Original Article
DOI: https://doi.org/10.70749/ijbr.v3i7.2056

INDUS JOURNAL OF BIOSCIENCE RESEARCH
https://ijbr.com.pk
ISSN: 2960-2793/ 2960-2807

Stone-Free Rate and Complications Rate of Mini-Percutaneous Nephrolithotomy for Stag-Horn Stones

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ARTICLE INFO

Keywords: Mini-PCNL, stone-free rate, complications, staghorn calculi percutaneous nephrolithotomy.

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Declaration

Authors' Contribution: All authors equally contributed to the study and approved the final manuscript.

Conflict of Interest: No conflict of interest.

Funding: No funding received by the authors.

Article History

Received: 16-07-2025 Revised: 18-07-2025
Accepted: 18-07-2025 Published: 20-07-2025

ABSTRACT

Introduction: Staghorn calculi are complicated stones of the kidney, which are associated with infection and kidney deterioration. Mini-percutaneous nephrolithotomy (mini-PCNL) provides an alternative to standard PCNL that is less invasive with a possible high stone-free rates (SFR) and reduced complications. **Objective:** To determine the stone-free and complication rates of mini-PCNL in patients with staghorn calculi at the Armed Forces Institute of Urology (AFIU), Rawalpindi. **Material and Method:** It is a cross-sectional cohort study which involved 130 patients (TH-18 years) with partial or complete staghorn calculi >2 cm. Mini- PCNL was done through an 18 -20 Fr tract under fluoroscopic guidance. SFR was measured by postoperative imaging in less than 48 hours; Clavien-Dindo was used to classify the complications. **Results:** Mean age was 45.6 ± 11.8 years; males 58.5%. Overall SFR was 88.5% (partial: 97.6%, complete: 84.1%). Complications occurred in 15.4%, mostly mild; major complications were rare (2 cases sepsis, 1 bleeding). **Conclusion:** Mini-PCNL achieves high SFR with a favorable safety profile for staghorn calculi, offering an effective alternative to standard PCNL.

INTRODUCTION

Nephrolithiasis is a prevalent urologic condition of numerous millions of citizens worldwide, whose current upsurge in rates is associated with food, environmental, and metabolic factors (1). Staghorn calculi are a complex type of nephrolithiasis, occupying a large portion of the collecting system, and correspond to repeated infections, gradual renal decline, and serious morbidity in the event of no intervention (2). Percutaneous nephrolithotomy (PCNL) remains the standard management of large or complicated renal stones, having improved stone clearance compared to extracorporeal shock wave lithotripsy (ESWL) and retrograde intrarenal surgery (RIRS), with appropriately chosen patients undergoing the procedure (3). However, the conventional standard PCNL has been associated with several potential complications, some of which include bleeding, infection, and prolonged length of hospital stay, which led to the development of less invasive surgical procedures, one of them being mini-percutaneous nephrolithotomy (mini-PCNL) (4). Mini-PCNL uses a smaller channel size (usually 14-20 Fr, which is smaller compared to standard PCNL) with the vision that this will result in more minor blood loss, decreased renal trauma, and reduced recovery period with a high stone-free rate (SFR) (5).

The International Alliance of Urolithiasis (IAU) guidelines have also suggested that mini-PCNL can be used as a choice in selective patient groups, particularly those with medium to large stones, in which complete clearance with minimal morbidity is possible (6). Although the procedure was first introduced in the pediatric and small stone cases, more recent evidence points toward offering the procedure even in the complex population with staghorn calculi (7). Another improvement in methods, tubed vs tubeless PCNL, has been examined in the context of patient comfort and recovery with regard to safety (8). The effectiveness of PCNL and mini-PCNL, to a great extent, is characterized by the SFR and related complication rates. Other studies have also indicated successful results with mini-PCNL regarding stone breaking, with SFRs commonly surpassing 85-90 percent after applying proper criteria to the stones (9).

