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ORIGINAL PAPER

Outcomes of percutaneous nephrolithotomy in a resource-limited setting: A retrospective study

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Summary *Background: Percutaneous nephrolithotomy (PCNL) is the gold standard for managing large renal calculi; however, data on its long-term efficacy in resource-limited settings such as Yemen are scarce. We evaluated the outcomes and complications of PCNL surgery in resource-limited settings over a nine-year period in a high-volume centre in Ibb City, Yemen.*

Methods: We conducted a retrospective analysis of 1,458 patients who underwent PCNL between October 2016 and June 2025. Data included patient demographics, stone characteristics, surgical techniques (standard, mini-PCNL, and supine), and outcomes. The stone-free rate (SFR) was defined as the absence of fragments greater than 4 mm on follow-up imaging at three months. Complications were classified using the Clavien-Dindo system.

Results: The cohort comprised 763 (52.3%) males and 695 (47.7%) females with a mean age of 43.8 ± 17.5 years (range: 2-87 years). Staghorn calculi were present in 647 cases (44.4%). Prone lower-pole access was the predominant approach (58.2%), with a progressive institutional shift toward mini-PCNL (5.7%), supine PCNL (3.1%), and ultrasound-guided access (1.4%) in later years. The primary stone-free rate after a single session was 76.0%, increasing to a final SFR of 92.6% following auxiliary interventions including repeat PCNL, ureteroscopy (2.8%), ESWL (1.5%), and conservative management of clinically insignificant residual fragments (6.0%). Major complications (Clavien-Dindo Grade III-V) occurred in 1.44% of cases, including colonic perforation (0.41%) and conversion to open surgery (0.62%). Mortality rate was 0.14% (n = 2). Minor complications (Grade I-II) affected 17.4% of patients, predominantly postoperative pain (7.3%) and transient fever (5.3%).

Conclusions: This large series demonstrates that PCNL can be performed with high stone-free rates and acceptable morbidity in resource-limited settings despite a high prevalence of complex staghorn calculi. The progressive adoption of miniaturized and supine techniques reflects institutional adaptability and confirms the feasibility of implementing contemporary endourological standards in low-resource environments.

KEY WORDS: *Percutaneous nephrolithotomy (PCNL); Stone-free rate; Staghorn calculi; Clavien-Dindo; Endourology; Resource-limited settings.*

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INTRODUCTION

Urolithiasis affects about 10 to 12% of the global population (1). Renal stones account for a significant health burden, with recurrence rates as high as 50% after five years and 80 to 90% after ten years following the initial stone formation (2). The management of kidney stones relies on various evidence-based methods. Treatment choices depend on stone size, location, composition, and individual patient factors (3, 4). For small stones (less than 5 mm), conservative management is typically recommended, which includes hydration and medical therapy using alpha-blockers like tamsulosin (5). Extracorporeal *shock wave lithotripsy* (SWL) is effective for renal stones smaller than 20 mm, achieving stone-free rates between 60 and 85%. Flexible ureteroscopy (fURS) combined with laser lithotripsy offers better clearance, reaching 85 to 95% for ureteric and similarly sized renal stones. For larger renal stones (greater than 2 cm) and complex stones like staghorn calculi, *percutaneous nephrolithotomy* (PCNL) is the established gold standard. This method has single-session stone-free rates between 75 and 95% using minimally invasive percutaneous access (5, 6). Recent improvements, including miniaturized and micro-PCNL techniques, have further lowered complications in both children and adults (4, 5).

However, areas with limited resources, such as Yemen, face significant challenges. Prolonged conflict, poor infrastructure, lack of equipment, and insufficient training affect the safety and feasibility of complex surgeries (7, 8). Consequently, the use and outcomes of PCNL in these regions are not well documented. This creates a gap in global surgical literature and limits understanding of equitable stone disease care.

Along with these geographic issues, PCNL techniques are still evolving. Although the standard prone position is common, alternative methods such as the supine position and miniaturized nephroscopy (Mini-PCNL or MIP) have been adopted to improve ergonomics and reduce complications. Also, ultrasound-guided renal access is increasingly used to lower radiation exposure (9-11). However, how well these technical improvements are implemented outside well-funded academic centers remains unclear.

