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Efficacy of Lower Calyceal Access in Percutaneous Nephrolithotomy for Staghorn Renal Calculi: A Single-Centre Experience

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Abstract

Background

Staghorn calculi represent a complex form of nephrolithiasis associated with recurrent infection, renal deterioration, and significant morbidity. Percutaneous nephrolithotomy (PCNL) remains the gold-standard treatment; however, the optimal calyceal access approach for achieving effective stone clearance with minimal morbidity has not been definitively established. We aimed to evaluate the efficacy and safety of lower calyceal access in PCNL for staghorn calculi and to compare perioperative outcomes between lower and non-lower calyceal access approaches.

Methods

We conducted a retrospective cohort study of PCNL performed for staghorn calculi between 2016 and 2024 at a single tertiary centre. The renal unit (stone episode) was the unit of analysis; 111 renal units in 104 patients met the inclusion criteria, having postoperative imaging obtained within 90 days of the relevant PCNL procedure. The primary outcome was the final stone-free rate (SFR) per renal unit, defined as no visible residual fragment or a residual fragment < 4 mm on any postoperative imaging modality after the last PCNL session; the single-session SFR after the index procedure was a secondary outcome. Second-look PCNL was counted as part of the PCNL treatment course. Perioperative outcomes (complication rate [Clavien–Dindo], haemoglobin change, length of stay, operative time, and the number of puncture attempts) were analysed at the level of the PCNL procedure, and the need for second-look PCNL at the level of the renal unit. Categorical variables were compared using Pearson's chi-squared or Fisher's exact test and continuous variables using the Wilcoxon rank-sum test; multivariable logistic regression adjusted for age, sex, and stone burden.

Results

Lower calyceal access was used in 83.8% of renal units. The final PCNL stone-free rate, assessed after the final PCNL session and including second-look PCNL, was 74.8% per renal unit (single-session 44.1%), with no significant difference between lower and non-lower access (72.0% vs 88.9%, p = 0.233). The procedure-level complication rate (11.7% vs 6.9%, p = 0.741), haemoglobin change, length of stay, and number of puncture attempts were comparable between groups. On multivariable analysis, lower calyceal access was not independently associated with the final stone-free rate (adjusted odds ratio 0.43, 95% CI 0.09–2.09, p = 0.293); no covariate was significantly associated with stone clearance.

Conclusions

Lower calyceal access is the dominant approach for staghorn PCNL and achieves stone-free, complication, and perioperative outcomes comparable to non-lower access approaches. These findings support lower calyceal access as a safe and effective default strategy when anatomically possible, with non-lower or additional access reserved for stones that cannot be adequately cleared through a lower-pole approach.

Background

Staghorn calculi represent one of the most complex forms of nephrolithiasis, characterised by extensive branching stones occupying the renal pelvis and multiple calyces [1]. If inadequately treated, these stones are associated with recurrent urinary tract infections, urosepsis, progressive renal deterioration, and eventual loss of renal function [1]. Achieving complete stone clearance remains the cornerstone of management, as residual fragments may serve as a nidus for persistent infection and recurrence [1]. Contemporary guidelines from the European Association of Urology (EAU) and the American Urological Association (AUA) recommend percutaneous nephrolithotomy (PCNL) as the first-line treatment for large and staghorn calculi, given its superior stone-free rates compared with alternative modalities such as shock wave lithotripsy and ureteroscopy [1–4].

Despite its established role, the optimal calyceal access strategy during PCNL for staghorn calculi remains controversial [5–7]. Upper-pole access offers a relatively straight tract to the renal pelvis and facilitates entry into multiple calyces, potentially improving stone clearance [5–7]. However, supracostal puncture is associated with an increased risk of thoracic complications, including pleural injury and hydrothorax, as well as bleeding-related morbidity [5–7]. Conversely, lower calyceal access is generally considered technically safer, particularly in minimising thoracic complications, but concerns remain regarding whether it allows adequate access to all stone-bearing calyces in complex staghorn calculi without requiring multiple access tracts [5–7].