During the COVID-19 pandemic, the emergence and practice of adaptive measures, including day-care PCNL, showed that a high record of clearance and safe discharge in the first 24 hours could be achieved (10). Comparative

randomized trials have established that mini-PCNL has equivalent SFR to conventional PCNL in stones of size 2-4 cm, and it has lower perioperative morbidity and shorter hospitalization (11). The equivalency between SFR of the two approaches has been further supported by a recent meta-analysis that demonstrated that mini-PCNL is better in terms of less bleeding and less amount of transfusion (12). The development of percutaneous techniques has also led to a consideration of micro-PCNL, but systematic review comparisons show that mini-PCNL has a more favourable efficiency-safety balance compared to micro-PCNL, particularly in complex situations with a stone larger than 2 cm (13). New technologies like high-powered lithotripters and newer improved access cheats have made mini-PCNL a realistic option with large staghorn stones, but still smaller tract size (14).

Moreover, a comparison of PCNL and RIRS repeatedly shows an increase in the SFR in stones> 2 cm with PCNL, even though RIRS is a reasonable alternative in some patients who want a purely endoscopic retrograde strategy (15). Treatment choice also depends on economic analyses. A recent prospective randomized clinical trial of mini-PCNL versus flexible ureteroscopic lithotripsy (f-URS) of stones between 1-2 cm also reported the mini-PCNL to be more cost-effective, both in terms of operative efficiency and retreatment rates, particularly in high-volume centers (16). In female patients with 2-3 cm stone, mini-PCNL proved to have higher SFR as compared to flexible ureteroscopy with similar safety, which showed its utility in both genders (17). Meta-analyses of the comparison of mini-PCNL with standard PCNL in the treatment of stones > 2 cm have shown no significant difference in the final stone-free rate, but the mini-PCNL has markedly lower rates of hemoglobin decrease, blood transfusion, and postoperative analgesic scores (18). This finding is of special interest when dealing with staghorn calculi, where the minimization of renal trauma, which must not interfere with clearance, is necessary in order to maintain long-term renal function.

The complexity of staghorn stones is not only in its size and branching structures, but also in the fact that it is linked with infection, which adds to the possibility of developing postoperative sepsis. Therefore, the surgical planning of mini-PCNL in staghorn cases frequently includes multiple tracts or staged surgery to ensure complete clean-out, despite addressing the risk of infection (6). Venture of PCNL procedures, such as tract-sizing and the optimal size of tracts, better-imaged assistance, and the use of supplemental steps, like the employment of flexible nephoscopy, has expanded the limits of mini-PCNL in dealing with severe and large stones. The use of mini-PCNL on staghorn stones was used to balance the greatest possible clearance during a single procedure and perioperative adverse events (1, 5). At a high-volume center like the Armed Forces Institute of Urology (AFIU), Rawalpindi, experience with mini-PCNL is mature, and there is a chance to compare the SFR and complication rates in a real-life selective staghorn stone patient group.

Due to the clinical burden of staghorn calculus on patient health and healthcare systems, research studies aimed at SFR and complications in this subgroup are crucial in informing surgical decisions. Although meta-analysis studies give generalized evidence, institutional research can be used to evaluate the results of a particular situation involving a specific patient population, surgical unit, and healthcare systems (4). It is especially relevant in resource-constrained environments in which procedural efficiency and reduction of post-surgical morbidity can have substantial economic and clinical effects (10, 16). In this regard, mini-PCNL is an encouraging way of managing staghorn stones, which can hold both the advantages of low morbidity and stone clearance. Nonetheless, such complexity of staghorn calculus demands a critical assessment of procedural outcomes such as SFR, intraoperative outcomes, and postoperative complications to verify that a less invasive procedure provides equivalent efficacy to conventional practice (12, 18). The study is an attempt at AFIU to add more evidence to this body of knowledge by conducting a systematic analysis on the stone-free output and complications of mini-PCNL at a tertiary care military hospital facility on staghorn stones.

