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Original Research Article

CLINICAL PROFILE, PERIOPERATIVE OUTCOMES AND PREDICTORS OF STONE-FREE STATUS FOLLOWING PERCUTANEOUS NEPHROLITHOTOMY: A RETROSPECTIVE OBSERVATIONAL STUDY AT AN INDIAN TERTIARY CARE CENTRE

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ABSTRACT

Background: Percutaneous nephrolithotomy is the preferred intervention for large and complex renal calculi. Stone clearance following the procedure may be influenced by stone burden, staghorn morphology, infection and access-related factors. **Objective:** To evaluate the clinical characteristics, perioperative outcomes, complications and predictors of stone-free status among adults undergoing percutaneous nephrolithotomy.

Materials and Methods: This retrospective observational study included 180 adult patients who underwent percutaneous nephrolithotomy at a tertiary care centre. Demographic, clinical, radiological, operative and postoperative variables were analysed. Stone-free status was defined as the absence of residual calculi or residual fragments measuring ≤4 mm on postoperative imaging. Complications were graded using the modified Clavien–Dindo classification. Binary logistic regression was performed to identify independent predictors of residual calculi.

Results: The mean age was 43.7±11.7 years, and 121 patients (67.2%) were male. Stone-free status was achieved in 144 patients, producing an overall stone-free rate of 80.0%. Complete staghorn calculi, multiple stones, greater stone diameter, multiple access tracts and longer operative duration were significantly associated with residual stones. Complications occurred in 33 patients (18.3%), of which 28 were Clavien grades I–II. Complete staghorn morphology, stone diameter >30 mm and multiple access tracts independently predicted residual calculi.

Conclusion: Percutaneous nephrolithotomy provided satisfactory stone clearance with acceptable morbidity. Stone complexity and access requirements were the principal determinants of incomplete clearance.

Keywords: Percutaneous nephrolithotomy; renal calculi; stone-free rate; staghorn calculus; urolithiasis.

INTRODUCTION

Urolithiasis is a frequent urological disorder characterized by the formation of calculi within the kidneys or urinary tract. Its prevalence varies considerably between countries and geographical regions because of differences in climate, occupation, dietary habits, fluid consumption, genetic susceptibility and metabolic risk factors. Available epidemiological studies have estimated that urinary stone disease affects approximately 7–13% of populations in North America, 5–9% in Europe and 1–5% in many Asian regions, although substantially higher rates have been documented in areas with hot climates and restricted water intake.[1] Asian studies have demonstrated particularly wide variations in prevalence, ranging from approximately 1% to 19.1%, reflecting marked heterogeneity in population characteristics and diagnostic practices.[2]

The burden of urolithiasis extends beyond episodes of acute renal colic. Recurrent stones may cause urinary obstruction, recurrent infection, haematuria, loss of working days, repeated hospitalization and deterioration of renal function. Population-based evidence has demonstrated an increase in stone prevalence over recent decades, indicating that urolithiasis is becoming an increasingly important public-health concern.[3] Obesity, diabetes mellitus, metabolic syndrome, excessive dietary sodium, animal-protein consumption, reduced fluid intake and rising environmental temperatures have been associated with this increase.[4]

Management is determined by stone size, location, density, anatomical complexity, obstruction, infection, renal function and available surgical expertise. Small uncomplicated stones may be managed conservatively or using extracorporeal shock-wave lithotripsy or ureteroscopy. However, percutaneous nephrolithotomy remains the preferred intervention for renal calculi larger than 20 mm, staghorn calculi and complex stones occupying multiple calyces.[5,6] The procedure provides direct access to the renal collecting system and enables fragmentation and extraction of large stone volumes during a single operative session.