Given the limited research in the resource-constrained environment of Yemen, this study aims to provide a detailed analysis of the demographic characteristics, proce-

dural trends, and complication rates associated with PCNL, focusing on its safety and effectiveness in this context.

Patients and methods

Study design and ethical considerations

This retrospective observational cohort study included all consecutive patients who underwent PCNL at Alhamd Teaching Hospital, Ibb, Yemen, between October 2016 and June 2025. The study protocol was reviewed and approved by the Ethics Committee of Alhamd Teaching Hospital. Given the retrospective design and the exclusive use of fully anonymized patient data extracted from medical records, the requirement for written informed consent was formally waived by the ethics committee. The study was conducted in full accordance with the ethical principles outlined in the Declaration of Helsinki (2013 revision) and complied with all applicable institutional standards for research involving human subjects. Patient confidentiality and data security were maintained throughout the study period.

Patient population and setting

The study included all consecutive patients who underwent PCNL between October 2016 and June 2025. All procedures were performed at Alhamd Hospital, Ibb, Yemen. Patients were identified through operating theatre logs and urology department registries. Exclusion criteria were applied to patients with incomplete medical records related to the surgical procedure or those whose primary intervention was open surgical lithotomy rather than PCNL.

Surgical procedure and data collection

All PCNL procedures were performed by a single experienced surgeon (*Professor Radman Ghaleb*), who had over a decade of specialised experience in endourology at the time of the study. The surgical technique, including patient positioning (prone or supine), calyceal access location (infracostal or supracostal), and the use of miniaturised instruments (Mini-PCNL), was tailored to each patient's anatomy and stone burden based on preoperative imaging. A dedicated data extraction sheet was used to collect information from patient files, including demographics, procedural details (laterality, access type, technical modifications), stone characteristics, and explicitly documented intraoperative or postoperative complications.

Statistical analysis

All statistical analyses were performed using SPSS software (*Version 26.0, IBM Corp*). Descriptive statistics were used to summarize cohort characteristics. Categorical variables, such as gender, laterality, and complication types, are presented as frequencies and percentages. Continuous variables, including patient age, are summarized as mean ± *standard deviation* (SD) or median with *interquartile range* (IQR). The complication rate was calculated as the proportion of procedures with a major documented event. As this was primarily a descriptive study, inferential comparative analyses were not performed; a p-value was therefore not applicable.

Results

Cohort characteristics and demographics

Between October 2016 and June 2025, our institution performed 1,458 percutaneous nephrolithotomy (PCNL) procedures. The cohort has a mean age of 43.8 ± 17.5 years, ranging from 2 to 87 years. Adults aged 18-65 years make up the majority of the population (n = 1,180; 80.9%), while geriatric patients over 65 years (n = 208; 14.3%) and a paediatric subset (n = 70; 4.8%) comprise the remainder. Gender distribution is nearly equal, with 763 (52.3%) males and 695 (47.7%) females (Table 1).

Table 1.
Patient demographics and baseline characteristics.

Variable	Value (n = 1,458)	Percentage (%)
Age (Years)		
Mean ± SD	43.8 ± 17.5	–
Range	2 - 87	–
Pediatric (< 18)	70	4.8%
Adult (18-65)	1,180	80.9%
Geriatric (> 65)	208	14.3%
Gender		
Male	763	52.3%
Female	695	47.7%
Stone Complexity		
Staghorn Calculi	647	44.4%
Non-Staghorn	811	55.6%

SD: Standard Deviation; N: Total number of patients. Staghorn calculi include both partial and complete staghorn stones as identified on preoperative imaging.

Stone characteristics and technical approaches

Stone locations included the lower pole (n = 334; 22.9%), upper pole (n = 207; 14.2%), renal pelvis (n = 146; 10.0%), and mid pole (n = 124; 8.5%); while, staghorn calculi were present in 647 cases (44.4%). Procedures were distributed equally between the left (48.8%) and right (48.8%) kidneys, with 34 cases (2.4%) performed as bilateral single-session procedures (Table 2).

Prone positioning with lower-pole access was the most commonly used technique (n = 848; 58.2%), while

Table 2.
Stone location and operative technique.