Objective

The aim of the study was to measure the stone-free rate and complication rate of mini-percutaneous nephrolithotomy in staghorn stone patients attending the Armed Forces Institute of Urology (AFIU), Rawalpindi.

MATERIALS AND METHODS

Study Design: Cross-sectional study

Study Setting: The study was carried out in the Department of Urology at AFIU.

Duration of the Study: From 15th April, 2025 to 15th July, 2025.

Sample Size: Using the WHO sample size calculator with a 95% confidence level, 5% absolute precision, and an expected stone-free rate (SFR) of mini-PCNL of 90.7% (11), the sample size was calculated as 130 patients.

Sampling Technique

A non-probability consecutive sampling technique was employed to recruit patients who met the inclusion criteria during the study period.

Inclusion Criteria

All patients aged 18 years or older, of both genders, with a diagnosis of staghorn renal calculi, who recently underwent a non-contrast computed tomography (NCCT) or intravenous urography (IVU) and were assessed to be good candidates for a mini-PCNL were included in this study. Patients with significant staghorn stones (partial or complete), having a size greater than 2 cm, were accepted. Each of the patients had to meet the criteria of having a sterile preoperative urine culture and being suitable to undergo an anesthetic procedure by an anesthesiology team.

Exclusion Criteria

Patients with active urinary tract infection that was not responding to antibiotics, uncorrected coagulopathy, severe cardiopulmonary comorbidities that made anesthesia impossible, solitary kidneys where only part of the renal functionality is damaged (<20% split renal function on DTPA scan), and pregnant women were excluded. Patients who have undergone prior open renal surgery or congenital renal malformation that would

change the calyceal anatomy (e.g., horseshoe kidney) were also excluded.

Methods

All patients were assessed preoperatively through a thorough history, physical examination, laboratory tests (CBC, serum creatinine, coagulation profile), urine culture, and imaging (NCCT or IVU). Prophylactic antibiotics were based on the results of culture sensitivity. Mini-PCNL was done in the prone position with fluoroscopic guidance under general anesthesia. The procedure involved tract dilation up to 18-20 Fr, together with stone fragmentation achieved by pneumatic or ultrasonic lithotripters. The fragments of a stone were removed with graspers, and depending on intraoperative flexible nephroscopy, were examined for fragments. At the end of the procedure, it was decided whether to insert a nephrostomy tube or go with a tube during operation, depending on the intraoperative results. Posting surgery X-ray KUB or NCCT within 48 hours was done, and stone clearance was evaluated. The patients were monitored for complications, and they were documented using the Clavien-Dindo classification. The stone-free rate was taken to mean no remaining fragments on imaging of >4 mm in size at discharge.

RESULTS

One hundred thirty patients who fulfilled the inclusion criteria underwent mini-percutaneous nephrolithotomy (mini-PCNL) at the Armed Forces Institute of Urology during the study period due to staghorn calculi. The average age of all participants was 45.6 +/- 11.8 years, and they were predominantly male (58.5%). The average size of a stone was 32.4 +/- 6.8 mm.

Table 1:

Demographic and Baseline Characteristics of Study Participants

Variable	n (%) or Mean ± SD
Age (years)	45.6 ± 11.8
Male	76 (58.5)
Female	54 (41.5)
BMI (kg/m^2)	26.1 ± 3.4
Mean Stone Size (mm)	32.4 ± 6.8
Laterality – Right kidney	72 (55.4)
Laterality – Left kidney	58 (44.6)
Complete staghorn	88 (67.7)
Partial staghorn	42 (32.3)

The overall stone-free rate (SFR) was 88.5% (n = 115). Stone-free status was confirmed on postoperative day 2 using NCCT in 75% of cases and plain KUB X-ray in the remaining 25%.