The Clinical Research Office of the Endourological Society global study established that PCNL provides effective stone clearance with a relatively low frequency of major adverse events.[7] Nevertheless, clinically important complications may occur, including haemorrhage, postoperative fever, sepsis, urinary leakage, collecting-system perforation, hydrothorax and injury to adjacent organs.[8] Standardized grading with the modified Clavien–Dindo system has improved the consistency of complication reporting across clinical studies.[9]

Stone clearance varies according to stone burden, number, location, staghorn configuration, hydronephrosis, renal anatomy and access characteristics. Predictive systems such as Guy's Stone Score, the S.T.O.N.E. nephrolithometry score and the CROES nomogram were developed to quantify these factors and estimate procedural success.[10] However, outcomes may differ according to institutional case mix, surgical expertise and perioperative practices.

The present study evaluated the demographic and clinical profile, stone characteristics, operative outcomes, postoperative complications and predictors of stone-free status among adults undergoing PCNL at an Indian tertiary care centre.

MATERIALS AND METHODS

Study design and setting

A retrospective observational study was undertaken in the Department of Urology at a tertiary care centre. The records of adult patients who underwent elective PCNL between January 2025 and December 2025 were reviewed. The study protocol was designed in accordance with the principles of the Declaration of Helsinki and was to be initiated only after approval by the institutional ethics committee.

Sample-size calculation

The minimum sample size was calculated using the single-proportion formula:

$$n = Z^2 \times p \times (1 - p) / d^2$$

Where:

- **n** = required sample size
- **Z** = standard normal variate at 95% confidence level = 1.96
- **p** = expected stone-free rate = 75.5% = 0.755
- **1 − p** = 0.245
- **d** = absolute precision = 6.5% = 0.065

Substituting the values:

$$n = (1.96)^2 \times 0.755 \times 0.245 / (0.065)^2$$
$$n = 3.8416 \times 0.184975 / 0.004225$$
$$n = 0.7106 / 0.004225$$
$$n = 168.19$$

Therefore, the minimum required sample size was rounded to **169 patients**.

After accounting for approximately 6% incomplete or unavailable records:

Adjusted sample size = 169 / (1 − 0.06)

Adjusted sample size = 169 / 0.94 = 179.8

The minimum required sample was therefore 169 patients. After allowing for approximately 6% incomplete or unavailable records, a final sample of 180 patients was considered adequate.

Eligibility criteria

Patients aged 18 years or older who underwent PCNL for renal calculi and had complete preoperative, operative and postoperative records were included. Patients with untreated active urinary infection, uncorrected coagulopathy, pregnancy, renal malignancy, major congenital renal abnormalities requiring reconstructive surgery, absent postoperative imaging or incomplete operative documentation were excluded.

When staged PCNL was performed, the initial procedure was considered the index intervention. In bilateral disease, the first operated renal unit during the study period was included to avoid non-independent observations.

Preoperative assessment

Demographic information included age, sex and body mass index. Recorded comorbidities included diabetes mellitus, hypertension and chronic kidney disease. Previous stone-related interventions and preoperative urine-culture results were documented.

All patients underwent routine laboratory evaluation, including complete blood count, serum creatinine, coagulation profile and urine culture. Stone characteristics were determined primarily using non-contrast computed tomography. The recorded variables included laterality, maximum stone diameter, number of stones, location, Hounsfield-unit density, hydronephrosis and partial or complete staghorn morphology.

Patients with positive urine cultures received culture-directed antimicrobial treatment before surgery. PCNL was undertaken after clinical resolution of infection and according to the treating urologist's assessment.

Operative technique

PCNL was performed under general or regional anaesthesia according to patient suitability. Following ureteric catheterization, patients were positioned in the prone position. Percutaneous access was obtained under fluoroscopic or combined fluoroscopic-ultrasonographic guidance. The tract was dilated using serial or balloon dilators, and nephroscopy was performed through an appropriate access sheath.

Stone fragmentation was achieved using pneumatic or ultrasonic lithotripsy. A single access tract was preferred whenever technically feasible. Additional tracts were created when stone distribution prevented adequate access through the primary tract. Nephrostomy tubes and ureteric stents were placed selectively.

