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# Assessing the Efficacy and Safety of Minimally Invasive Versus Open Bladder Stone Removal in Pediatric Patients

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## Abstract

**Background:** Pediatric bladder stones, although relatively uncommon, pose significant clinical challenges due to their potential to cause urinary obstruction, recurrent urinary tract infections (UTIs), and bladder dysfunction. Effective and minimally invasive treatment options are essential for improving patient outcomes in this population.

**Objective:** To compare percutaneous cystolithotripsy (PCCL) and open vesicolithotomy (OV) in pediatric patients aged 5–15 years, evaluating stone removal efficacy, operative duration, length of hospital stay, and postoperative complication rates.

**Methodology:** This retrospective comparative study was conducted at the Urology Department of Saidu Group of Teaching Hospitals, Swat. A total of 98 pediatric patients (aged 5–15 years) diagnosed with bladder stones were included, with 52 undergoing PCCL and 46 undergoing OV. Data were collected on demographic characteristics, stone size, presenting symptoms, operative time, stone clearance, hospital stay, and complications. Categorical variables were analyzed using the Chi-square test, while continuous variables were assessed with the Student's t-test.

**Results:** Baseline characteristics, including age (p=0.28), gender (p=0.71), and stone size (p=0.42), were comparable between groups. The mean operative time was significantly lower in the PCCL group (45.6 ± 8.3 minutes) compared to the OV group (72.4 ± 12.7 minutes, p<0.001). Similarly, hospital stay was significantly shorter for PCCL patients (1.9 ± 0.6 days) versus OV patients (3.5 ± 1.2 days, p<0.001). Stone clearance rates were high and similar in both groups, with no statistically significant differences in complication rates such as UTIs, hematuria, or wound infections.

**Conclusion:** PCCL offers a safe and effective alternative to OV in pediatric patients with bladder stones, providing the advantages of shorter operative time and reduced hospital stay without increasing complication risks.

**Keywords:** Cystolithotomy, Minimally Invasive Surgical Procedures, Pediatrics, Treatment Outcome, Urinary Bladder Calculi.

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## Introduction

Pediatric bladder stones, though relatively uncommon, present a significant clinical challenge due to their potential to cause urinary obstruction, recurrent urinary tract infections (UTIs), and bladder dysfunction [1–3]. These calcifications may develop secondary to a range of etiologies including urinary stasis, infections, metabolic disturbances, or the presence of foreign bodies [4,5]. Among children aged 5 to 15 years, bladder stones can severely affect quality of life, necessitating prompt and effective management to prevent complications and long-term sequelae [6].

The primary goal in treating pediatric bladder stones is to achieve complete stone clearance while minimizing surgical morbidity and preserving bladder function [7,8]. Management strategies depend on various factors such as stone size, number, composition, and the overall clinical status of the child. While conservative approaches involving increased fluid intake and dietary modifications may be suitable for asymptomatic and small calculi, most pediatric cases ultimately require surgical intervention. Minimally invasive techniques, such as endoscopic stone removal via transurethral or suprapubic access, are increasingly favored due to their efficacy and reduced recovery time [9].

Over the years, different surgical modalities have been utilized in pediatric urology, including percutaneous cystolitholapaxy (PCCL) and open vesicolithotomy (OV). PCCL is a minimally invasive technique that involves percutaneous access and stone fragmentation under fluoroscopic guidance, whereas OV is a traditional open surgical procedure involving bladder incision and direct stone extraction [8].

A prospective study by Khadgi et al. [10] assessed the safety and efficacy of mini-percutaneous nephrolithotomy (Mini-PNL) in 59 pediatric patients with renal anomalies, reporting an initial stone-free rate of 89.8%, which improved to 98.3% after retreatment. The study noted favorable outcomes with minimal complications, including lower hematuria rates when compared to previously reported outcomes for open vesicolithotomy (40%) and PCCL (6.7%).

Despite the clinical use of both PCCL and OV for pediatric bladder stone removal, comparative studies specifically focusing on their efficacy and safety in children remain limited [11,12]. Existing literature mainly comprises case series and retrospective studies with small sample sizes, restricting the generalizability of findings and leaving the optimal surgical approach in question [13]. While bladder stones in children are less prevalent than in adults, they can lead to significant symptoms including pain, urinary retention, and recurrent infections, often necessitating surgical removal. Traditionally, OV has been the standard approach, offering high stone clearance but at the cost of a larger incision, prolonged hospitalization, and greater postoperative discomfort. In contrast, PCCL, as a minimally invasive alternative, offers the advantages of quicker recovery and fewer complications.