Parameter	Frequency (n)	Percentage (%)
Primary stone location		
Lower pole	334	22.9%
Upper pole	207	14.2%
Renal pelvis	146	10.0%
Midpole	124	8.5%
Multiple locations	647	44.4%
Surgical approach		
Prone	848	58.2%
Supracostal	452	31.0%
Mini-PCNL (MIP)	83	5.7%
Supine (csPCNL)	45	3.1%
Ultrasound-guided	20	1.4%
Bilateral single-session	34	2.4%

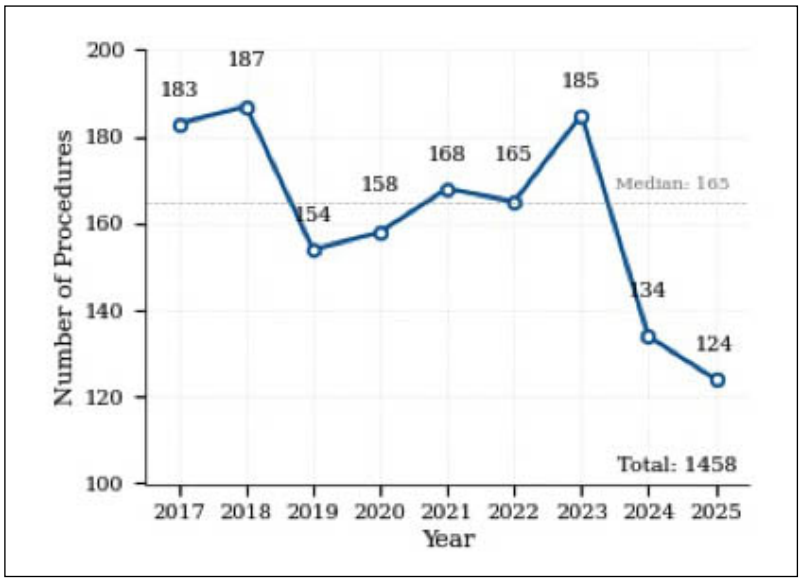

Figure 1.
Annual Surgical Volume and Technical Trends (2016-2025). Longitudinal trend analysis showing the growth in annual surgical volume and the gradual adoption of supine PCNL and miniaturized techniques. The data demonstrates institutional adaptability and the integration of modern endourological standards in a resource-limited setting.

supracostal access was required in 452 cases (31.0%). In the later years of the study, there was an institutional shift towards procedural refinement, including the adoption of mini-PCNL (MIP) in 83 cases (5.7%), *supine positioning* (sPCNL) in 45 cases (3.1%), and ultrasound-guided access in 20 cases (1.4%) (Figure 1).

Surgical outcomes and complications

The primary *stone-free rate* (SFR) achieved after a single session was 76.0% (n = 1,108). This success rate increased significantly to a final SFR of 92.6% (n = 1,350) through a combination of auxiliary interventions and conservative management. Conservative management was successfully employed for clinically insignificant residual fragments in 87 cases (6.0%). To achieve complete clearance in more complex cases, auxiliary endourological procedures were used, including repeat PCNL (re-PCNL) and *ureteroscopy* (URS) in 41 cases (2.8%), and *extracorporeal shockwave lithotripsy* (ESWL) in 22 cases (1.5%) (Table 3).

Safety profiles showed that PCNL is highly safe even in complex cases. The major complication rate (Clavien-Dindo Grade III-V) was 1.44% (n = 21). Colonic perforation occurred in 6 cases (0.41%), with 50% managed successfully through conservative strategies. Conversion to open surgery was required in 9 cases (0.62%), mainly for haemorrhage control or visceral repair. The total mortality rate was 0.14% (n = 2), resulting from one intraoperative cardiac arrest and one case of postoperative septic shock. Minor complications (Grade I-II) affected 17.4% (n = 254) of the cohort, with postoperative pain (7.3%) and fever (5.3%) being the most frequent events (Table 4).

Table 3.
Stone-free rates (SFR) and postoperative outcomes.

Outcome metric	Frequency (n)	Percentage (%)
Primary SFR (single session)	1,108	76.0%
Final SFR (post-auxiliary/conservative)	1,350	92.6%
Auxiliary procedures required		
Conservative managements	87	6.0%
Repeat PCNL (re-PCNL) or URS	41	2.8%
ESWL	22	1.5%
Hospital stay (mean ± SD)	2.4 ± 1.2 days	–

SFR: Stone-Free Rate (defined as no visible residuals or fragments ≤ 4 mm on CT/KUB); ESWL: Extracorporeal Shockwave Lithotripsy; URS: Ureteroscopy. Final SFR includes patients cleared after secondary interventions or those with clinically insignificant residual fragments (CIRFs).