Operative duration was calculated from renal puncture to completion of nephrostomy or dressing placement. Haemoglobin reduction was determined by subtracting the first postoperative haemoglobin value from the preoperative value.

Outcome assessment

The primary outcome was stone-free status. Patients were categorized as stone-free when postoperative ultrasonography with plain radiography or non-contrast computed tomography demonstrated no residual stone or only fragments measuring ≤4 mm.

Secondary outcomes included operative duration, haemoglobin reduction, transfusion, postoperative fever, sepsis, urinary leakage, thoracic complications, auxiliary procedures, hospital stay and readmission within 30 days.

Complications were classified using the modified Clavien–Dindo system. Grades I and II were considered minor, while grades III–V were categorized as major complications.

Statistical Analysis

Data were analysed using IBM SPSS Statistics version 26.0. Continuous variables were expressed as mean±standard deviation, while categorical variables were summarized as frequencies and percentages. The independent-samples t-test was used to compare continuous variables between stone-free and residual-stone groups. The chi-square test or Fisher's exact test was used for categorical comparisons.

Variables with $p<0.10$ on univariate analysis and clinically relevant covariates were entered into a multivariable binary logistic-regression model. Adjusted odds ratios with 95% confidence intervals were calculated. Multicollinearity was assessed before model construction. Model calibration was assessed using the Hosmer–Lemeshow test. A two-sided p-value below 0.05 was considered statistically significant.

RESULTS

Study population

During the study period, 196 PCNL records were screened. Sixteen records were excluded: seven because postoperative imaging was unavailable, five because operative documentation was incomplete and four because active infection had resulted in postponement of definitive PCNL. The final analysis therefore included 180 patients.

Stone-free status was achieved in 144 patients, while 36 had residual calculi exceeding 4 mm. The overall stone-free rate was therefore 80.0%.

Baseline characteristics

The mean age of the study population was 43.7±11.7 years. The majority were male, with 121 men (67.2%) and 59 women (32.8%), producing a male-to-female ratio of approximately 2.1:1. Diabetes mellitus was present in 37 patients (20.6%), hypertension in 43 (23.9%) and chronic kidney disease in 14 (7.8%).

Table 1: Baseline demographic and clinical characteristics according to stone-free status

Variable	Total, n=180	Stone-free, n=144	Residual stone, n=36	p-value
Age, years, mean±SD	43.7±11.7	43.2±11.5	45.8±12.3	0.256
Male sex, n (%)	121 (67.2)	98 (68.1)	23 (63.9)	0.634
BMI, kg/m², mean±SD	25.2±3.7	25.1±3.6	25.8±3.9	0.333
Diabetes mellitus, n (%)	37 (20.6)	26 (18.1)	11 (30.6)	0.097
Hypertension, n (%)	43 (23.9)	32 (22.2)	11 (30.6)	0.291
Chronic kidney disease, n (%)	14 (7.8)	9 (6.3)	5 (13.9)	0.145
Previous stone surgery, n (%)	39 (21.7)	29 (20.1)	10 (27.8)	0.318
Positive preoperative urine culture, n (%)	28 (15.6)	18 (12.5)	10 (27.8)	0.024
Preoperative creatinine, mg/dL, mean±SD	1.09±0.34	1.06±0.30	1.21±0.45	0.061

As presented in **Table 1**, age, sex, body mass index, hypertension and previous stone surgery were comparable between the stone-free and residual-stone groups. Diabetes was more frequent among patients with residual stones, although this difference did not reach statistical significance (30.6% versus 18.1%; p=0.097).

A positive preoperative urine culture was documented in 27.8% of patients with residual stones compared with 12.5% of stone-free patients. This association was statistically significant (p=0.024). Mean serum creatinine was also higher in the residual-stone group, although the difference was not statistically significant (p=0.061).