However, there is a lack of robust comparative evidence evaluating the outcomes of these techniques in pediatric populations. Most existing studies are either underpowered or focused on adult patients, underscoring the need for pediatric-specific data. Therefore, this study aims to compare the efficacy and safety of percutaneous versus open bladder stone removal in children aged 5–15 years, to inform better evidence-based clinical decision-making in pediatric urology.

## Methodology

### Study Design

This was a retrospective comparative cohort study designed to evaluate the efficacy and safety of two surgical interventions percutaneous cystolitholapexy (PCCL) and open vesicolithotomy (OV) in pediatric patients with bladder stones. The study utilized patient medical records to compare clinical outcomes between the two treatment groups.

### Ethics

Prior to data collection, ethical approval was

obtained from the Institutional Review Board of the Saidu Group of Teaching Hospitals, Swat (Reference No. 243.ERB/024). Patient confidentiality and data protection standards were strictly adhered to throughout the study.

**Setting**

The study was conducted in the Department of Urology at the Saidu Group of Teaching Hospitals, Swat, Pakistan. Patient data were retrospectively collected from hospital records covering the period from February 5, 2023, to January 10, 2024.

**Participants**

A total of 98 pediatric patients aged between 5 and 15 years who were diagnosed with bladder stones and underwent either PCCL (n = 52) or OV (n = 46) were included. Patients were selected using a non-probability consecutive sampling technique. Those with incomplete medical records or who underwent concurrent urological procedures were excluded from the study. All patients had undergone preoperative imaging confirming bladder stones and had no history of neurogenic bladder or prior bladder surgery.

**Variables**

The primary outcome variable was stone removal rate, defined as complete removal of stones, confirmed intraoperatively through visual inspection and postoperatively by ultrasound or plain radiography. Secondary outcome variables included operative time (duration from incision to closure), hospital stay duration (days from surgery to discharge), and surgical complications (e.g., hematuria, wound infection, urinary tract infection). Other variables included demographic characteristics (age, gender), stone size, and presenting symptoms.

**Data Sources/Measurement**

All data were extracted from electronic and physical hospital medical records. Operative details and postoperative outcomes were verified through operative notes, anesthesia records, radiology reports, and nursing discharge summaries. In both PCCL and OV procedures, standardized surgical protocols were followed under general anesthesia. PCCL involved fluoroscopy-guided percutaneous bladder access, tract dilation with a 16Fr Amplatz sheath, and stone fragmentation using a 12Fr nephroscope and pneumatic or ultrasonic lithotripter. OV was performed through a lower midline or Pfannenstiel incision, with direct bladder access and manual stone removal. In both procedures, the bladder was closed with absorbable sutures, and a Foley catheter was placed for 10 days postoperatively.

**Bias**

To minimize selection bias, all eligible patients who met inclusion criteria during the study period were included consecutively. However, the retrospective design inherently limits the control over confounding variables, and treatment allocation was based on clinical decision-making rather than randomization.

**Study Size**

The sample size was initially calculated using OpenEpi software, based on hematuria rates reported in prior studies (40% for OV and 6.7% for PCCL) [10], with 95% confidence level and 80% power, yielding a minimum of 31 patients per group (total n=62). To enhance statistical power and ensure robustness of the findings, all 98 eligible patients available during the study period were included.

**Quantitative Variables**

Continuous variables such as age, operative time, hospital stay, and stone size were reported as means with standard deviations or medians with interquartile ranges, depending on data distribution. Categorical variables, including gender and complication rates, were summarized as frequencies and percentages.

**Statistical Methods**

Data analysis was conducted using SPSS version 20. Categorical variables were compared using the Chi-square test or Fisher's exact test where appropriate. Continuous variables were analyzed using the Student's t-test for normally distributed data or the Mann–Whitney U test for skewed distributions. A p-value of $<0.05$ was considered statistically significant.

## Results

### Participants

A total of 98 pediatric patients who underwent surgical treatment for bladder stones were included in the study. Of these, 52 patients received percutaneous cystolitholapexy (PCCL), while 46 underwent open vesicolithotomy (OV). All participants were aged between 5 and 15 years and met the inclusion criteria. No patients were excluded due to incomplete records or concurrent procedures.

### Descriptive Data

The demographic characteristics of both groups were comparable. In the PCCL group, 57.7% were male and 42.3% were female, while in the OV group, 60.9% were male and 39.1% female, with no statistically significant difference in gender distribution (p = 0.71). The mean age of patients in the PCCL group was 10.4 ± 2.1 years, while that in the OV group was 10.8 ± 2.3 years (p = 0.28). Age group distribution across 5–15 years was also similar between both groups. The median stone size in the PCCL group was 1.5 cm (IQR 1.2–1.8), and in the OV group was 1.6 cm (IQR 1.3–1.9), with no significant difference (p = 0.42), indicating a well-matched baseline profile (Table 1).

