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Efficacy of Percutaneous Nephrolithotomy in Pediatric Renal Stone Clearance in Khyber Pakhtunkhwa: A Cross-Sectional Analytical Study

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ABSTRACT

Renal stone disease is increasingly recognized in the Pediatric population and poses significant clinical challenges. Timely and effective intervention is essential to prevent long-term complications such as recurrent infections, renal damage, or impaired growth. Percutaneous nephrolithotomy(PCNL)has emerged as a key surgical technique in managing moderate to large renal stones in children, but data on its efficacy and safety in the local context remain limited. **Objectives:** To assess the effectiveness of PCNL in achieving renal stone clearance in Pediatric patients aged 5 to 15 years presenting to a tertiary care centre in Khyber Pakhtunkhwa. **Methods:** This descriptive study was conducted at the Department of Urology, Institute of Kidney Diseases, Peshawar. A total of 216 children with uncomplicated, single renal stones measuring ≤8 mm, confirmed on a KUB X-ray, were enrolled through consecutive non-probability sampling. Standard PCNL was performed under general Anesthesia, and clearance was assessed postoperatively. Data were analyzed using SPSS version 23.0. Chi-square test was used for associations between stone clearance and variables age, gender, stone size, site, and operative time. **Results:** Stone clearance was achieved in 78.2% of cases. Clearance was higher in children with smaller stones (≤5 mm) and shorter operative times, though the differences were not significant (p>0.05). No major procedural complications were reported. **Conclusions:** PCNL is an effective and safe procedure for treating Pediatric renal stones. While factors like stone size and operative duration may influence outcomes, further large-scale studies are warranted to confirm these associations in the Pediatric population of low-resource settings.

INTRODUCTION

Pediatric urolithiasis is a growing concern worldwide, with a rising incidence attributed to changes in dietary patterns, metabolic disorders, and environmental factors [1]. In children, renal stones present a unique challenge due to anatomical and physiological differences, making both diagnosis and management more complex compared to adults [2]. Early detection and timely intervention are crucial to prevent complications such as infection, obstruction, and long-term renal impairment [3, 4]. Among the various treatment options, Percutaneous Nephrolithotomy (PCNL) has emerged as a preferred modality for managing moderate to large renal calculi,

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especially in cases where extracorporeal shock wave lithotripsy (ESWL) or conservative approaches fail [5]. Compared to ESWL, PCNL offers higher stone clearance rates in a single session and is less dependent on stone composition or anatomical variations, making it especially advantageous for pediatric patients with moderate-to-large stones [6]. With technological advancements and the development of miniaturized instruments, PCNL has become safer and more feasible even in pediatric populations [6, 7]. However, despite its increasing use, concerns remain regarding its efficacy, safety profile, and potential complications in younger patients [8]. In the context of Pakistan, particularly in regions like Khyber Pakhtunkhwa, existing data on pediatric PCNL is limited in both scope and scale. Most studies are either small, single-center reports or lack detailed analysis of clinical outcomes and predictive factors [9]. Additionally, there is a scarcity of published data in the national literature addressing pediatric PCNL using miniaturized techniques. Socioeconomic constraints, variation in clinical expertise, and differing access to health care facilities often influence treatment outcomes. Understanding the success rate and associated factors of PCNL in local pediatric populations is therefore essential to inform practice and guide improvements in surgical care. By generating indigenous evidence, this study aims to contribute to the optimization of pediatric stone management strategies in similar low-resource settings.

This study aimed to evaluate the efficacy of PCNL in achieving renal stone clearance among children aged 5 to 15 years treated at a tertiary care center in Peshawar. In doing so, it also explores the influence of demographic and clinical factors such as age, gender, stone size, location, and operative time on stone clearance

