean stone size was 2.8±0.6 cm in Group-A and 2.7±0.5 cm in Group-B. Most stones involved the renal pelvis, with or without extension into calyces. Mean operative time was shorter in Group-A than Group-B (78.5±12.4 versus 85.2±14.1 minutes).

Table-II: Outcomes and postoperative complications (n=210)

Outcome	Group-A: Upper Calyx	Group-B: Lower Calyx	*p*-value
Successful stone clearance	96(91.4%)	81(77.1%)	0.006
Residual stones	9(8.6%)	24(22.9%)	0.006
Bleeding complications	7(6.7%)	10(9.5%)	0.420
Postoperative fever	6(5.7%)	9(8.6%)	0.410
Need for second puncture	12(11.4%)	18(17.1%)	0.240
Hospital stay >3 days	14(13.3%)	20(19.0%)	0.260

Complete stone clearance was significantly higher in Group-A than Group-B (91.4% versus 77.1%; p=0.006). Residual stones were significantly less frequent in Group-A than Group-B (8.6% versus 22.9%; p=0.006). Bleeding complications, postoperative fever, requirement for a second puncture and hospital stay exceeding three days were numerically more common in Group-B; however, these differences did not reach statistical significance (Table-II).

DISCUSSION

This study found a clinically meaningful and statistically significant advantage of upper calyceal puncture for stone clearance in complex renal calculi. Complete clearance was achieved in 91.4% of patients in the upper puncture group compared with 77.1% in the lower puncture group, giving an absolute difference of 14.3%. Residual stones followed the same pattern. Because both groups were similar in age, gender, stone side and stone size, this difference is more likely to reflect the working access route rather than a major baseline imbalance.

These findings closely match the Indian study by Singh *et al.*, who reported success rates of 90.70% for upper calyceal access and 76.47% for lower calyceal access in complex renal calculi.[9] The absolute benefit in that study was 14.23%, almost identical to this study i.e 14.3%. The present results differ from the Pakistani retrospective series by Memon *et al.*, in which complete clearance was numerically higher in the lower-pole access group than in the upper-pole access group.[10] This opposite direction is important because their study was retrospective, had unequal group sizes and included a broader range of renal calculi rather than only complex stones.

The smaller Bangladeshi study by Mazumder *et al.*, reported higher complete clearance with upper calyceal access than lower calyceal access, although the difference did not reach the statistical significance, most likely because of limited sample size.[11] This study is also concordant with the systematic review and meta-analysis by Ma *et al.*, which found that superior calyceal access reduced failed stone clearance, reduced additional puncture rate and shortened operative time without a significant increase in overall complications.[12] In our study, operative time was shorter with upper access by 6.7 minutes, and the need for second puncture was numerically lower. The direction of effect supports the concept that a favourable upper tract may reduce excessive torque, improve instrument reach and shorten fragmentation time.

Critical reviews of PCNL shows that stone-free status is influenced by stone configuration, tract number, access route, imaging method and surgeon experience; therefore, access route should not be interpreted in isolation.[13,14] The regional findings in

this study support the anatomical explanation that an upper calyceal tract can provide a straighter working axis to the renal pelvis and branching calyces, but this advantage must be balanced against access safety and individual anatomy. The data regarding percentage of supra-11 versus supra-12 PCNL puncture was not recorded as a variable in this study.

From a practical standpoint, these findings support structured preoperative access planning rather than routine preference for either calyx. Upper calyceal puncture appears advantageous when the dominant stone burden lies in the renal pelvis with calyceal extension and when a controlled tract can be created safely. Lower calyceal puncture remains appropriate when it offers the safest direct access or when upper access would require an unfavourable supracostal trajectory. Preoperative imaging should therefore be reviewed for stone burden, infundibular angle, pleural reflection, adjacent bowel and likelihood of needing an additional puncture.

This study has limitations. It was quasi-experimental and conducted at a single centre, so selection and operator factors cannot be fully excluded. Computed tomography-based stone-free assessment, stone density, detailed pelvicalyceal anatomy, supracostal versus subcostal puncture level and long-term recurrence were not fully analysed. Future multicentre randomized studies should compare access routes after stratifying patients by stone complexity score, puncture level and imaging guidance. Despite these limitations, the sample size was adequate, and the findings provide useful local evidence for selecting puncture technique in complex renal calculi.

CONCLUSION

Upper calyceal puncture appears to provide higher stone clearance and shorter operative time in selected patients with complex renal calculi while maintaining comparable early postoperative safety.

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Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

WUB & HA: Data acquisition, data analysis, critical review, approval of the final version to be published.

KM & ND: Study design, data interpretation, drafting the manuscript, critical review, approval of the final version to be published.

TH & TH: Conception, data acquisition, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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