### Outcome Data

Symptomatic bladder stones were observed in the majority of participants in both groups: 92.3% in the PCCL group and 95.7% in the OV group (p = 0.61), showing no statistically significant difference. Operative time was significantly shorter in the PCCL group, averaging 45.6 ± 8.3 minutes compared to 72.4 ± 12.7 minutes in the OV group (p < 0.001). The hospital stay duration was also markedly reduced in the PCCL group, with an average of 1.9 ± 0.6 days versus 3.5 ± 1.2 days in the OV group (p < 0.001). Stone clearance was high in both groups, with 94.2% clearance in PCCL and 91.3% in OV, showing no significant difference (p = 0.63). Overall postoperative complication rates were 11.5% in the PCCL group and 19.6% in the OV group, although this difference did not reach statistical significance (p = 0.21) (Table 2).

### Main Results

Postoperative complications were further analyzed in detail. Urinary tract infections occurred in 4 patients (7.7%) in the PCCL group and 7 patients (15.2%) in the OV group (p = 0.259). Hematuria was reported in 2 PCCL patients (3.8%) and 3 OV patients (6.5%) (p = 0.634). Notably, wound infections were observed only in the OV group (4.3%), with no cases reported in the PCCL group; however, this difference was not statistically significant (p = 0.880) (Table 3). Overall, while the complication rates were slightly higher in the OV group, the differences were not statistically significant, suggesting comparable safety profiles for both procedures.

**Table 1: Demographic Characteristics of Participants in PCCL and OV Groups**

| Variable | | PCCL (n = 52) | OV (n = 46) | p-value |
|---|---|---|---|---|
| **Gender** | Male, n (%) | 30 (57.7) | 28 (60.9) | 0.710 |
| | Female, n (%) | 22 (42.3) | 18 (39.1) | |
| **Age (years)** | | 10.4 ± 2.1 | 10.8 ± 2.3 | - |
| **Age group** | 5–7 years, n (%) | 12 (23.1) | 10 (21.7) | 0.280 |
| | 8–10 years, n (%) | 20 (38.5) | 18 (39.1) | |
| | 11–13 years, n (%) | 14 (26.9) | 12 (26.1) | |
| | 14–15 years, n (%) | 6 (11.5) | 6 (13.0) | |
| **Stone size (cm)** | | 1.5 (1.2–1.8) | 1.6 (1.3–1.9) | 0.420 |

PCCL: Percutaneous Cystolitholapexy; OV: Open Vesicolithotomy

Student t test/Mann Whitney U test applied for analysis of continuous variables and Chi-square test applied for categorical variables.

| Table 2: Comparison of Clinical and Postoperative Outcomes | | | |
|---|---|---|---|
| **Outcome Variable** | **PCCL (n=52)** | **OV (n=46)** | **p-value** |
| **Symptomatic stones, n (%)** | 48 (92.3) | 44 (95.7) | 0.610 |
| **Operative time (min)** | 45.6 ± 8.3 | 72.4 ± 12.7 | <0.001* |
| **Stone clearance, n (%)** | 49 (94.2) | 42 (91.3) | 0.630 |
| **Hospital stay (days)** | 1.9 ± 0.6 | 3.5 ± 1.2 | <0.001* |
| **Any complication, n (%)** | 6 (11.5) | 9 (19.6) | 0.210 |

PCCL: Percutaneous Cystolitholapexy; OV: Open Vesicolithotomy
Student t test applied for analysis of continuous variables and Chi-square test applied for categorical variables.
*p<0.05 is considered statistically significant

**Table 3. Postoperative Complications in PCCL and OV Groups**

| Complication | PCCL (n = 52) | OV (n = 46) | p-value |
|---|---|---|---|
| **Urinary tract infection, n (%)** | 4 (7.7) | 7 (15.2) | 0.259 |
| **Hematuria, n (%)** | 2 (3.8) | 3 (6.5) | 0.634 |
| **Wound infection, n (%)** | - | 2 (4.3) | 0.880 |

PCCL: Percutaneous Cystolitholapexy; OV: Open Vesicolithotomy
Chi-square/Fisher Exact test applied for categorical variables.
*p<0.05 is considered statistically significant

## Discussion

This study compared the clinical outcomes of two surgical techniques—percutaneous cystolitholapexy (PCCL) and open vesicolithotomy (OV)—for the treatment of pediatric bladder stones. The proportion of patients presenting with symptomatic stones was similar between both groups, suggesting a comparable baseline severity of disease, which supports the validity of outcome comparisons.