The number and location of access tracts during PCNL are important determinants of perioperative outcomes [8–10]. Multiple tracts have been associated with increased bleeding and higher transfusion rates [8–10]. Therefore, identifying an access strategy that maximises stone clearance while maintaining an acceptable safety profile is of significant clinical importance in the management of complex renal stones [8–10]. Previous work from our institution evaluated the outcomes of lower calyceal single-access PCNL for staghorn calculi and demonstrated that this approach is both safe and effective, achieving high stone-free rates with minimal complications. However, that study was limited by a smaller sample size and focused exclusively on single-access procedures without direct comparison to alternative access strategies [11].

Accordingly, the present study aims to build upon these findings by evaluating the efficacy and safety of lower calyceal access in a larger and more contemporary cohort of patients with staghorn calculi. In addition, we sought to compare perioperative and postoperative outcomes between lower and non-lower calyceal access approaches, with particular emphasis on stone-free rates and complication profiles.

Methods

Study design and population

We conducted a retrospective cohort study of PCNL procedures performed for staghorn renal calculi between January 2016 and July 2024 at a single tertiary referral centre (King Abdulaziz Medical City, Riyadh, Saudi Arabia). Patients of any age with a staghorn calculus confirmed on preoperative non-contrast computed tomography were eligible. In keeping with established reporting of staghorn PCNL outcomes, the renal unit was used as the unit of analysis [12]; each renal unit was represented by a discrete stone episode, defined as the treatment course (one or more PCNL sessions) directed at a single kidney. Repeat (second-look) PCNL sessions performed on the same kidney within a single treatment course were grouped within the same stone episode, and the index procedure was taken as the first session of the episode. Renal units were included only if postoperative imaging assessing stone clearance was available within 90 days of the relevant PCNL procedure; procedures without postoperative imaging, or with imaging obtained 90 days or more after surgery, were excluded. The final analytic cohort comprised 111 renal units (stone episodes) in 104 patients. Demographic, clinical, stone-related, operative, and outcome data were extracted from the hospital's electronic medical records.

Endpoints and definitions

The primary outcome was the final stone-free rate (SFR) per renal unit, defined as the absence of any visible residual stone fragment or the presence of a clinically insignificant residual fragment measuring less than 4 mm on the postoperative imaging obtained after the final PCNL session of the episode, within 90 days of that procedure. Where an episode comprised more than one PCNL session — including a planned second-look PCNL — all sessions were grouped within the same renal unit, and the final SFR was assessed on the imaging following the last PCNL session; second-look PCNL was counted as part of the PCNL treatment course.

Postoperative imaging included non-contrast computed tomography, plain radiography (KUB), or ultrasonography; where more than one modality was available, the most definitive study was used. Stone burden was estimated in mm^2 using the nephrolithometric nomogram formula (Stone burden = 0.785 × maximum length × maximum width); for multiple discrete stones, the individual stone areas were summed.

Perioperative outcomes — operative time, overall complication rate graded by the Clavien–Dindo classification, change in haemoglobin concentration, length of hospital stay, and the number of puncture attempts — were analysed at the level of the individual PCNL procedure. The requirement for second-look PCNL was assessed at the level of the renal unit. Lower calyceal access was defined as recorded lower-pole access; the non-lower group comprised middle-pole, upper-pole, or multiple-pole access. The recorded puncture count reflected the number of needle puncture attempts to obtain renal access. For the renal-unit analyses, the access group was assigned according to the index procedure of each renal

unit; for procedure-level analyses, access was classified according to the access used in that specific procedure.

Statistical analysis

Statistical analyses were performed using RStudio (version 2024.9.1.394, Boston, MA, USA) running R version 4.4.2. Descriptive statistics summarised patient demographics, clinical characteristics, stone parameters, operative details, and postoperative outcomes. Categorical variables were presented as frequencies and percentages, and continuous variables as medians with interquartile ranges (IQR). The association between lower calyceal access and categorical variables was assessed using Pearson's chi-squared test or Fisher's exact test, as appropriate, and continuous variables were compared using the Wilcoxon rank-sum test. To evaluate whether lower calyceal access was independently associated with the final stone-free rate after accounting for potential confounders, a multivariable logistic regression model was constructed including lower calyceal access, age, sex, and stone burden (per 100 mm^2 increment) as a priori covariates. Because a minority of patients contributed more than one renal unit or more than one procedure, the robustness of the regression was confirmed using patient-clustered robust standard errors, and procedure-level comparisons were interpreted with this clustering in mind. Results are reported as adjusted odds ratios (aOR) with 95% confidence intervals (CI). A two-sided p-value < 0.05 was considered statistically significant.

