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Safety and Efficacy of Mini Percutaneous Nephrolithotomy Using Smaller Nephroscope for Kidney Stones in Children

Firasat Majid, Mumtaz Rasool, Muhammad Usman

Abstract

Objective: To evaluate the safety and effectiveness of mini percutaneous nephrolithotomy (mini PCNL) with a smaller nephroscope in children aged 12 years and under with kidney stones

Study Design and Setting: It is a Prospective Cohort Study conducted at the department of Paediatric Urology, Bahawal Victoria Hospital Bahawalpur from 11th August 2020 to 10th August 2024.

Methodology: This study included 52 children (=12 years) with kidney stones =2.5 cm. Exclusions were children with non-functional kidneys, positive urine cultures, or coagulation disorders. After obtaining parental consent and assessing anaesthesia fitness, MPCNL was performed under general anaesthesia. A rigid 8/9.8 Fr nephroscope, 12 Fr amplatz sheath, and 1.5 mm pneumatic lithoclast probe were used. A supra-costal tract (above the 12th rib) was made in 36 patients and sub-costal in 16. Postoperative care included nephrostomy tube, ureteric catheter, and set tube removal protocol. Outcome measures included operative time, hospital stay, blood transfusion need, and stone clearance on follow-up ultrasound.

Results: The mean age was 5.2 years. Thirty two (61%) were male, with a male-to-female ratio of 1.6:1. Average hospital stay was 48 hours, and mean operative time was 42 minutes. Stone clearance was complete in 69.23% of cases, with 36.76% having >85% clearance. Blood transfusions were needed in 19.23%, with no pleural effusions or chest tube placements.

Conclusion: Mini PCNL is safe and effective for well-selected pediatric patients. Additional comparative studies are recommended for further validation.

Keywords: Percutaneous Nephrolithotomy; Nephrolithiasis; Pediatrics; Minimally Invasive Surgical Procedures; Lithotripsy; Kidney Calculi; Treatment Outcome

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INTRODUCTION

Kidney stones have become an increasingly common condition across all age groups, including pediatric populations worldwide.[1] Although historically considered rare among children, recent epidemiological data suggests a noticeable rise in pediatric kidney stone cases, likely due to changes in diet, lifestyle, and environmental factors.[2] In Pakistan, the prevalence of pediatric nephrolithiasis has also been on the rise, driven by both genetic and environmental influences such as high temperatures, low water intake, and specific dietary patterns prevalent in the region. With urolithiasis affecting the lives and renal health of young patients, there is a critical need for effective, minimally invasive treatment options tailored to the unique anatomical and physiological characteristics of pediatric patients. Percutaneous nephrolithotomy (PCNL) has long been established as an effective intervention for large or complex kidney stones. However, when it comes to children, especially those under the age of 12, traditional PCNL poses risks due to the relatively large instruments and tract size but still gaining popularity due to good outcomes.[3]

The introduction of mini PCNL has marked a significant advancement in pediatric urology. Mini PCNL involves the use of smaller nephroscopes, typically under 18 French, allowing for a reduced tract size, which is beneficial in minimizing the potential complications associated with PCNL, such as renal trauma, hemorrhage, and injury to surrounding tissues.[4] International studies, particularly those from Europe and North America, have demonstrated that mini PCNL can achieve comparable stone-free rates to traditional PCNL, with significantly reduced morbidity and improved recovery times in pediatric patients.[5] For Pakistani children, mini PCNL offers particular promise given the

Firasat Majid
Assistant Professor, Department of Urology
Quaid-i-Azam Medical College, Bhawalpur
Email: drfirasatm@gmail.com

Mumtaz Rasool
Professor, Department of Urology
Quaid-i-Azam Medical College, Bhawalpur
Email: dmr250@hotmail.com

Muhammad Usman
Technologist, Department of Urology
Quaid-i-Azam Medical College, Bhawalpur
Email: khan.usman164@gmail.com

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relatively high incidence of pediatric nephrolithiasis and limited access to advanced healthcare in some regions. By minimizing hospitalization and recovery times, mini PCNL could provide a more accessible and feasible solution for young patients across different socioeconomic backgrounds.[6]

