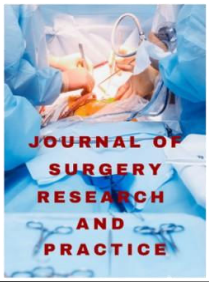

e-ISSN: 3068-3742
Journal of Surgery Research and Practice

ATHENAEUM SCIENTIFIC PUBLISHERS

Research Article

Prospective Evaluation of Outcomes and Complications in Ultra-Mini-Percutaneous Nephrolithotomy for Pediatric Nephrolithiasis: A Three-Year Study

Onur Dede[1*], Mazhar Utanğaç[1]

[1]Associate Professor, Dicle University Department of Urology, Turkey

***Correspondence author:** Onur Dede, Associate Professor, Dicle University Department of Urology, Turkey; Email: dronurdede@hotmail.com

Citation: Dede O, et al. Prospective Evaluation of Outcomes and Complications in Ultra-Mini-Percutaneous Nephrolithotomy for Pediatric Nephrolithiasis: A Three-Year Study. J Surg Res Prac. 2024;5(3):1-6.

https://doi.org/10.46889/JSRP.2024.5304

Received Date: 10-10-2024

Accepted Date: 28-10-2024

Published Date: 05-11-2024

Abstract

Objective: This prospective study aimed to evaluate the outcomes and complications of Ultra-Mini Percutaneous Nephrolithotomy (UM-PCNL) in pediatric patients with renal calculi over a three-year period (2021-2023). We assessed Stone-Free Rates (SFR), operative success and perioperative complications to determine the efficacy and safety of UM-PCNL in children.

Methods: Seventy-eight pediatric patients (aged 1-17 years) underwent UM-PCNL for renal calculi larger than 10 mm. Preoperative imaging, including ultrasonography and computed tomography, was utilized to assess stone size and location. Surgical outcomes, including SFR, operative time and the need for second-look procedures, were evaluated. Complications were graded using the Clavien-Dindo classification. Statistical analysis was conducted using SPSS, with a significance threshold of $p < 0.05$.

Results: The mean stone size was 18.2 ± 5.4 mm and the overall SFR after a single UM-PCNL procedure was 78.2%. Clinical success (defined as either stone-free status or clinically insignificant residual fragments) was achieved in 89.7% of patients. The mean operative time was 67 ± 22 minutes. Second-look procedures were required in 11.5% of cases. The overall complication rate was 19.2%, with no major complications (Clavien grade III-V). Minor complications included transient fever (6.4%), hematuria (12.8%) and urinary leakage (5.1%).

Conclusion: UM-PCNL is a safe and effective procedure for managing pediatric nephrolithiasis, offering high stone-free rates and low complication risks. The use of smaller instruments reduces renal trauma, bleeding and the need for blood transfusions. These findings support UM-PCNL as a first-line treatment option for larger renal stones in pediatric patients. Further studies with long-term follow-up are recommended to assess recurrence and long-term renal function outcomes.

Keywords: Pediatric Nephrolithiasis; Ultra-Mini Percutaneous Nephrolithotomy; UM-PCNL; Stone-Free Rate; Complications; Minimally Invasive Surgery

Introduction

Nephrolithiasis in pediatric populations is an increasingly recognized health concern, with a reported rise in incidence rates over the last decade due to changing dietary patterns, sedentary lifestyles and the global obesity epidemic [1]). While once considered primarily an adult disease, recent data suggest that pediatric nephrolithiasis now accounts for up to 10% of all renal stone cases [2]. Renal stones in children are associated with metabolic abnormalities, Urinary Tract Infections (UTIs) and anatomical malformations. The treatment strategies for nephrolithiasis in children depend on stone size, location and symptom severity. Conservative approaches may be appropriate for smaller stones, but larger or symptomatic stones often necessitate surgical intervention [3,4].

The advent of minimally invasive techniques such as Percutaneous Nephrolithotomy (PCNL) has revolutionized the management of nephrolithiasis, offering high stone clearance rates with reduced morbidity compared to open surgery [5]. However, traditional PCNL involves the use of larger instruments, which increases the risk of complications, particularly in pediatric patients with smaller renal anatomy. Ultra-Mini Percutaneous Nephrolithotomy (UM-PCNL) has emerged as an alternative, utilizing smaller sheaths (11-14 Fr) and instruments, thus minimizing renal trauma and postoperative complications while maintaining high efficacy for stone clearance [6,7].