Results

Cohort and calyceal access

A total of 111 renal units (stone episodes) in 104 patients met the inclusion criteria, with postoperative imaging obtained within 90 days of the relevant PCNL procedure. Stone clearance was assessed by non-contrast computed tomography in 71.2% of renal units, plain radiography in 13.5%, and ultrasonography in 15.3%; the median interval from surgery to imaging was 6 days (IQR 1–38). Lower calyceal access was used in 93 renal units (83.8%), followed by middle (10.8%) and upper (5.4%) calyceal access (Fig. 1). Thirty-nine renal units (35.1%) underwent second-look PCNL (one or more additional PCNL sessions within the same episode).

Demographic and clinical characteristics stratified by lower calyceal access

The cohort was predominantly male (67.6%), with a median age of 52 years (IQR 36–62). Patients undergoing lower calyceal access tended to be older than those undergoing non-lower access (median 55 vs 41.5 years, $p = 0.047$). Common comorbidities included hypertension (45.0%), diabetes (41.4%), and dyslipidaemia (26.1%), none of which differed significantly between access groups. Renal units were left-sided in 53.2% and right-sided in 46.8% (Table 1).

Table 1
Demographic and clinical characteristics stratified by lower calyceal access (per renal unit).

Characteristic	Overall (N = 111)	Non-lower (N = 18)	Lower (N = 93)	p-value
Sex				
Male	75 (67.6%)	13 (72.2%)	62 (66.7%)	0.645
Female	36 (32.4%)	5 (27.8%)	31 (33.3%)	
Age, years — median (IQR)	52 (36–62)	41.5 (35–53.5)	55 (42–62)	0.047
Comorbidities				
Diabetes mellitus	46 (41.4%)	6 (33.3%)	40 (43.0%)	0.446
Hypertension	50 (45.0%)	8 (44.4%)	42 (45.2%)	0.955
Dyslipidaemia	29 (26.1%)	3 (16.7%)	26 (28.0%)	0.393
Chronic kidney disease	7 (6.3%)	1 (5.6%)	6 (6.5%)	1.000
Side				
Right	52 (46.8%)	8 (44.4%)	44 (47.3%)	0.823
Left	59 (53.2%)	10 (55.6%)	49 (52.7%)	

Data are n (%) unless otherwise stated. No other characteristic differed significantly. Comparisons by Pearson's chi-squared or Fisher's exact test; age by Wilcoxon rank-sum test.

Stone characteristics and stone-free outcomes stratified by lower calyceal access

The median stone burden was 336 mm² (IQR 220–596) and was greater in the lower-access group (347 vs 247 mm², p = 0.043). Calcium oxalate was the most common stone composition (36.0%), followed by uric acid (28.8%), cystine (12.6%), and mixed stones (9.9%); the composition was unknown or not analysed in 10.8% (Table 2). The final PCNL stone-free rate was 74.8% per renal unit (83/111), and the single-session stone-free rate after the index procedure was 44.1% (49/111). There were no statistically significant differences between the lower and non-lower access groups in the final stone-free rate (72.0% vs 88.9%, p = 0.233), single-session stone-free rate (40.9% vs 61.1%, p = 0.113), or need for second-look PCNL (36.6% vs 27.8%, p = 0.594) (Table 2).

Table 2
Stone characteristics and stone-free outcomes stratified by lower calyceal access (per renal unit).

Characteristic	Overall (N = 111)	Non-lower (N = 18)	Lower (N = 93)	p-value
Stone burden, mm² — median (IQR)	336 (220–596)	247 (169–424)	347 (224–606)	0.043
Stone composition				
Calcium oxalate	40 (36.0%)	6	34	
Uric acid	32 (28.8%)	5	27	
Cystine	14 (12.6%)	1	13	
Mixed	11 (9.9%)	2	9	
Struvite	2 (1.8%)	2	0	
Unknown / not analysed	12 (10.8%)	2	10	
Stone-free outcomes				
Final stone-free rate	83 (74.8%)	16 (88.9%)	67 (72.0%)	0.233
Single-session stone-free rate	49 (44.1%)	11 (61.1%)	38 (40.9%)	0.113
Second-look PCNL	39 (35.1%)	5 (27.8%)	34 (36.6%)	0.594

Data are n (%) or median (IQR). The final stone-free rate reflects PCNL and includes clearance achieved by second-look PCNL. Comparisons by Pearson's chi-squared, Fisher's exact, or Wilcoxon rank-sum test, as appropriate.