Despite these potential advantages, there are still considerable concerns regarding the overall safety and efficacy of mini PCNL, especially when applied to children younger than 12 years. In pediatric patients, the kidney is smaller and more delicate, and the possibility of long-term impacts on renal growth and function from miniaturized instruments remains a key consideration. While mini PCNL is associated with fewer complications, the reduced size of nephroscope may limit visualization and access to larger stones, potentially affecting stone clearance rates and increasing the risk of residual fragments.[7] Studies from international centers have shown varied results, with some research indicating high stone-free rates and low complication rates, while other studies point out potential limitations, including residual stone fragments and the possibility of repeat procedures in complex cases. In Pakistan, recent small-scale studies have explored the outcomes of mini PCNL, generally reporting favorable outcomes but emphasizing the need for broader research to validate these results across diverse pediatric populations.

One of the main alternative treatments for pediatric urolithiasis is extracorporeal shock wave lithotripsy (ESWL), which, while effective for smaller stones, often proves insufficient for larger, more complex stones or for stones that are difficult to access anatomically. ESWL's reliance on multiple sessions and its potential for incomplete stone fragmentation present limitations, particularly for larger stones frequently observed in Pakistani children due to late presentations. Ureteroscopy, another minimally invasive option, also poses challenges, especially for very young patients due to their smaller uretral and renal anatomy. Therefore, mini PCNL stands out as a promising option in such cases, offering a more direct approach to stone removal and thus reducing the need for multiple treatments.[8]

This study aims to evaluate the safety and efficacy of mini PCNL specifically in children aged 12 years and younger, utilizing smaller nephroscopes that are better suited to the pediatric anatomy. By assessing postoperative outcomes, complications, and stone-free rates, this research seeks to fill the gap in existing knowledge regarding mini PCNL's applicability in younger populations, particularly within the Pakistani context.[9] As this age group often presents unique challenges in terms of anatomical considerations and stone composition, the findings from this study could contribute valuable insights into optimal treatment approaches for pediatric kidney stones.[10] In a healthcare system with variable access to advanced urological procedures, evidence supporting the safety and effectiveness of mini-PCNL can play an important role. It may encourage its adoption as a standard and accessible treatment for children with kidney stones in Pakistan and beyond. Despite improvements in minimally invasive techniques, considerable variation still exists in operative outcomes and postoperative recovery following mini-PCNL, especially in resource-limited settings. Therefore, locally generated evidence is essential to guide clinical decision-making and ensure patient safety. This study aims to address this gap by systematically evaluating perioperative outcomes in our population.

This study provides locally generated evidence on the safety and feasibility of mini-PCNL in pediatric patients within a resource-limited setting. The findings may help guide clinical decision-making and promote adoption of minimally invasive stone management strategies in similar healthcare environment.

METHODOLOGY

After the ethical approval by ethical review committee of Bahawal Victoria Hospital Bahawalpur (ERC NO 345/DME/QAMC Bahawalpur), Department of Paediatric Urology B.V Hospital Bahawalpur from 11th August 2020 to 10th August 2024. written informed consent was obtained from the parents or legal guardians of all the pediatric participants prior to enrollment patient data was anonymized , and confidentiality maintained throughout the study.

This study included patients aged 12 years and belowdiagnosed with kidney stones. The selection done by convinient purposive sampling , and met specific inclusion and exclusion criteria. Eligibility for the study required that patients have kidney stones with a maximum size of 2.5 cm, as determined by ultrasound and/or non-contrast computed tomography (CT) scan of the kidney, ureter, and bladder (KUB).

Patients with larger stones (>2.5 cm) or those with non-functional kidneys were excluded from the study. Additionally, patients with a positive urine culture or those with coagulation disorders were excluded.

In total, 52 patients who fulfilled the predefined inclusion criteria were enrolled in the study. All participants underwent a comprehensive preoperative evaluation, which included clinical examination, anesthetic assessment, and review of laboratory investigations, to ensure they were medically fit for general anesthesia. To minimize the risk of perioperative infections, prophylactic antibiotics were administered pre-operatively, following established institutional protocols and, when available, tailored according to culture and sensitivity results. This standardized approach ensured uniformity in preoperative care across all patients.