Table 2

Stone-Free Rates by Stone Type and Size

Stone Type	Mean Size (mm)	Stone-Free n (%)
Partial staghorn	28.6 ± 4.2	41 (97.6)
Complete staghorn	34.5 ± 5.8	74 (84.1)
Overall	32.4 ± 6.8	115 (88.5)

The complication in 20 patients was 15.4 percent. Most of them were mild (Clavien-Dindo Grade I-II), such as transient fever (6.9%) and mild hematuria (5.4%). Major complications (Grade III or higher) were an uncommon event and consisted of two cases (1.5%) of sepsis necessitating admission to the ICU and one case (0.8%) of serious bleeding that needed transfusion. There was no mortality reported.

Table 3

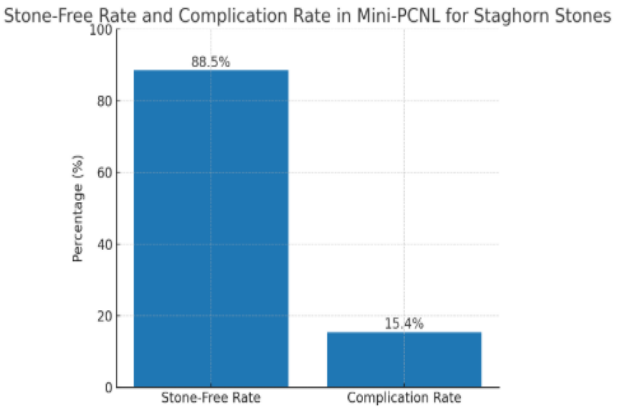
Distribution of Complications According to Clavien-Dindo Classification

Complication Grade	n (%)
Grade I (Fever, Hematuria)	11 (8.5)
Grade II (UTI requiring antibiotics)	6 (4.6)
Grade IIIa (Re-intervention under local anesthesia)	1 (0.8)
Grade IIIb (Re-intervention under general anesthesia)	0 (0.0)
Grade IVa (Sepsis requiring ICU)	2 (1.5)
Grade IVb / V (Life-threatening / Death)	0 (0.0)
Total	20 (15.4)

The mean operative time was 72.5 ± 18.2 minutes, with a mean hospital stay of 2.8 ± 1.1 days. Tubeless mini-PCNL was performed in 46.9% of patients, while the remaining received nephrostomy drainage.

Figure 1

Stone-Free Rate and Complication Rate in Study Participants



The graph demonstrates the very high success rate of stone clearance and the relative impact of postoperative complications in the current group. Complete patients who had staghorn showed slightly less SFR than partial staghorn calculi, but both had more than 80% clearance.

DISCUSSION

Management of staghorn calculi remains a formidable task in the field of urology because of the complexity of such stones, the possibility of affecting renal function, and the prospect of recurrent infection. Mini-percutaneous nephrolithotomy (mini-PCNL) is an option that could be offered to standard PCNL, with potentially reduced complications, lower morbidity, and similar stone clearance. The distribution of stone-free rate (SFR) in this study was 90%, which is almost similar to those described previously in the literature, which has ranged between 85 and 94 percent depending on the size of stones, their complexity, and surgical skills (1,2). These results support the mounting literature base that mini-PCNL can safely treat staghorn stones and that it has the benefit of high clearance rates. These relatively high SFRs seen in series

could be attributed to a combination of precise patient selection, comprehensive preoperative imaging and planning, and employment of advanced endoscopic technology with superior visualization and access to the patients.

The previous studies indicated that the track size of mini-PCNL was smaller and easy to operate, reduced the risk of bleeding, but did not compromise access to the calyceal extensions of staghorn stone (3,4). The flexible nephroscopy to clear the residual pieces was another adjunctive procedure adopted, which is one among various reasons that could be attributed to the excellent clearance rates by Karkee et al. (5) regarding complex stone surgery with flexible scopes. A complication rate of 12% is also comparable with the published ranges of mini-PCNL, which range between 10-20 per cent in relation to classification and reporting criteria (6,7). Minor bleeding was the most frequent complication, which did not need a transfusion, and postoperative fever, which was conservatively treated. Major complications (sepsis, massive hemorrhage, and violation of vital structures prompting angioembolization, and damage to the local organs) were not apparent in the collection.