Procedure-level perioperative outcomes stratified by lower calyceal access

At the level of the individual PCNL procedure (n = 157), a single puncture attempt was recorded in 87.9% of procedures, with no significant difference between access groups (two or more attempts in 10.9% vs 17.2%, p = 0.351), and operative time commonly ranged between two and three hours. Median preoperative and postoperative haemoglobin concentrations were 13.6 and 12.7 g/dL, respectively (Fig. 2), with a median haemoglobin drop of 0.9 g/dL. The median hospital stay was 6.0 days (IQR 4.0–9.0). Most procedures were free of complications (89.2%); 10.8% were associated with at least one postoperative complication graded by the Clavien–Dindo classification (Table 3). The most frequent complications were haematuria, bleeding, and sepsis (Fig. 3). None of the procedure-level perioperative outcomes — number of puncture attempts (p = 0.351), operative time (p = 0.054), haemoglobin drop (p = 0.912), length of hospital stay (p = 0.251), complication rate (11.7% vs 6.9%, p = 0.741), or Clavien–Dindo grade (p = 0.135) — differed significantly between the lower and non-lower access groups (Table 3).

Table 3
Procedure-level perioperative outcomes stratified by lower calyceal access (per PCNL procedure).

Outcome	Overall (N = 157)	Non-lower (N = 29)	Lower (N = 128)	p-value
Number of punctures				
One	138 (87.9%)	24 (82.8%)	114 (89.1%)	0.351
Two	15 (9.6%)	3 (10.3%)	12 (9.4%)	
Three	4 (2.5%)	2 (6.9%)	2 (1.6%)	
Operative time, hours — median (IQR)	3 (2–3)	3 (3–4)	3 (2–3)	0.054
Preoperative Hgb, g/dL — median (IQR)	13.6 (12.0–14.7)	13.5 (11.6–14.4)	13.7 (12.0–14.8)	0.391
Postoperative Hgb, g/dL — median (IQR)	12.7 (10.9–13.7)	12.0 (10.1–13.6)	12.7 (11.1–13.7)	0.251
Haemoglobin drop, g/dL — median (IQR)	0.9 (0.4–1.8)	0.6 (0.3–2.0)	0.9 (0.4–1.6)	0.912
Length of stay, days — median (IQR)	6 (4–9)	7 (5–12)	6 (4–9)	0.251
Clavien–Dindo grade				0.135
None (0)	140 (89.2%)	27 (93.1%)	113 (88.3%)	
I	5 (3.2%)	0 (0.0%)	5 (3.9%)	
II	7 (4.5%)	0 (0.0%)	7 (5.5%)	
IIIa	1 (0.6%)	1 (3.4%)	0 (0.0%)	
IVa	4 (2.5%)	1 (3.4%)	3 (2.3%)	
Any complication	17 (10.8%)	2 (6.9%)	15 (11.7%)	0.741

Data are n (%) or median (IQR). Outcomes are reported per PCNL procedure (157 procedures within the 111 renal units), with access classified according to the access used in that procedure. Complication events reflect the adjudicated Clavien–Dindo grading. Comparisons by Pearson's chi-squared, Fisher's exact, or Wilcoxon rank-sum test, as appropriate.

Sensitivity analysis

A sensitivity analysis restricted to the 79 renal units assessed by non-contrast computed tomography within 90 days yielded a final PCNL stone-free rate of 74.7%, with no significant difference between lower and non-lower access (72.7% vs 84.6%, p = 0.498), confirming the primary finding under strict tomographic assessment.

Multivariable logistic regression analysis

Multivariable logistic regression was performed for the final stone-free rate, including all 111 renal units. After adjustment for age, sex, and stone burden, lower calyceal access was not independently associated with the final stone-free rate (aOR 0.43, 95% CI 0.09–2.09, p = 0.293), and no covariate — including stone burden (aOR 0.94 per 100 mm², 95% CI 0.85–1.05, p = 0.256) — was significantly associated with stone clearance (Table 4). Renal anomaly was excluded from the model because all affected renal units were stone-free, producing complete separation. These findings indicate that, in this cohort, the final stone-free rate was not determined by calyceal access location after accounting for patient- and stone-related factors.