METHODS

This was a cross-sectional analytical study conducted to evaluate the efficacy of percutaneous nephrolithotomy (PCNL) in achieving renal stone clearance among pediatric patients. The study was carried out at the Department of Urology, Institute of Kidney Diseases (IKD), Peshawar, a tertiary care referral center in Khyber Pakhtunkhwa, Pakistan. The study was conducted over six months, from Jun 16, 2023, to November 16, 2023. Before the commencement of the study, approval was obtained from the Institutional Ethical Committee of the Institute of Kidney Diseases, under reference number 463. Written informed consent was obtained from the parents or guardians of all participants. A total of 216 pediatric patients were included. The sample size was calculated using the WHO sample size estimation formula, assuming a 90% stone clearance rate, a 95% confidence level, and a 4% margin of error. A non-probability consecutive sampling technique was employed. All eligible patients presenting within the study duration and meeting the inclusion criteria were enrolled consecutively. Although convenient for recruitment, this method may introduce selection bias and may limit generalizability of the findings to broader pediatric populations. Inclusion criteria were children aged between 5 and 15 years diagnosed with a single, uncomplicated renal stone measuring ≤8 mm on KUB X-ray were included. While PCNL is typically reserved for stones larger than 10 mm, this threshold was chosen based on local practice guidelines and to assess the efficacy of PCNL in smaller stones where ESWL was either contraindicated, previously failed, or not available. Exclusion criteria were Patients with anatomical renal abnormalities (e.g., horseshoe or malrotated kidney), staghorn calculi or complex stones, positive urine cultures, bleeding disorders, deranged renal function, or other systemic comorbidities were excluded. Once consent was secured, all eligible children underwent standardized PCNL procedures under general anesthesia. A 15 Fr mini-nephroscope was used, and tract dilation was performed using serial coaxial dilators up to 16 Fr, suitable for pediatric access. The stones were accessed via the posterior calyx, and pneumatic lithotripsy was employed to fragment the stones. Fragments were extracted using a three-prong grasper. A nephrostomy tube was placed in all patients and removed on the second postoperative day. Stone clearance was assessed using a KUB X-ray on the first postoperative day. Follow-up imaging was not routinely performed unless clinically indicated, due to resource constraints and the need to minimize radiation exposure in children. Data were collected using a structured proforma that included demographics (age and gender), stone characteristics (size, site, and location), operative details (operative time in minutes), and clinical presentation (e.g., vomiting, flank pain, or left abdominal pain >4 on VAS). Outcomes assessed included stone clearance on the first postoperative day and length of hospital stay. All patients underwent baseline investigations, including urine culture, renal function tests, and coagulation profiles. Radiological confirmation of stone size and location was performed using a KUB X-ray. To ensure data reliability, stone size and operative time measurements were taken by trained staff using standardized tools. Validity was maintained through consistent surgical protocols, identical equipment, and lithotripsy methods across cases. The pre-tested proforma helped minimize interobserver variation. The data were analyzed using IBM SPSS version 23.0. Descriptive procedures (Frequencies, Descriptive) were used to summarize numerical variables as mean ± standard deviation, and categorical variables as frequencies and percentages. Normality of continuous data was tested using the Shapiro-Wilk test to justify the use of mean and

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SD. For inferential analysis, the Chi-square test (Crosstabs procedure) was used to evaluate associations between stone clearance and variables such as age group, gender, stone size (dichotomized using the sample median of 5 mm), operative time (cutoff at 35 minutes), and stone site. A p-value≤0.05 was considered statistically significant.

RESULTS

The descriptive analysis of continuous variables revealed that the age of participants ranged from 5 to 14 years, with a mean ± SD of 9.50 ± 2.89 years. The average stone size was 4.06 ± 1.69 mm, ranging from 1.1 to 7.0 mm. Operative time varied between 32.1 and 52.0 minutes, and the mean surgical duration was 42.04 ± 5.62 minutes. These values provide a foundational understanding of the clinical characteristics of pediatric patients undergoing PCNL, Table 1.

Table 1: Descriptive Statistics of Continuous Variables (n=216)

Variables	Minimum	Maximum	Mean ± SD
Age (Years)	5	14	9.50 ± 2.89
Stone Size (mm)	1.1	7.0	4.06 ± 1.69
Operative Time (Minutes)	32.1	52.0	42.04 ± 5.62

The age-wise distribution of participants showed that the majority (57.4%) were in the 5–10 years' group, while 42.6% were aged 11–15 years.Male patients were predominant (66.2%) compared to females (33.8%), reflecting a gender trend consistent with pediatric urolithiasis literature, Table 2.

Table 2: Demographic Characteristics of the Study Population (n=216)

Variables	Category	Frequency (%)
Age Group	5–10 Years	124 (57.4%)
	11–15 Years	92 (42.6%)
Gender	Male	143 (66.2%)
	Female	73 (33.8%)

The relationship between age group and stone clearance. Children aged 5–10 years had a clearance rate of 80.6%, while those aged 11–15 years had a slightly lower rate at 75.0%. However, this difference was not statistically significant (χ^2 = 0.989, df=1, p=0.320). Similarly, male had a clearance rate of 79.0%, and female 76.7%, which was also statistically non-significant (χ^2 = 0.151, df=1, p=0.697), Table 3.