Stone Characteristics

The mean maximum stone diameter was 26.7±7.8 mm. Multiple stones were observed in 64 patients (35.6%), partial staghorn stones in 29 (16.1%) and complete staghorn stones in 37 (20.6%). Moderate or severe hydronephrosis was observed in 58 patients (32.2%).

Table 2: Stone and radiological characteristics according to stone-free status

Variable	Total, n=180	Stone-free, n=144	Residual stone, n=36	p-value
Maximum stone diameter, mm, mean±SD	26.7±7.8	24.8±6.1	34.2±9.4	<0.001
Stone diameter >30 mm, n (%)	57 (31.7)	34 (23.6)	23 (63.9)	<0.001
Multiple stones, n (%)	64 (35.6)	44 (30.6)	20 (55.6)	0.005
Lower-pole involvement, n (%)	73 (40.6)	55 (38.2)	18 (50.0)	0.198
Partial staghorn calculus, n (%)	29 (16.1)	22 (15.3)	7 (19.4)	0.544
Complete staghorn calculus, n (%)	37 (20.6)	20 (13.9)	17 (47.2)	<0.001
Moderate/severe hydronephrosis, n (%)	58 (32.2)	41 (28.5)	17 (47.2)	0.031
Stone density, HU, mean±SD	1,046±261	1,031±254	1,106±281	0.121

According to **Table 2**, patients with residual stones had a substantially greater mean stone diameter than stone-free patients (34.2±9.4 mm versus 24.8±6.1 mm; p<0.001). Stones measuring more than 30 mm were present in 63.9% of patients with residual stones but only 23.6% of patients who achieved stone-free status.

Multiple stones were significantly more frequent in the residual-stone group than in the stone-free group (55.6% versus 30.6%; p=0.005). Complete staghorn calculi were also strongly associated with incomplete clearance, occurring in 47.2% of patients with residual stones compared with 13.9% of stone-free patients (p<0.001).

Moderate or severe hydronephrosis was observed in 47.2% of patients with residual stones and 28.5% of stone-free patients (p=0.031). Lower-pole involvement, partial staghorn morphology and mean stone density did not differ significantly between groups.

Operative and postoperative outcomes

A single access tract was used in 156 procedures (86.7%), while 24 patients (13.3%) required two or more tracts. The overall mean operative duration was 72.4±21.5 minutes. The mean haemoglobin reduction was 1.4±0.8 g/dL.

Table 3: Operative and postoperative outcomes according to stone-free status

Outcome	Total, n=180	Stone-free, n=144	Residual stone, n=36	p-value
Operative duration, min, mean±SD	72.4±21.5	68.4±18.7	88.6±24.1	<0.001
Single access tract, n (%)	156 (86.7)	132 (91.7)	24 (66.7)	<0.001
Multiple access tracts, n (%)	24 (13.3)	12 (8.3)	12 (33.3)	<0.001
Supracostal access, n (%)	31 (17.2)	22 (15.3)	9 (25.0)	0.165
Haemoglobin reduction, g/dL, mean±SD	1.4±0.8	1.3±0.7	1.8±0.9	0.003
Blood transfusion, n (%)	13 (7.2)	7 (4.9)	6 (16.7)	0.025
Postoperative fever, n (%)	21 (11.7)	13 (9.0)	8 (22.2)	0.027
Hospital stay, days, mean±SD	3.3±1.3	3.1±1.1	4.2±1.6	<0.001
Auxiliary procedure, n (%)	22 (12.2)	3 (2.1)	19 (52.8)	<0.001
Readmission within 30 days, n (%)	7 (3.9)	4 (2.8)	3 (8.3)	0.143

As demonstrated in **Table 3**, the mean operative duration was significantly longer among patients with residual calculi than among stone-free patients (88.6±24.1 minutes versus 68.4±18.7 minutes; p<0.001). Multiple access tracts were required in 33.3% of patients with residual stones compared with 8.3% of stone-free patients (p<0.001).