This study presents a retrospective analysis of the outcomes and complications of UM-PCNL performed on 78 pediatric patients over a three-year period (2021-2023) at a single institution. We aim to evaluate the demographic characteristics, operative success rates and perioperative complications, comparing the results with existing literature to further elucidate the safety and efficacy of UM-PCNL in the pediatric population.

Material and Methods

Study Design and Patient Selection

This study was designed as a prospective analysis to evaluate the outcomes and complications of Ultra-Mini Percutaneous Nephrolithotomy (UM-PCNL) in pediatric patients with nephrolithiasis. Ethical approval for this research was obtained from the institutional review board of Dicle University, in accordance with the Declaration of Helsinki. All participants or their legal guardians, provided written informed consent prior to enrollment. The study adhered to ethical standards regarding patient confidentiality, data handling and safety monitoring throughout the course of the investigation.

This prospective study included 78 pediatric patients aged between 1 and 17 years who underwent UM-PCNL at our institution between January 2021 and December 2023. Ethical approval for this study was obtained from the institutional review board and written informed consent was acquired from the parents or guardians of all participants. The patients included had symptomatic renal calculi larger than 10 mm or smaller but refractory stones that had not responded to conservative treatments. All patients underwent preoperative imaging with renal Ultrasonography (US) and non-contrast Computed Tomography (CT) to assess stone size, location and renal anatomy [8].

Exclusion criteria included anatomical anomalies such as horseshoe kidney or severe coagulopathies that could increase the surgical risk. Patients with recurrent Urinary Tract Infections (UTIs) or those who had undergone previous interventions for nephrolithiasis were not excluded, as this reflects a common clinical scenario [9].

Preoperative Assessment

Before surgery, all patients underwent a thorough clinical evaluation, including laboratory tests such as serum electrolytes, Blood Urea Nitrogen (BUN), creatinine levels and urine cultures. Antibiotic prophylaxis was administered intravenously, with specific agents chosen based on urine culture sensitivity. If the urine was sterile or appropriately treated for any positive cultures, surgery proceeded. For patients with metabolic disorders (e.g., hypercalciuria, hypocitraturia), a nephrology consultation was performed to manage underlying metabolic derangements [10,11].

Surgical Technique

All UM-PCNL procedures were performed under general anesthesia with the patients positioned prone. A ureteral catheter (5 Fr) was inserted cystoscopically for retrograde instillation of contrast. Percutaneous renal access was achieved under fluoroscopic guidance using an 18-gauge needle. Access was primarily gained into the lower pole calyx, which is considered optimal for maximal stone clearance and minimal renal parenchymal damage [12].

The access tract was sequentially dilated to accommodate an 11-14 Fr ultra-mini nephroscope (Karl Storz, Germany). Stone fragmentation was achieved using a holmium laser set at 0.6 to 1.0 Joules and frequencies of 6-10 Hz. For larger stones, pneumatic lithotripsy was used. Stone fragments were retrieved using basket forceps or via suction. In cases where the stone burden was high or if there was significant bleeding, a nephrostomy tube (10-12 Fr) was left in place; otherwise, a tubeless procedure was performed and a double-J ureteral stent was placed when deemed necessary [13,14].

Postoperative Management

Postoperatively, patients were observed in a recovery unit where vital signs and urine output were closely monitored. Hemoglobin and hematocrit levels were rechecked within 12-24 hours. Imaging (US or CT) was performed on postoperative day 1 to evaluate for residual stones, urinary leakage or other complications [15]. Nephrostomy tubes, if placed, were removed within 24-48 hours based on the patient's clinical status and the absence of residual stones. Follow-up evaluations were conducted at 1 week, 1 month and 6 months postoperatively. Stone-free status was defined as no visible stones on imaging or Clinically Insignificant Residual Fragments (CIRF) smaller than 4 mm [16].

Complication Grading

Perioperative complications were categorized using the Clavien-Dindo classification. Complications were documented and classified from grade I (minor complications managed without intervention) to grade V (death) [17]. This system allows for a standardized comparison of complication rates with existing literature.

Statistical Analysis

Data were collected and analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY). Continuous variables were reported as mean ± Standard Deviation (SD), while categorical data were expressed as frequencies and percentages. Stone-Free Rates (SFR) were compared across different age groups, stone sizes and locations using chi-square tests. A p-value < 0.05 was considered statistically significant.