Table 4
Multivariable logistic regression for the final stone-free rate (N = 111 renal units).

Variable	Adjusted OR	95% CI	p-value
Lower calyceal access (vs. non-lower)	0.43	0.09–2.09	0.293
Age (per year)	0.98	0.95–1.01	0.121
Male sex (vs. female)	0.83	0.32–2.10	0.688
Stone burden (per 100 mm²)	0.94	0.85–1.05	0.256
OR, odds ratio; CI, confidence interval. Stone burden modelled per 100 mm² increment.			

Discussion

Nephrolithiasis remains a prevalent urological condition with a high recurrence rate, and staghorn calculi represent one of its most complex forms, often requiring meticulous planning and multimodal management strategies [12]. PCNL continues to be the gold standard for the treatment of large and staghorn renal stones, given its ability to achieve maximal stone clearance with acceptable morbidity [12]. A critical determinant of procedural success is the selection of an optimal access route, which allows adequate entry into the collecting system while minimizing complications [13].

In the present study, lower calyceal access was the most frequently utilized approach, used in 83.8% of renal units, reflecting its practical applicability and the anatomical advantages of a lower-pole puncture in complex renal stone management. Our findings demonstrate that lower calyceal access achieves a final stone-free rate, complication profile, and perioperative outcomes comparable to non-lower calyceal approaches. These results are consistent with prior work from our institution, which demonstrated that lower calyceal single-access PCNL is a safe and effective approach with high stone-free rates and minimal complications [11]; the present analysis extends those findings by providing a direct comparison between lower and non-lower access strategies in a larger, contemporary cohort analysed at the level of the renal unit.

The final PCNL stone-free rate in our cohort (74.8% per renal unit) is consistent with contemporary series for complex staghorn calculi and was achieved through PCNL alone, including planned second-look PCNL where required. This figure is comparable to Singla et al., who reported clearance in 70.7% of renal units after a single session rising to 89.0% after a second procedure, although their cohort comprised only 26% complete staghorns [12]. Stone-free status was defined conservatively as no visible fragment, or a residual fragment smaller than 4 mm, on postoperative imaging obtained within 90 days. To confirm this definition did not bias the result, we repeated the analysis using only non-contrast computed tomography, the most sensitive modality for detecting residual fragments. This produced a nearly identical stone-free rate (74.7%) and, as in the main analysis, showed no significant difference between the lower-calyceal-access and non-lower-calyceal-access groups. The single-session rate (44.1%) reflects the substantial median stone burden (336 mm^2, upper quartile approaching 600 mm^2) of this exclusively complete-staghorn population, with the remaining clearance achieved by second-look PCNL. Taken together, these features indicate that the present outcomes reflect a particularly complex patient population treated to a high final clearance by PCNL.

The final stone-free rate did not differ significantly between the lower and non-lower access groups (72.0% vs 88.9%, p = 0.233), and lower access was not an independent predictor of stone clearance on multivariable analysis (aOR 0.43, 95% CI 0.09–2.09). The numerically higher rate in the small non-lower group (n = 18) should be interpreted cautiously in light of the significantly greater stone burden in the lower-access group (median 347 vs 247 mm^2) and the wide confidence interval, and no association persisted after adjustment for stone burden and other covariates. The number of puncture attempts, operative time, haemoglobin change, length of stay, and need for second-look PCNL were likewise comparable between groups, indicating that the choice of a lower-pole puncture did not compromise the efficiency or completeness of stone clearance relative to alternative access routes in this cohort.

From a safety perspective, the overall complication rate was 10.8%, with no statistically significant difference between access strategies (11.7% vs 6.9%, p = 0.741). Most complications were low-grade (Clavien–Dindo I–II); high-grade events (Clavien ≥ III) occurred in five procedures (3.2%), comprising four episodes of sepsis requiring intensive care and one haemothorax, and length of hospital stay was comparable between groups (median 6 days, p = 0.251). These results are consistent with contemporary PCNL literature, which reports overall complication rates of approximately 10% to 30% across large series and systematic reviews, with major complication rates generally around 15% or below. Shin et al. reported relatively low overall rates of significant bleeding and transfusion (6.9%) in a large 16-year PCNL series, although complications were more frequent in patients with staghorn stones [14], and the systematic review by Grosso et al. demonstrated that major complications following PCNL range between 2% and 17%, with most adverse events being manageable [15]. Altogether, our findings confirm that lower calyceal access does not increase perioperative morbidity in complex stone disease and align with established safety profiles in the literature [14, 15].