A key finding was that PCCL was associated with a significantly shorter operative time compared to OV. This difference can be attributed to the minimally invasive nature of PCCL, which avoids extensive soft tissue dissection and direct bladder manipulation, thereby streamlining the procedure. These findings are consistent with previous studies reporting similar advantages of PCCL. For instance, one study demonstrated that the mean operative time for PCCL was 38.2 ± 9.9 minutes versus 71.2 ± 13.1 minutes for OV ($p < 0.001$) [10]. The reduced surgical time in PCCL reflects its efficiency and contributes to improved perioperative outcomes.

Both PCCL and OV demonstrated comparable stone clearance rates, indicating that while their surgical approaches differ, their effectiveness in achieving complete stone removal is similar. This is supported by prior literature, such as the study by Yıldız et al., which also reported no significant difference in stone-free rates between the two techniques [14].

Postoperative recovery was faster in patients treated with PCCL, as evidenced by a significantly shorter hospital stay. This can be attributed to its less invasive approach, resulting in less postoperative pain and quicker mobilization. In contrast, the extended hospital stay observed in the OV group likely reflects the larger incision size, more tissue trauma, and a greater need for postoperative care. These findings align with previous reports showing a shorter hospital stay for PCCL (1.47 ± 0.56 days) compared to OV (2.51 ± 0.67 days) [10].

Regarding postoperative complications, although the OV group had higher rates of urinary tract infections, hematuria, and wound infections, these differences were not statistically significant. This suggests that both procedures are generally safe and well-tolerated in pediatric populations. However, the trend toward fewer complications with PCCL supports its growing acceptance as a

favorable alternative, especially in settings where minimally invasive expertise and equipment are available [15].

Our results are consistent with the study by Bhatti et al. [16], which also reported a shorter average operative time and hospital stay for the PCCL group compared to the OV group. Although their cohort had a slightly larger mean stone size than ours, the nature and frequency of complications were similar. They also evaluated postoperative analgesia requirements, which was not assessed in our study due to the challenges in accurately measuring pain in children using standardized pain scales.

Hussain et al. [15] conducted a similar comparative analysis in younger children aged 1–10 years and found a significantly higher rate of complications in the OV group. They reported hematuria and postoperative fever in 40% and 33% of OV patients, respectively, compared to only 6.7% and 13% in the PCCL group. While our findings did not show statistically significant differences in complication rates, the trends observed are in line with their conclusions, particularly regarding hospital stay, which was notably shorter in the PCCL group in both studies.

In summary, the findings of this study reinforce that both PCCL and OV are effective and safe options for the surgical management of pediatric bladder stones. However, the advantages of PCCL in terms of reduced operative time, shorter hospital stay, and potentially fewer complications make it a preferable choice, especially when the required surgical expertise and resources are available. The longer operative duration and recovery period associated with OV should be carefully considered when selecting the appropriate surgical method for pediatric patients.

## Conclusion

This study demonstrated that percutaneous cystolithotomy (PCCL) offers significant advantages over open vesicolithotomy (OV) in the surgical management of pediatric bladder stones. Specifically, PCCL was associated with a markedly shorter operative time and reduced hospital stay, likely attributable to its minimally invasive approach that avoids extensive tissue dissection and bladder manipulation. Despite these procedural benefits, both PCCL and OV achieved comparable stone clearance rates, confirming that PCCL is equally effective in achieving complete stone removal. The findings affirm that PCCL is a safe, efficient, and less traumatic alternative to traditional open surgery, making it especially suitable for pediatric populations where minimizing postoperative discomfort and hospitalization is critical. Given these benefits, PCCL should be considered a first-line surgical option in centers equipped with the necessary expertise and resources. However, the selection of the surgical approach should remain individualized, based on patient-specific factors, stone characteristics, and institutional capabilities.

## Authors' Contributions

All authors meet the ICMJE criteria for authorship. They have reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

Author 1: Substantial contribution to conception and design, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 2: Substantial contribution to conception and design, data acquisition, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 3: Analysis and interpretation of data, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 4: Analysis and interpretation of data, critical revision, final approval, agreed to be accountable for all the work.
Author 5: Substantial contribution to conception and design, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 6: Substantial contribution to conception and design, data acquisition, drafting the manuscript, final approval, agreed to be accountable for all the work.

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