Results

Patient Demographics

A total of 78 pediatric patients (44 males, 34 females) underwent UM-PCNL during the study period. The mean patient age was 8.6 ± 3.9 years (range: 1-17 years). The mean stone size was 18.2 ± 5.4 mm. Most stones were located in the renal pelvis (65.4%), followed by the lower pole calyx (24.4%) and upper pole calyx (10.2%). Table 1 summarizes the demographic and clinical characteristics of the patient population.

Patient Demographics	Value
Mean age (years)	8.6 ± 3.9
Gender (Male/Female)	56% / 44%
Mean stone size (mm)	18.2 ± 5.4
Stone location	Renal pelvis (65.4%), lower calyx (24.4%), upper calyx (10.2%)

Table 1: Summarizes the demographic and clinical characteristics of the patient population.

Surgical Outcomes

The mean operative time was 67 ± 22 minutes. The overall Stone-Free Rate (SFR) after a single procedure was 78.2%. A second-look procedure was required in 9 patients (11.5%) due to the presence of residual fragments larger than 4 mm. Clinical success, defined as stone-free status or the presence of CIRF, was achieved in 89.7% of patients. Operative details and outcomes are outlined in Table 2.

Surgical Outcomes	Value
Mean operative time (minutes)	67 ± 22
Stone-Free Rate (SFR)	78.20%
Clinical success rate	89.70%
Second-look procedures	11.50%

Table 2: Operative details and outcomes.

Complications

Complications were classified according to the Clavien-Dindo grading system. The overall complication rate was 19.2%, with no Clavien grade IV or V complications observed. Grade I complications included mild hematuria in 12.8% of patients and transient fever in 6.4%, both managed conservatively. Urinary leakage occurred in 5.1% of patients (Clavien grade II), managed with

prolonged nephrostomy drainage. One patient (1.3%) required a blood transfusion due to significant intraoperative bleeding (Clavien grade II). No patients experienced long-term renal impairment or required nephrectomy. The complication rates are summarized in Table 3.

	Clavien Grade	Incidence
Complications		
Hematuria	I	12.80%
Fever	I	6.40%
Urinary leakage	II	5.10%
Blood transfusion	II	1.30%
Major complications (III-IV)	-	0%

Table 3: Complication rates.

Discussion

This study evaluated the outcomes of 78 pediatric patients who underwent Ultra-Mini Percutaneous Nephrolithotomy (UM-PCNL) for the management of renal stones between 2021 and 2023. The findings support UM-PCNL as an effective and safe procedure in pediatric patients, with a high clinical success rate (89.7%) and a low overall complication rate (19.2%). These results are in line with the broader literature on pediatric PCNL and UM-PCNL, which consistently demonstrate the utility of miniaturized instruments in reducing perioperative morbidity without compromising stone clearance efficacy.

The overall Stone-Free Rate (SFR) in this study after a single UM-PCNL procedure was 78.2%, with 89.7% of patients achieving clinical success (either stone-free or with clinically insignificant residual fragments, CIRF). This success rate is comparable to that reported in previous studies evaluating pediatric UM-PCNL, where SFRs typically range from 72% to 92% [21,22]. The slightly lower SFR in our cohort could be attributed to a higher incidence of lower pole stones (24.4%), as lower calyceal anatomy often presents challenges for complete stone clearance due to dependent position and difficulty in accessing the lower calyx during PCN [23].

In a similar study of 103 pediatric patients, Ozden, et al., reported an SFR of 81.5% after initial PCNL, with secondary procedures required in 15% of cases [24]. Our second-look procedure rate (11.5%) is consistent with these findings, further supporting that secondary procedures are occasionally necessary to achieve optimal outcomes, particularly for larger or lower pole stones. Miniaturized instruments in UM-PCNL, including smaller sheaths and nephroscopes, contribute to reduced invasiveness, but may also limit visibility and access to certain stone locations, which could explain the need for secondary interventions [25].

When compared to standard PCNL, the miniaturized approach of UM-PCNL has shown distinct advantages, particularly in pediatric populations. Standard PCNL involves larger sheaths (typically 22-30 Fr) and instrumentation, which can cause greater renal parenchymal damage and higher rates of complications, such as significant bleeding and the need for blood transfusions [26]. In contrast, UM-PCNL, utilizing sheaths as small as 11-14 Fr, minimizes renal trauma and reduces postoperative pain, hematuria and hospital stay durations.