Collectively, our findings indicate that lower calyceal access achieves stone clearance and perioperative morbidity comparable to non-lower approaches in the management of staghorn calculi. Given that a

lower-pole puncture is generally technically straightforward and avoids the thoracic risks associated with supracostal upper-pole access, these data support lower calyceal access as a safe and effective default strategy when the stone configuration and pelvicalyceal anatomy are favourable, while reserving non-lower or additional access for stones that cannot be adequately cleared through a lower-pole approach.

Strengths and limitations

This study has several strengths, including a relatively large cohort of patients with complex staghorn calculi, a direct comparison between lower and non-lower calyceal access strategies in a real-world clinical setting, analysis at the level of the renal unit in keeping with established staghorn PCNL reporting, and stone-free assessment confirmed on postoperative imaging obtained within a defined 90-day window using a conservative definition of stone clearance (no visible fragment or a residual fragment < 4 mm). Nevertheless, several limitations should be acknowledged. The retrospective, single-centre design introduces potential selection bias and limits generalisability, as the choice of access was based on surgeon judgement rather than randomisation. The strong predominance of lower calyceal access (83.8%) left a relatively small non-lower comparison group (18 renal units; 22 procedures), which limits the statistical power to detect modest between-group differences; accordingly, the comparable outcomes reported here should be interpreted as an absence of evidence of a difference rather than as evidence of equivalence. Stone burden was significantly greater in the lower-access group, and although the multivariable model adjusted for this, residual confounding cannot be excluded. Postoperative imaging was heterogeneous (non-contrast CT, plain radiography, and ultrasonography), which may affect the sensitivity of residual-fragment detection, although the non-contrast CT sensitivity analysis yielded concordant results. Detailed intraoperative data — including patient positioning (supine vs. prone), access sheath calibre, and the specific lithotripsy device used — were not uniformly captured, precluding subgroup comparisons by technique, and long-term renal functional outcomes were not evaluated. Future prospective, multicentre investigations with standardised imaging protocols and uniform technique documentation are required to validate these findings and more precisely define the optimal access strategy for staghorn calculi.

Conclusions

In this single-centre cohort of renal units undergoing PCNL for staghorn calculi, lower calyceal access was the dominant approach and achieved a final stone-free rate, complication profile, and perioperative outcomes comparable to non-lower access strategies. Lower-pole puncture appears to perform at least as well as alternative approaches across all measured outcomes, even though the lower-access group carried a greater stone burden. These findings support lower calyceal access as a safe and effective default strategy in appropriately selected patients with staghorn calculi when anatomical alignment permits, while reserving non-lower or additional access for stones requiring it for adequate clearance.

Abbreviations

AUA
American Urological Association
CKD
Chronic kidney disease
Clavien–Dindo
Clavien–Dindo classification of surgical complications
CT
Computed tomography
EAU
European Association of Urology
Hgb
Haemoglobin
IQR
Interquartile range
IRB
Institutional Review Board
KUB
Kidney–ureter–bladder radiograph
PCNL
Percutaneous nephrolithotomy
SFR
Stone-free rate
SWL
Shock wave lithotripsy.

Declarations

Ethics approval

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board of King Abdullah International Medical Research Center (KAIMRC), Riyadh, Saudi Arabia (Protocol No. NRR24/002/12).

Consent to participate

Informed consent to participate was obtained from all participants included in the study.

Consent to publish

Not applicable. This manuscript does not contain any individual person’s data in any form (including individual details, images or videos).

Clinical trial number

Clinical trial number: not applicable.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

YG is the principal investigator; he conceived and designed the study, supervised the project, and critically revised the manuscript. BHA and NAlb contributed to the study design and the interpretation of the data and critically revised the manuscript. AAsk, AAlk, AAth and SBH contributed patient cases and clinical oversight, interpreted the data, and critically revised the manuscript. NAth, AAlm and IA collected and curated the data. KA performed the statistical analysis, interpreted the results, and drafted and revised the manuscript. YA contributed to data collection and analysis. All authors read and approved the final manuscript.