Table 4.
Complications according to Clavien-Dindo classification.

Grade	Complication type	N (%)	Total %
Minor (Grade I-II)			17.4%
	Postoperative Pain	106 (7.3%)	
	Fever (Transient)	77 (5.3%)	
	Hematuria (Minor)	71 (4.8%)	
Major (Grade III-V)			1.44%
	Grade III (Surgical/Radiological Intervention)	13 (0.89%)	
	Grade IV (ICU admission/Life-threatening)	6 (0.41%)	
	Grade V (Death)	2 (0.14%)	
Specific Injuries			
	Colonic Perforation	6 (0.41%)	–
	Conversion to Open Surgery	9 (0.62%)	–

Grade III includes interventions under regional/general anesthesia or radiological drainage; Grade IV includes life-threatening complications requiring ICU management; Grade V denotes mortality. Colonic perforation management was conservative in 50% of cases (n = 3).

Discussion

In this study, we retrospectively evaluated PCNL outcomes in a large cohort in a resource-limited setting. The results showed that PCNL remains a robust and effective intervention, achieving a 92.6% final stone-free rate and a notably low major complication rate (1.44%). Our findings also indicated a significant trend towards increased

use of ultrasound-guided access and miniaturised techniques, reflecting a broader institutional shift towards more refined and imaging-precise surgical approaches.

The mean age in this study was 43.8 years, with most participants being adults (80.9%) and a slight male predominance (52.3%). Our findings are consistent with epidemiological reports of urolithiasis in the Middle East, which show a male predominance, with prevalence rates typically 1.5 to 2 times higher in males than females across regional studies (12-14). Age distribution also showed a peak incidence in the third to sixth decades of life, often associated with metabolic and environmental factors such as heat exposure and lifestyle-related changes (13, 14).

PCNL marks a definitive shift away from the complications associated with traditional open surgical techniques. It has become the benchmark for achieving high SFR (15). The current AUA 2026 guidelines support this transition, recommending PCNL as the preferred intervention for renal calculi larger than 2 cm and for lower-pole stones larger than 1 cm (16). Our study shows that even in a resource-constrained environment, a high-volume practice can achieve a primary SFR of 76.0% after a single session. This success rate increases to a final clearance of 92.6% when supplementary procedures and careful management of residual fragments are included.

These findings are consistent with established benchmarks in the Middle Eastern region. Recent studies in Saudi Arabia report primary success rates ranging from 69.4% to 71.3%, while recent Middle East PCNL SFR studies indicate primary single-session rates typically range from 70% to 85%, rising to 90% overall (17, 18). Similarly, in South Lebanon, the stone-free rate one month postoperatively was 82.35%, with only 8.1% of patients requiring second interventions (19). This outcome is particularly significant, as our cohort has a staghorn stone prevalence of 44.4%, which exceeds the 20-30% prevalence reported in many international studies. By aligning our results with those from specialised medical centres and efficiently employing additional procedures to address residual disease, our findings underscore the reliability of PCNL as a treatment modality that complies with established guidelines, even in challenging clinical settings.

Our complication profile shows the safety and resilience of PCNL in a resource-limited setting. We recorded a major adverse event rate (Clavien III-V) of 1.44%. This rate is comparable to, or lower than, Middle Eastern series, which report rates of 1-3% (20, 21), and global averages from the CROES database (approximately 2%) (22, 23). In a multicentre study by the *Spanish Urology Association's Renal Transplant Group*, *Sierra et al.* reported an overall complication rate for PCNL of 10.2% (24). Colonic perforation, our most serious visceral injury, occurred in 0.41% of cases, consistent with international literature rates of 0.2% to 0.5% (25, 26). Notably, conservative management was successful in 50% of these cases; the rare nephrectomies in our cohort were required due to the discovery of non-viable kidneys rather than procedural failure.

In our study, conversion to open surgery was required in 9 cases (0.62%), mainly for haemorrhage control or visceral repair. In our setting outside the capital, where radiological interventions are unavailable and such services are only accessible in the capital at considerable expense, the absence of interventional radiology precluded angioembolisation, directing all significant bleeding cases towards open surgery. This approach was further necessitated by urologists bearing all costs without insurance coverage or institutional support, as well as vulnerability to governmental and social media scrutiny, prompting a preference for definitive open intervention over conservative measures.