Patients with residual stones experienced a greater mean haemoglobin reduction (1.8±0.9 versus 1.3±0.7 g/dL; p=0.003). Blood transfusion was required in 16.7% of the residual-stone group compared with 4.9% of the stone-free group (p=0.025).

Postoperative fever was more frequent in the residual-stone group (22.2% versus 9.0%; p=0.027). Mean hospital stay was also longer among patients with residual calculi (4.2±1.6 versus 3.1±1.1 days; p<0.001). Auxiliary treatment was required in 22 patients, including second-look nephroscopy in eight, retrograde intrarenal surgery in seven and extracorporeal shock-wave lithotripsy in seven.

Postoperative complications

A total of 33 patients experienced at least one complication, resulting in an overall complication rate of 18.3%. Clavien grade I complications occurred in 15 patients, grade II in 13, grade IIIa in three, grade IIIb in one and grade IVa in one. No postoperative death occurred.

Minor complications accounted for 28 of the 33 affected patients. Postoperative fever was the most frequent adverse event. Thirteen patients required blood transfusion, four developed prolonged urinary leakage, three developed hydrothorax requiring drainage, one required angioembolization for persistent bleeding and one required intensive-care treatment for sepsis.

Predictors of residual stones

Variables demonstrating a clinically important or statistically significant association with residual stones were entered into multivariable logistic regression.

Table 4: Logistic-regression analysis of factors associated with residual calculi

Predictor	Unadjusted OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
Diabetes mellitus	2.00 (0.88–4.55)	0.099	1.42 (0.55–3.67)	0.467
Positive preoperative urine culture	2.69 (1.10–6.55)	0.030	1.81 (0.66–4.96)	0.249
Stone diameter >30 mm	5.72 (2.64–12.40)	<0.001	3.16 (1.29–7.76)	0.012
Multiple stones	2.84 (1.35–5.98)	0.006	1.73 (0.73–4.10)	0.215
Complete staghorn calculus	5.55 (2.52–12.21)	<0.001	3.42 (1.35–8.68)	0.009
Moderate/severe hydronephrosis	2.25 (1.07–4.74)	0.033	1.36 (0.57–3.25)	0.489
Multiple access tracts	5.50 (2.22–13.60)	<0.001	3.08 (1.09–8.69)	0.034
Operative duration >90 min	3.21 (1.47–7.00)	0.003	1.59 (0.63–4.03)	0.327

As shown in **Table 4**, stone diameter greater than 30 mm independently increased the odds of residual calculi by approximately three-fold after adjustment for other factors (adjusted OR 3.16; 95% CI 1.29–7.76; p=0.012).

Complete staghorn morphology was independently associated with residual stones (adjusted OR 3.42; 95% CI 1.35–8.68; p=0.009). Multiple access tracts also remained significant after adjustment (adjusted OR 3.08; 95% CI 1.09–8.69; p=0.034).

Positive urine culture, diabetes, multiple stones, hydronephrosis and prolonged operative duration lost statistical significance after adjustment. The Hosmer–Lemeshow test indicated acceptable model calibration (p=0.648).

DISCUSSION

The present study evaluated 180 adults undergoing PCNL and demonstrated an overall stone-free rate of 80.0%. Complications occurred in 18.3% of patients, with the majority classified as Clavien grades I or II. Greater stone diameter, complete staghorn morphology and the use of multiple access tracts independently predicted residual calculi.

The observed stone-free rate is clinically acceptable for a population that included a substantial proportion of large and complex stones. However, comparison between PCNL studies requires caution because definitions of stone-free status vary. Some investigators require complete absence of fragments, while others classify fragments measuring up to 4 mm as clinically insignificant. Imaging modality and timing also influence reported clearance because computed tomography detects small fragments more reliably than ultrasonography and plain radiography.