The mini-percutaneous nephrolithotomy (MPCNL) procedure was performed under general anesthesia in every case. A rigid nephroscope measuring 8/9.8 French (Fr) was employed for visualization, allowing effective access to the renal collecting system while maintaining a minimally invasive

tract size. Along with this, a 12 Fr Amplatz sheath facilitated tract stabilization, and a pneumatic lithotripter with a 1.5 mm probe was used for stone fragmentation, enabling efficient disintegration of calculi with reduced thermal injury risk.

In 36 patients, an upper-pole puncture was carried out through a supra-costal approach, entering the kidney above the 12th rib. This route was selected to provide improved access to stones located within the upper calyx or renal pelvis, especially in cases where lower-pole or mid-pole access would have resulted in suboptimal alignment with the targeted calyces. Although supra-costal entry may increase the theoretical risk of pleural injury, it often offers a more direct channel for complete stone clearance in anatomically challenging cases.

In the remaining 16 patients, a sub-costal approach was utilized, with puncture performed below the 12th rib. This technique is generally considered safer with respect to pleural complications and is preferred when the stone burden is located more inferiorly or when upper-pole access is not required. However, sub-costal access may provide comparatively limited maneuverability for upper calyceal stones, which was taken into account during tract selection based on individual stone characteristics. The tract size and choice of approach were individualized based on stone location, size, and the patient's anatomy, as visualized pre-operatively through imaging studies.

Postoperative drainage and tube placement followed a standardized protocol. A 10 Fr nephrostomy tube was placed through the tract site to allow drainage of urine and any residual stone fragments. Additionally, a 4 Fr ureteric catheter was inserted to ensure unobstructed urinary flow from the kidney to the bladder, and a 10 Fr silicone Foley catheter was placed per urethra for bladder drainage. These tubes were removed based on a set protocol to allow gradual adjustment of the urinary tract and prevent urinary stasis.

The primary variables recorded included the total operative time from the initial puncture, the length of the hospital stay, and the requirement for blood transfusion if the postoperative hemoglobin level fell by more than 2g/dl. Postoperative imaging, primarily via ultrasound, was conducted on the second postoperative day to assess the immediate stone clearance. A follow-up ultrasound was then performed one week after surgery to confirm the absence of residual fragments and to monitor for any delayed complications. In cases where residual stones were observed, additional follow-up or alternative management strategies were considered based on patient symptoms and stone characteristics.

Complications such as pleural injury requiring chest tube placement, postoperative infection, and pain requiring analgesic administration were meticulously documented. The incidence of these complications helped assess the procedure's safety profile, providing insight into potential risks associated with the supra- and sub-costal approaches in a pediatric population. Pain was managed with a standardized analgesic protocol, and the total analgesic requirement was recorded for each patient.

All recorded variables, including demographic profiles, detailed operative parameters, and postoperative clinical outcomes, were systematically analyzed using standard statistical techniques. Data entry and processing were performed using IBM SPSS Statistics, version 24, ensuring accuracy and consistency throughout the analysis. Descriptive statistics were applied to outline the baseline characteristics of the study population and to summarize intra-operative and postoperative performance indicators.

Data accuracy was maintained through a structured double-entry verification process, in which all variables were independently entered and cross-checked to minimize typographical or transcription errors. Any discrepancies identified during this process were resolved by referring back to the original clinical records, ensuring that the final dataset reflected the most reliable and consistent information. To protect patient privacy, all identifying details were removed, and each case was assigned a unique study code, allowing analysis to be conducted without compromising confidentiality

Continuous variables, such as operative time, duration of hospital stay, and patient age, were expressed as means with corresponding standard deviations to reflect both central tendency and variability within the data-set. Categorical variables, including overall complication rates, distribution of Clavien–Dindo grades, and the requirement for peri-operatively blood transfusion, were presented as frequencies and percentages to provide a clear representation of proportional outcomes. This structured statistical approach allowed for a comprehensive assessment of the safety and effectiveness of mini-PCNL within the studied cohort.

Statistical Analysis: Data were analyzed using IBM SPSS Statistics version 24. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Independent sample t-test and chi-square test were applied where appropriate. A p-value of =0.05 was considered statistically significant.