Table 3: Association of Stone Clearance with Age Group and Gender (n=216)

Variables	Category	Clearance Achieved, n (%)	Not Achieved, n (%)	Total	χ^2 (df), p-value
Age Group	5–10 Years	100 (80.6%)	24 (19.4%)	124	0.989 (1), 0.320
	11–15 Years	69 (75.0%)	23 (25.0%)	92	
Gender	Male	113 (79.0%)	30 (21.0%)	143	0.151 (1), 0.697
	Female	56 (76.7%)	17 (23.3%)	73	

To justify categorical comparisons, the study used data driven cutoffs based on the median values observed in our cohort for stone size (5 mm) and operative time (35 minutes). These were used to dichotomize the variables for chi-square analysis. Stone clearance was higher in children with stones ≤5 mm (81.7%) compared to those with stones >5 mm (71.6%). This difference approached borderline significance (χ^2 = 2.897, df=1, p=0.089). Operative time also did not significantly affect outcomes. Among those with procedures ≤35 minutes, 77.1% achieved clearance, while the >35-minute group had a clearance rate of 78.5% (χ^2 = 0.030, df=1, p=0.863). The stone site (distal vs proximal) showed nearly identical results, with no statistical difference (χ^2 = 0.000, df=1, p=0.983), Table 4.

Table 4: Association of Stone Clearance with Stone Size, Operative Time, and Stone Site (n=216)

Variables	Category	Clearance Achieved, n (%)	Not Achieved, n (%)	Total	χ^2 (df), p-value
Stone Size	≤5 mm	116 (81.7%)	26 (18.3%)	142	2.897 (1), 0.089
	>5 mm	53 (71.6%)	21 (28.4%)	74	
Operative Time	≤35 min	27 (77.1%)	8 (22.9%)	35	0.030 (1), 0.863
	>35 min	142 (78.5%)	39 (21.5%)	181	
Stone Site	Distal	83 (78.3%)	23 (21.7%)	106	0.000 (1), 0.983
	Proximal	86 (78.2%)	24 (21.8%)	110	

To further quantify the strength of association between potential predictors and stone clearance, I performed a binary logistic regression analysis. Although none of the variables were statistically significant, stone size showed a trend toward significance (p=0.088), suggesting a potential influence on clearance outcomes. The results, expressed as odds ratios with 95% confidence intervals.To complement the chi-square analysis, a binary logistic regression was performed to estimate the effect sizes of key predictors on stone clearance. The regression model included age group, gender, stone size, operative time, and stone site. While none of the predictors reached statistical significance at the 0.05 level, stone size demonstrated a borderline association with the outcome (OR=1.79, 95% CI: 0.92–3.49, p=0.088), suggesting that larger stones may be associated with lower clearance rates. Age group (OR=1.43, 95% CI: 0.74–2.76, p=0.292) and gender (OR=1.15, 95% CI: 0.58–2.30, p=0.686) showed weak associations with the outcome, and their wide confidence intervals included the null value, indicating a lack of strong predictive power. Similarly, operative time and stone site did not show meaningful associations, with ORs close to 1 and p-values of 0.648 and 0.910, respectively. The overall model did not significantly improve prediction over chance (χ^2 = 4.156, df=5, p=0.527), and the Hosmer-Lemeshow test (p=0.219) indicated a good model fit. These findings reinforce that none of the clinical factors evaluated, including age, gender, stone size, operative duration, or location, were

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statistically significant predictors of stone clearance in this cohort, although stone size may warrant further investigation in larger, powered studies, Table 5.

Table 5: Binary Logistic Regression for Predictors of Stone Clearance (n=216)

Predictors	Odds Ratio (OR)	95% CI	p-value
Age Group (11–15 vs. 5–10)	1.43	0.74 – 2.76	0.292
Gender (Female vs. Male)	1.15	0.58 – 2.30	0.686
Stone Size (per mm ↑)	1.79	0.92 – 3.49	0.088
Operative Time (per min ↑)	0.81	0.34 – 1.98	0.648
Stone Site (Distal vs. Proximal)	0.96	0.50 – 1.86	0.910

The stone clearance rates were slightly higher in children with smaller stones (≤5 mm), shorter procedures (≤35 minutes), and distal stone locations. However, these differences did not reach statistical significance. The consistency in clearance rates across subgroups indicates that none of these clinical predictors had a major impact on outcome in this cohort (Figure 1).