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Data Availability

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Figures

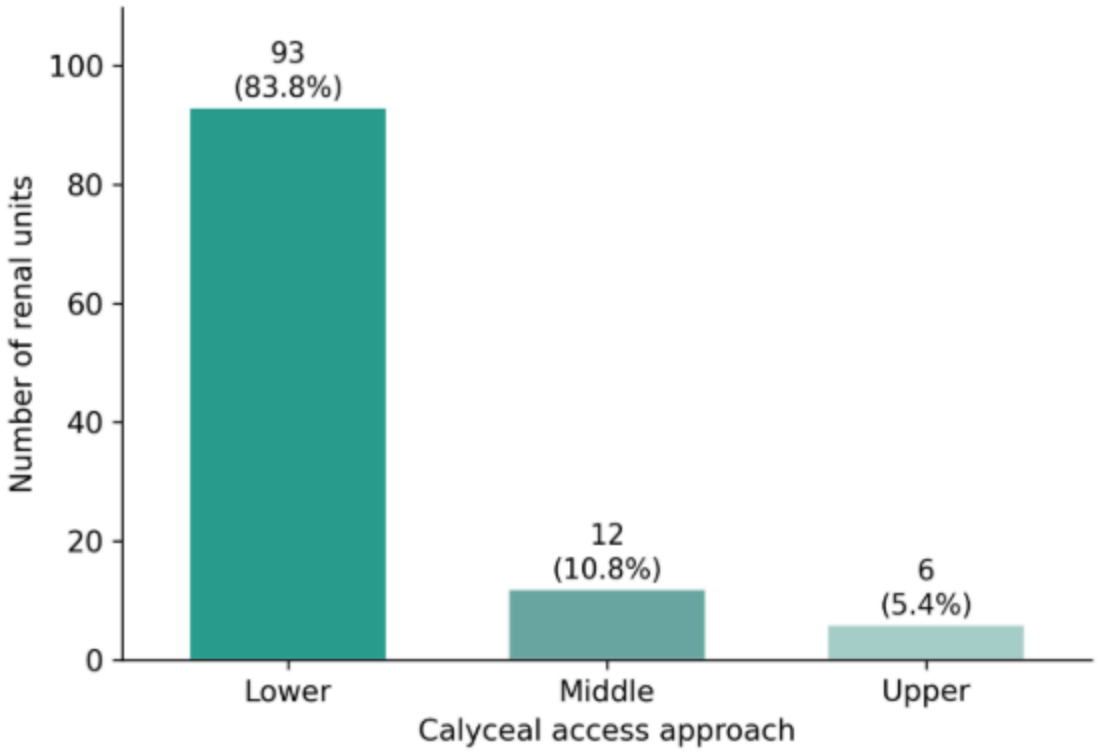


Figure 1

Distribution of calyceal access approaches among 111 renal units treated with PCNL for staghorn calculi. Lower calyceal access was the most frequently utilised approach (83.8%), followed by middle (10.8%) and upper (5.4%) access.