RESULTS:

In this study of 52 patients, the average age of the participants was just over five years, reflecting the predominantly paediatric nature of the cohort. Males made up a larger share of the sample, with nearly two-thirds of the children being boys, resulting in a male-to-female ratio of approximately 1.6:1. Hospital stay after the procedure averaged about two days, although there was some variation among individuals. Following the puncture, the operative duration was a little over 40 minutes on average, again with noticeable variation depending on case complexity. Regarding treatment

outcomes, the procedure was largely successful. Overall success rate, defined as complete clearance plus clinically insignificant residual fragments (<3 mm), was 85.9%.Complete stone clearance was achieved in more than two-thirds of the patients, and when the criterion was broadened to include those with only minimal residual fragments (less than 3 mm), the rate of satisfactory clearance rose substantially, reaching nearly 85%.

The summarized results are presented in the following table.

Table 1: Preoperative Variables

Variable	Value
Mean Age	5.2 ± 2.2 years
Gender	32 Male (61%), 20 Female (38%)
Mean Stone Size	1.8 ±0.2 cm

Table 2: Operative and Postoperative Outcomes

Variable	Value
Operative Time	42 ± 8.78 min
Hospital Stay	48 ± 10.48 hrs
Complete Clearance	69.23%
Overall Success (CIRF included)	85.9%
Blood Transfusion	19.23%
Pleural Complications	0

DISCUSSION

This study explored the safety and efficacy of mini PCNL in children aged 12 years and under, with results indicating a favorable outcome in terms of stone clearance rates and a manageable complication profile. The mean age of 5.2 years, with a male predominance (male-to-female ratio of 1.6:1).[9] It is consistent with the demographic patterns observed in pediatric nephrolithiasis. Globally, studies have reported a higher prevalence of Urolithiasis in males, which may be due to gender-based anatomical or physiological differences influencing stone formation risk factors.[10] This trend aligns with previous studies in South Asia, where males have been more frequently affected.

The mean operative time after puncture, recorded at 42 minutes, falls within the typical range reported in pediatric mini PCNL procedures. Studies have shown that, in experienced hands, mini PCNL can achieve effective stone clearance within a similar operative time frame, which helps to minimize anesthesia exposure in young patients and contributes to an overall safer procedure.11 The choice of equipment, such as the 8/9.8 Fr nephroscope and 12 Fr amplatz sheath, facilitated an effective miniaturized approach, allowing for reduced trauma to the renal parenchyma.[12] This aligns with reports that advocate miniaturized tracts to reduce complications like bleeding and parenchymal damage, both crucial considerations in pediatric patients with smaller anatomical structures.

Stone clearance rates in this study were also notable, with 69.23% of patients achieving complete stone clearance, and 36.76% achieving more than 85% clearance with residual calculi less than 3 mm in size.[13] This aligns well with international studies on mini PCNL in children, where complete or near-complete stone clearance rates typically range between 65% and 85%, depending on stone size, composition, and surgeon expertise.[14] Residual fragments smaller than 3 mm are considered clinically insignificant (clinically insignificant residual fragments or CIRF).[15]

A key finding in this study is the low complication rate associated with the mini PCNL procedure.[16] Notably, there were no instances of pleural effusion or chest tube placement, complications that are often associated with supra-costal access, particularly in pediatric patients. Studies have shown that with appropriate imaging guidance and surgical experience, the risk of major complications such as pleural injury can be minimized in mini PCNL. The use of a supra-costal approach in 69% of patients without resulting in pleural complications highlights that, with careful planning, upper pole access can be safely achieved in pediatric patients to maximize stone clearance, especially for stones located in challenging upper calyces or renal pelvis.[17]

Blood transfusions were required in 19.23% of cases, a rate that aligns with other pediatric studies, which report transfusion rates ranging from 10% to 20% depending on operative factors such as tract size, stone burden, and patient age.[18] Although blood loss remains a concern in mini PCNL, the minimized tract size and refined techniques employed here contributed to maintaining this complication within manageable limits as compared to standard PCNL.[19]

The average hospital stay post-surgery was approximately 48 hours, which is consistent with recovery periods in similar studies where mini PCNL has been shown to allow for shorter hospitalizations due to its minimally invasive nature. Shortened hospital stays contribute positively to patient outcomes by reducing healthcare costs and decreasing the risk of hospital-acquired infections.[20]

This study has several important limitations that warrant consideration when interpreting the findings. First, it reflects the experience of a single center with a relatively small sample size, which restricts the external validity of the results and may not accurately represent outcomes in institutions with different case loads, surgical setups, or levels of endourological expertise. Second, the selection of patients for mini-PCNL versus standard PCNL was not randomized; instead, it may have been influenced by surgeon preference, stone characteristics, or anatomical considerations. This introduces a degree of selection bias that could affect the comparability of the two groups. Additionally, the follow-up duration was limited, preventing evaluation of long-term endpoints such as stone recurrence, renal growth, renal scarring, and preservation of renal function—factors that

are particularly important in the pediatric population.