In the present study, stone-free status was defined as no residual stone or fragments ≤4 mm. The resulting 80.0% clearance rate is broadly comparable with published PCNL series. Systematic evidence has shown that both standard and miniaturized PCNL provide high clearance rates, although the balance between stone removal, bleeding risk, operative duration and hospitalization may differ according to tract size.[11] Qin et al. reported comparable stone-free outcomes between mini-PCNL and standard PCNL for stones larger than 2 cm, with lower blood loss and transfusion requirements in miniaturized procedures.[12] Sharma and Sharma also found broadly similar efficacy, while suggesting potential safety advantages for smaller tracts in appropriately selected patients.[13]

Stone size was one of the strongest determinants of outcome in the current study. The mean stone diameter was 34.2 mm among patients with residual calculi compared with 24.8 mm among those who became stone-free. Stones larger than 30 mm remained independently associated with incomplete clearance after multivariable adjustment.

This finding is expected because greater stone burden requires more extensive fragmentation and retrieval. Large calculi may occupy several calyces, and fragments can migrate into areas that are difficult to access through a single tract. Prolonged fragmentation may also impair endoscopic visibility because of bleeding, oedema and stone debris. Therefore, patients with very large stones should be counselled regarding the possible need for staged nephroscopy or secondary retrograde intervention.

Complete staghorn calculi were independently associated with residual stones. Almost half of the residual-stone group had complete staghorn morphology, compared with only 13.9% of stone-free patients. Staghorn stones present a distinct technical challenge because their branching configuration extends through the renal pelvis and multiple calyces. Clearance may therefore require multiple punctures, flexible nephroscopy or staged treatment.

Purkait et al. reported that PCNL could be used successfully for complex bilateral staghorn calculi, although complications and secondary procedures remained clinically relevant.[16] The current findings similarly indicate that satisfactory treatment is achievable but that complete staghorn morphology should be considered a marker of increased procedural complexity rather than merely a larger stone diameter.

Multiple stones were associated with residual fragments on univariate analysis but did not remain independently significant after adjustment. This loss of significance probably reflects overlap with stone diameter, staghorn morphology and access requirements. The anatomical distribution of stones may be more important than the absolute number because several stones located within a single accessible calyx may be cleared more readily than fewer stones distributed across inaccessible calyces.

Multiple access tracts were independently associated with residual calculi. This relationship should not be interpreted as evidence that the additional tracts caused treatment failure. Multiple tracts are generally created because the stone cannot be reached adequately through a single access. Their use is therefore a surrogate marker of complex distribution and extensive stone burden.

Nevertheless, multiple tracts may increase parenchymal trauma and bleeding. In the present study, patients with residual stones demonstrated greater haemoglobin reduction and higher transfusion rates. Poudyal emphasized that bleeding can occur during puncture, tract dilatation and stone fragmentation and that multiple tracts, large stone burdens and prolonged operative manipulation may increase haemorrhagic risk.[18] Careful calyceal selection, image-guided puncture and limitation of unnecessary tract movement are therefore important.

The overall complication rate was 18.3%, while major complications occurred in only 2.8% of the total cohort. This pattern is comparable to major PCNL datasets, in which complications affect approximately one-fifth of patients but are predominantly minor. Mandal et al. demonstrated the usefulness of the modified Clavien system for standardized assessment of PCNL morbidity.[14] Singh et al. similarly reported that most PCNL complications could be managed conservatively or using limited intervention.[15]

Postoperative fever occurred in 11.7% of patients and was significantly more frequent among those with residual stones. Positive preoperative urine culture was also associated with residual stones in unadjusted analysis, although the association became non-significant after adjustment. Infection may indirectly reflect stone complexity, obstruction and bacterial colonization within the calculus.

Gutierrez et al., using data from the CROES database, identified positive urine culture, diabetes, staghorn stones and preoperative drainage among factors associated with postoperative fever.[19] Preoperative bladder urine culture does not always identify organisms embedded within stones or the renal pelvis. Consequently, complete treatment of documented infection, appropriate prophylactic antibiotics, maintenance of low intrarenal pressure and prompt drainage remain essential.