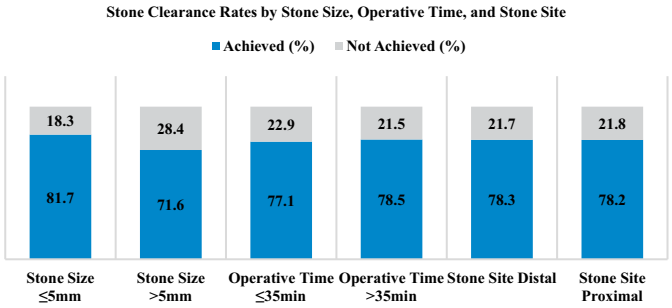

Figure 1: Stone Clearance Rates by Stone Size, Operative Time, and Stone Site

DISCUSSION

In this study involving 216 pediatric patients who underwent PCNL, a stone clearance rate of 78.2% was achieved. While this figure is moderately successful, it falls short of the >90% clearance rates reported in several regional and international studies. For example, Rehman *et al.* reported a 93.3% clearance rate in Iraqi children undergoing mini-PCNL, and Ahmad *et al.* observed similar outcomes in infants treated with miniaturized approaches [10, 11]. The relatively lower clearance rate in the present study may be attributed to several contextual factors. Firstly, only the first postoperative day imaging was used for outcome assessment, without follow-up imaging to confirm residual fragments, potentially underestimating true clearance. Secondly, the inclusion of small stones (≤8 mm) rather than larger stones, which are typically more suitable for PCNL, may have influenced procedural effectiveness.Moreover, resource limitations, varied surgical experience, and institutional protocols may also have played a role in the observed discrepancy. Despite the modest clearance rate, PCNL remains effective for selected pediatric populations. Mahmood *et al.* demonstrated a significantly higher clearance rate with PCNL (92.9%) compared to ESWL (53.6%) in infants, supporting the reliability of PCNL even for younger age groups [12]. Other multicenter studies have consistently reported clearance rates ranging from 86% to 91.1%, reinforcing the value of PCNL as a minimally invasive standard of care [13]. This study also found no significant associations between stone clearance and variables such as age, gender, stone size, operative time, or anatomical location. These findings are consistent with a randomized controlled trial conducted, which reported that sheath size and procedural duration did not significantly impact stone-free outcomes in children [14]. However, the lack of statistical significance in our analysis may partly reflect limited statistical power for detecting small effect sizes. The logistic regression analysis indicated a borderline association between stone size and clearance (p=0.088), suggesting that with a larger sample, this factor might reach significance. This limitation has been acknowledged and highlights the need for more extensive, adequately powered studies to explore these relationships further. The role of predictive tools in pediatric stone management is becoming increasingly recognized. Akdogan *et al.* and Fernandez *et al.* demonstrated that scoring systems like CROES and Guy's Stone Score can be helpful in pediatric populations, even though they were originally developed for adults [15, 16]. Recent consensus frameworks, such as the Pediatric PCNL Reporting Checklist, advocate for consistent definitions and outcome measures, which could improve comparability across future studies [17]. Furthermore, broader research supports the superiority of PCNL over ESWL in terms of stone clearance and patient-reported outcomes such as pain, anxiety, and hospital stay duration [18, 19]. This adds weight to the argument for using PCNL as a preferred treatment, especially in settings where follow-up compliance and access to alternative technologies may be limited [20]. In summary, although the clearance rate observed in this study was slightly lower than in previous reports, the procedure remains safe and effective. The consistency of outcomes across age groups, genders, and stone characteristics suggests that PCNL continues to hold value in pediatric urolithiasis management, particularly in low-resource settings.

CONCLUSIONS

Percutaneous nephrolithotomy is a safe and effective treatment option for pediatric renal stones, achieving a stone clearance rate of 78.2% in this cohort. While the clearance rate was modest compared to some international benchmarks, the procedure showed consistent outcomes regardless of age, gender, stone size, operative duration, or anatomical site. These findings align with the study's objective to assess the efficacy of PCNL in

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a local pediatric population. The results also underscore the importance of context-specific evaluations, especially in regions with limited access to alternative modalities like ESWL. The study reinforces the utility of PCNL, particularly miniaturized approaches, as a first-line option for renal stones up to 8 mm in pediatric patients.

Authors Contribution

Conceptualization: WK
Methodology: TSK, RAK, MK, AA
Formal analysis: WK, RAK, MK, AA
Writing review and editing: WK, TSK, AIK

All authors have read and agreed to the published version of the manuscript

Conflicts of Interest

All the authors declare no conflict of interest.

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