Minor complications occurred in 17.4% of patients and mainly included manageable issues such as postoperative pain and temporary fever. Our mortality rate of 0.14% is similar to results from high-volume centres worldwide, even with a higher rate of staghorn complexity in our cohort, which typically increases surgical risk (23, 27). These findings support that careful evolution of technique, specifically the use of mini-PCNL and ultrasound-guided access, is crucial for reducing risk and ensuring safety in challenging clinical situations.

The development of surgical techniques is a key aspect of the growth of medical institutions, reflecting a broader shift towards improving surgical procedures and enhancing patient safety. Our study documents a progressive shift towards miniaturised PCNL (mini-PCNL) and complete supine positioning (csPCNL) in the later years of the cohort. This transition mirrors a global movement towards smaller tract sizes and ergonomic alternatives aimed at reducing postoperative pain and hospital stay (28, 29).

Moreover, the introduction of ultrasound-guided access technology – although still in its early stages at our institution – demonstrates a fundamental commitment to the Achievable Minimum (ALARA) principle by minimising exposure to ionising radiation for both patients and the surgical team. These technical advancements show that surgical innovation is not confined to developed nations, but rather arises from the physician's drive to improve quality and safety. By successfully implementing these advanced techniques in a challenging regional setting, our experience confirms that technical mastery and adaptive learning remain the key drivers of excellence in urological care (24).

Study limitations

Although this study represents one of the largest PCNL series from Yemen, several limitations should be acknowledged. The retrospective design is the primary limitation, which may have resulted in under-reporting of minor postoperative complications (Clavien-Dindo Grade I) compared to prospective registries. As a single-centre study, the outcomes reflect the specific expertise and equipment available at our institution, which may not be fully generalisable to other centres in different geographic or economic contexts within Yemen. Another limitation is data heterogeneity; detailed perioperative data, such as precise operative time and estimated blood loss, were available only for a small group of patients rather than the entire cohort. Furthermore, follow-up constraints meant that long-term metabolic follow-up and stone recurrence rates were difficult to track consistently due to regional

conflict and patient displacement, which often disrupted ongoing care. Lastly, regarding imaging modality, SFR was mostly assessed using plain radiography (KUB) and ultrasound instead of the "*gold standard*" non-contrast CT, which may have led to an overestimation of final clearance rates. Future prospective studies from similar settings should aim to incorporate standardised outcome reporting, including stone-free rates and quality-of-life measures, to fully evaluate therapeutic benefit.

Conclusions

Our nine-year institutional experience shows that PCNL is a highly safe and effective method for managing complex renal calculi, even in the resource-limited and conflict-affected environment of Yemen. In a substantial cohort, we achieved a high final stone-free rate and maintained a low rate of major complications.

The study shows that prone lower-pole access remains a reliable standard across all age groups, delivering consistent outcomes with minimal visceral injury. Additionally, the increasing adoption of miniaturised (mini-PCNL) and ultrasound-guided techniques in recent years indicates a positive shift towards greater surgical precision. These findings provide an important benchmark for endourological practice in humanitarian settings, demonstrating that surgical excellence and patient safety can be maintained despite significant external systemic challenges.

Declarations

Ethical approval and consent for participate: *The study protocol was reviewed and approved by the Ethics Committee of Alhamd Teaching Hospital, Ibb, Yemen (Reference No.: IRB/ALHAMD/26/089). All procedures performed in this study involving human participants were in accordance with the ethical standards of the 1964 Helsinki Declaration and its later amendments. Due to the retrospective nature of the study and the exclusive use of fully anonymized patient data extracted from medical records, the requirement for written informed consent was formally waived by the ethics committee.*

Availability of data and material: *The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.*

Competing interests: *The authors declare that they have no competing interests.*

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Declaration of Generative AI and AI-assisted Technologies in the Writing Process: *During the preparation of this work, the authors used Gemini (Google AI) in order to improve the linguistic flow, grammatical accuracy, and structural organization of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the accuracy and scientific integrity of the contents of the publication. The AI tool was not used to generate, analyze, or interpret primary clinical data.*

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