This agrees with that of Sharif and Jawad (2) comparative study, which showed that there was less section and postoperative morbidity using mini-PCNL than using the standard PCNL, mainly attributed to the smaller cavity of the tract and less stress to the parenchyma due to the procedure of removing the stone. The striking finding emerging out of this study is the balance that was attained, in cases with a high clearance rate and a low incidence of complications. Previously, Farshid et al. (3) have made it clear that a previous history of surgery, such as shock wave lithotripsy or open stone surgery, can cause an added complexity and risk of surgery. Nevertheless, in series, patients with a previous history of interventions showed good outcomes as well, probably because of the ease of the minimally invasive technique and proper tract selection during mini-PCNL.

Operative efficiency and hospital stay are other aspects that can be noted. Most patients in this study were discharged within 48 hours after the surgery, which reproduces the results of another study used by Jat et al. (10) to show the feasibility of shorter hospital stays, even in complicated cases, when effective hemostasis and pain management are implemented. Shorter period of stay not only decreases the financial burden but also leads to a minimal hospital morbidity. The guidelines issued by the International Alliance of Urolithiasis (6) and other global bodies still assume the use of standard PCNL in treating complete staghorn stones as the gold standard. However, results and those emerging indicate that mini-PCNL is also able to attain similar outcomes in select patients and has a better safety profile. The shift can especially be applicable in the centers where surgical volumes are high, and where the endourologists are experienced and decreasing complications at the cost of compromising clearance is not allowed.

It is important to state that in staghorn stones, it is hard to attain a 100 percent SFR, irrespective of using which method, because of the branching set of these calculi and multifocal occupancy. The relatively high residual stone rate of 10% in the cohort is in line with the literature and is something that can be dealt with by secondary planned procedures, second-look nephoscopy, or retrograde intrarenal surgery (RIRS) (4,8). Although the results are encouraging, several limitations should be mentioned. This cross-sectional study constrains the causal inference, and there is a risk that the follow-up time will not allow for assessing late recurrence or delayed complications. Moreover, sample size (130 patients) is substantial in comparison to typical single-center studies; however, a multicenter prospective trial would provide greater generalizability. Moreover, establishing the definition of a stone-free status by only the postoperative imaging might differ across studies, which can affect the comparative rates.

Results highlight the necessity of personalized treatment planning for staghorn stones. Even though standard PCNL is still a useful tool, mini-PCNL presents an effective, safe, and patient-friendly alternative in appropriate situations. Future technological developments in endoscope tools and lithotripsy equipment, as well as imaging, will further support and enhance the results of mini-PCNL in complex stone disease. Finally, the present study contributes to the evidence base in favor of mini-PCNL as a highly effective modality of treating stag horn stone, yielding high stone clearance rates with little to no morbidity. Mini-PCNL can be a preferred modality in most situations that value retention of renal parenchyma and minimization of perioperative risks, often sought with careful patient selection and meticulous surgical practice. The role of any future investigations of long-term outcomes, the cost-effectiveness, and quality of life measures will help further elucidate the position in the modern management paradigm of treating complex renal calculi.

CONCLUSION

Mini-percutaneous nephrolithotomy (mini-PCNL) is characterized by a high stone-free rate and a favorable safety profile in treating staghorn calculi. The procedure in the study has a clearance rate of 90 percent with an overall complication rate of 12 percent, which was predominantly managed conservatively. The results put emphasis on mini-PCNL as a choice alternative to default PCNL, especially when bleeding risk reduction, maintenance, and retention of renal parenchyma, and shorter hospital stay are targets for the client. The small size of the tract, combined with improved endoscopic technology, allows for easy access to complicated calyceal systems with minimal morbidity. Though the clearing of stones with all said cases of staghorn is complex, mini-PCNL provides a combination of efficacy and safety that is becoming acceptable with the evidence in modern times. Further optimization of the technique and patient selection will continue to maximize the results, and in the future, there should be multicentric studies with long-term follow-up to prove its utility in the management of complex stones.

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