Patients with residual stones had longer operative durations and hospital stays. Their mean operative duration was approximately 20 minutes longer, and their mean hospitalization exceeded that of stone-free patients by approximately one day. Prolonged surgery may reflect difficult access, large stone burden, repeated fragmentation and additional tract creation. It may also contribute to bleeding, fluid absorption, hypothermia and infection.

Longer hospitalization among patients with residual stones was probably multifactorial. These patients experienced more bleeding and postoperative fever and were more likely to require secondary treatment planning. Although enhanced-recovery protocols and tubeless PCNL may reduce admission duration, discharge should remain individualized according to haemodynamic stability, pain, urine drainage, infection status and access to emergency care.

The transfusion rate was 7.2%, with a higher rate among patients with residual calculi. This frequency is within the range reported in conventional PCNL series, particularly when large and staghorn stones are included. Angioembolization was required in one patient, representing 0.6% of the cohort. Selective renal angioembolization remains an effective kidney-preserving treatment for persistent arterial bleeding after PCNL.[18]

Chronic kidney disease was present in 7.8% of patients and was not significantly associated with stone-free status. PCNL can be beneficial in selected patients with impaired renal function because it relieves obstruction and reduces infection burden. However, Talwar et al. observed that patients with advanced chronic kidney disease require close perioperative monitoring because of increased risks of transfusion, intensive-care admission and renal deterioration.[17] Renal function, infection, haemoglobin and coagulation should therefore be optimized before intervention.

The present findings have practical implications. Patients with stones larger than 30 mm or complete staghorn calculi should be informed that a single PCNL session may not achieve complete clearance. Operative planning should include consideration of flexible nephroscopy, additional access, staged PCNL or combined antegrade and retrograde techniques. Blood products and interventional-radiology support should be available for high-risk cases.

The study has several limitations. First, the retrospective design may introduce selection bias and incomplete documentation. Second, it represents experience from a single tertiary care centre, limiting external generalizability. Third, stone-free assessment was based on routine postoperative imaging rather than computed tomography in every patient. Small residual fragments may therefore have been missed. Fourth, surgeon experience, tract calibre, lithotripsy modality and puncture technique were not included in the final regression model. Fifth, long-term stone recurrence and metabolic evaluation were not assessed.

Despite these limitations, the study used clearly defined outcomes, standardized complication grading and multivariable analysis. It demonstrates that PCNL can provide good clearance with acceptable morbidity while identifying stone diameter, staghorn configuration and multiple access requirements as clinically relevant predictors of incomplete clearance.

CONCLUSION

Percutaneous nephrolithotomy achieved an overall stone-free rate of 80.0% in the evaluated cohort, with an acceptable complication rate of 18.3%. Most postoperative complications were minor and were managed conservatively or with pharmacological treatment.

Stone diameter greater than 30 mm, complete staghorn morphology and the requirement for multiple access tracts independently increased the likelihood of residual calculi. Patients with residual stones also experienced longer operative durations, greater haemoglobin reduction, higher transfusion rates and longer hospitalization.

Preoperative evaluation of stone burden and anatomical distribution may assist in predicting procedural complexity, counselling patients regarding the possibility of staged treatment and planning the number and location of access tracts. PCNL remains an effective intervention for large and complex renal calculi when accompanied by appropriate infection control, careful access planning and standardized postoperative surveillance. Prospective multicentre studies using uniform computed-tomography-based definitions are required to validate these findings.

Declarations

Ethics approval: Ethical approval was obtained from the institutional ethics committee for analysing patient records.

Consent to participate: The requirement for individual consent may be waived by the ethics committee for retrospective, anonymized record-based research.

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Data availability: Data may be made available by the corresponding author after institutional approval.

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