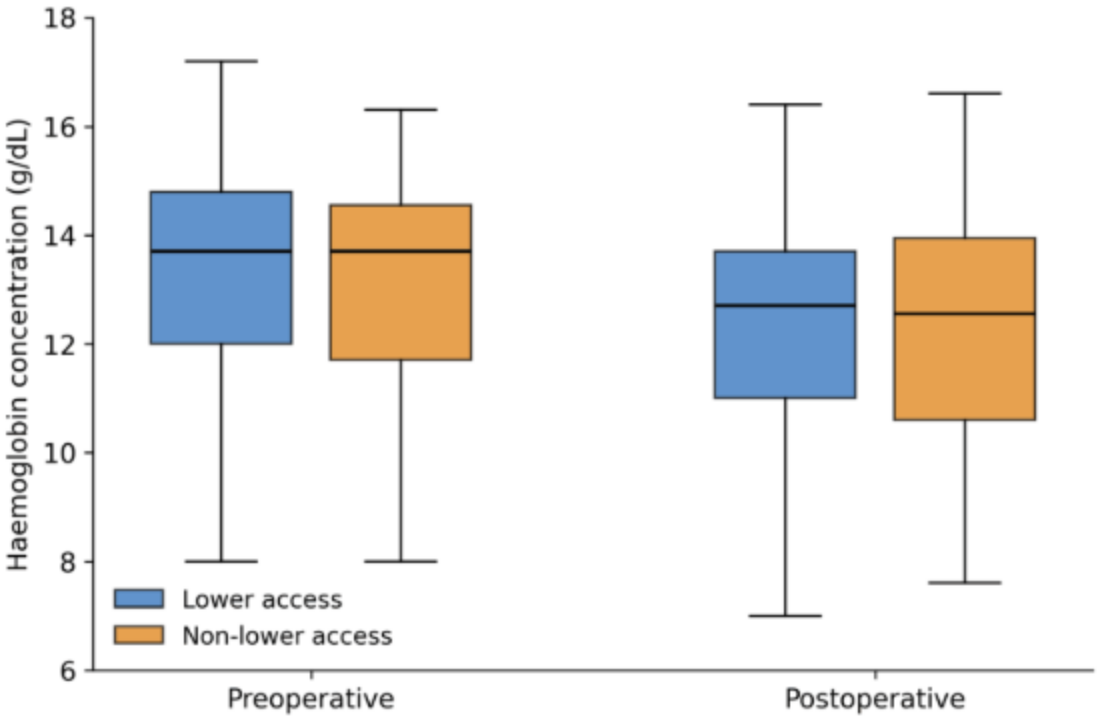


Figure 2

Preoperative and postoperative haemoglobin concentration (g/dL) stratified by lower calyceal access. Boxplots display the median, interquartile range, and range for procedures with and without lower calyceal access.

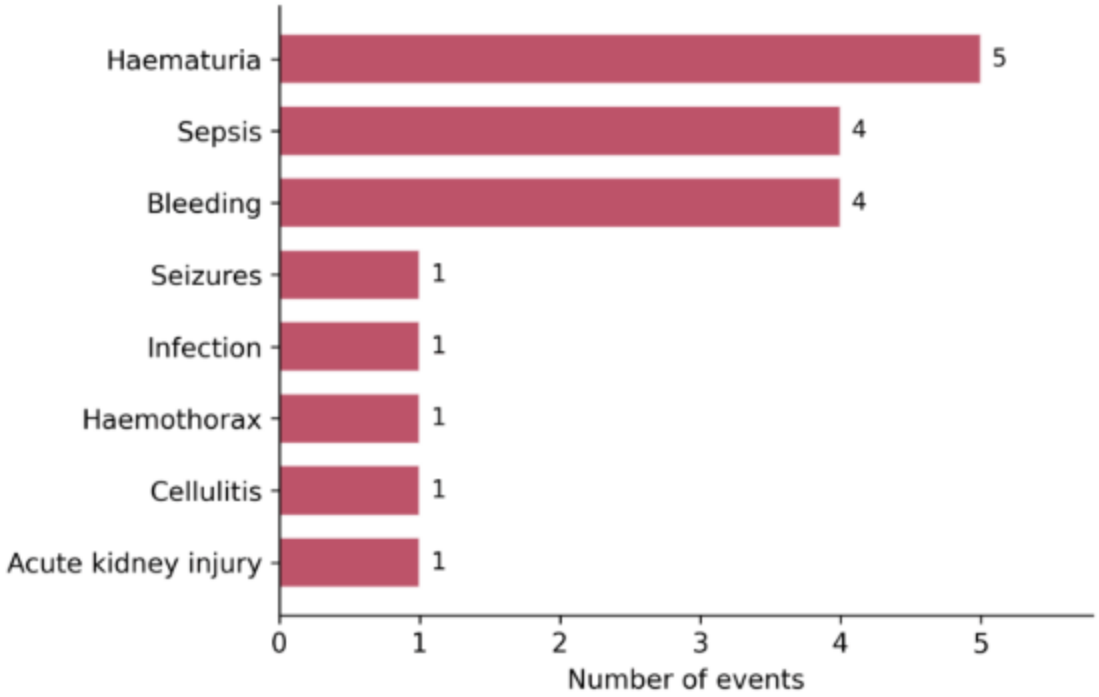


Figure 3

Frequencies of postoperative complications across the PCNL procedures in the cohort. Haematuria, bleeding, and sepsis were the most frequent events.