Another limitation is the heterogeneity of the included cases, as variations in stone burden, location, composition, and degree of hydronephrosis could have influenced intraoperative difficulty and postoperative outcomes. The study also relied on ultrasonography and plain radiography for postoperative assessment, which are known to be less sensitive than CT imaging. This may have resulted in underestimation of clinically insignificant residual fragments or low-volume residual stones. Furthermore, metabolic evaluation—which plays a critical role in identifying the underlying etiology of pediatric urolithiasis—was not comprehensively performed, limiting the ability to correlate stone type with recurrence risk or tailor preventive strategies.

The study also did not incorporate cost analysis, patient-reported outcomes, or quality-of-life measures, all of which are increasingly recognized as essential components of evaluating surgical interventions in children. Despite these limitations, the study contributes meaningful preliminary data on the safety, feasibility, and outcomes of mini-PCNL in the local pediatric population and provides a platform for the development of larger, multicenter, prospective trials across Pakistan and the broader South Asian region..

Based on the findings of this study, several recommendations can be made to improve clinical practice and guide future research. Larger, multicenter studies with standardized operative protocols are needed to validate the safety and efficacy of mini-PCNL across diverse surgical settings in Pakistan. Randomized or well-matched comparative trials would help minimize selection bias and provide more reliable evidence on when mini-PCNL should be preferred over standard PCNL in children. Longer follow-up is essential to evaluate long-term renal function, recurrence rates, and the impact of residual fragments, especially in growing kidneys. Incorporating low-dose CT protocols or other advanced imaging techniques may improve the accuracy of postoperative stone-free assessment. Routine metabolic evaluation should be integrated into pediatric stone management pathways to better understand etiology and optimize recurrence prevention. Future studies should also explore the cost-effectiveness, parental satisfaction, and quality-of-life outcomes associated with mini-PCNL, enabling a more holistic assessment of its role within pediatric urolithiasis care. Collectively, these steps will help refine treatment algorithms and enhance the overall management of pediatric stone disease in the region.

Although all procedures in this study were performed in the prone position, recent literature suggests that supine PCNL may offer advantages such as reduced cardiopulmonary compromise and simultaneous retrograde access. However, surgeon familiarity and institutional protocols continue to influence positioning choice. Recent studies (2021–2025) have emphasized further miniaturization techniques such as ultra-mini and micro-PCNL, aiming to further reduce morbidity while maintaining efficacy. However, concerns remain regarding visualization and operative efficiency, highlighting the need for balanced technique selection.

This study's findings underscore that mini PCNL can be a safe and effective option for managing kidney stones in pediatric patients, provided that cases are carefully selected based on stone size, patient health status, and anatomical considerations. However, The findings should be interpreted cautiously due to the descriptive nature of the analysis and absence of a comparative group. More comparative studies are essential to substantiate these findings. Randomized controlled trials comparing mini PCNL with other minimally invasive techniques like extracorporeal shock wave lithotripsy (ESWL) and ureteroscopy (URS) in pediatric patients could provide further evidence on the ideal treatment choice based on stone characteristics and patient factors.[21] Additionally, a comparative analysis between mini PCNL and ultra-mini PCNL could reveal valuable insights into whether further reduction in nephroscope size might offer benefits or present limitations in terms of visualization and stone clearance.

CONCLUSION:

Mini PCNL is safe and effective in children when performed in well selected patients. However comparative studies are required for more evidence.

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Authors Contribution:
Firasat Majid: Objective, surgery data collection, write up
Mumtaz Rasool: write up, data analysis, result interpretation final approval
Muhammad Usman: Surgery assistance, data entry, data collection

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