In our study, the overall complication rate was 19.2%, with no major complications (Clavien grade III-V). This is consistent with other pediatric UM-PCNL studies, where overall complication rates typically range between 10% and 25% [27,28]. The rate of minor complications, such as transient fever (6.4%) and mild hematuria (12.8%), was low and comparable to published data from studies utilizing similar UM-PCNL techniques. For example, Desai, et al., reported a complication rate of 18% in pediatric UM-PCNL cases, with no grade IV-V complications [29]. This suggests that UM-PCNL may offer a safer profile compared to standard PCNL, especially in younger patients with smaller renal units.

Blood transfusion rates are an important marker of the invasiveness and safety of any surgical intervention. In standard pediatric PCNL, transfusion rates range from 3% to 5%, largely due to the larger access sheaths used [30]. In our series, only one patient (1.3%) required a blood transfusion, demonstrating the hemostatic advantage of smaller instruments in UM-PCNL. Similar low transfusion rates (1-2%) have been reported in other pediatric UM-PCNL studies, further supporting its safety profile [31].

The complications observed in this study were predominantly minor (Clavien grade I-II), with no grade III-V complications. This aligns well with the findings of Zeng, et al., who reported a complication rate of 20% in a pediatric UM-PCNL cohort, the majority being grade I-II complications such as hematuria and fever, both manageable with conservative treatment [32]. Moreover, the absence of severe complications such as urosepsis, renal loss or death (Clavien grade IV-V) in our study suggests that, when performed by experienced surgeons, UM-PCNL is a safe procedure in pediatric patients [33].

Urinary leakage, occurring in 5.1% of our patients, was managed conservatively with prolonged nephrostomy drainage. Similar rates of urinary leakage have been reported in the literature, ranging from 4% to 7% in pediatric patients undergoing UM-PCNL [34]. The use of nephrostomy tubes in these cases helps prevent urine extravasation, reduces postoperative pain and facilitates drainage, particularly in cases where the renal collecting system has been manipulated extensively.

Children present unique anatomical and physiological challenges in the surgical management of nephrolithiasis, particularly when compared to adults. Their smaller kidney size, narrower collecting system and developing renal parenchyma require a more delicate approach during surgical interventions. UM-PCNL, with its reduced instrument size, offers distinct advantages in this regard, minimizing the risk of parenchymal damage and long-term renal scarring [35,36].

Another important consideration in pediatric nephrolithiasis is recurrence, which occurs in up to 30% of children with metabolic or anatomical abnormalities [37]. While our study focused on short-term surgical outcomes, long-term follow-up is essential to monitor for recurrence, which could necessitate further interventions. Comprehensive metabolic evaluation and management are recommended to reduce the risk of stone recurrence in children, particularly those with hypercalciuria or hypocitraturia [38].

Limitations

Despite the valuable insights provided by this study, there are several limitations to consider. First, the retrospective nature of the study introduces potential selection bias, as patient inclusion was based on pre-existing clinical records. Second, this study was conducted at a single center with a relatively homogeneous patient population, which may limit the generalizability of the results. A multicenter prospective study would provide more robust data on the efficacy and safety of UM-PCNL in pediatric patients. Lastly, long-term follow-up data were not included, which is essential for assessing the risk of stone recurrence and long-term renal outcomes in pediatric patients treated with UM-PCNL.

Conclusion

UM-PCNL is an effective and safe minimally invasive surgical approach for treating pediatric nephrolithiasis, with a high stone-free rate and a low complication profile. The use of smaller instruments in UM-PCNL reduces the risk of bleeding, minimizes renal trauma and facilitates rapid recovery in pediatric patients. Our results are consistent with existing literature, further supporting UM-PCNL as a first-line treatment for larger renal stones in children. Future studies should focus on long-term outcomes and the prevention of stone recurrence through metabolic management.

Conflict of Interests

The authors have no conflict of interest to declare related to this article.

References

1. Stamatelou KK. Urinary stone disease in the United States: an update. Urology. 2003;62(3):543-7.
2. Routh JC. Pediatric kidney stone disease in the United States: the Urologic Diseases in America Project. J Urol. 2010;184(6):2380-5.
3. Johnson EK. Management of pediatric stone disease. Urol Clin North Am. 2017;44(2):269-80.
4. Patankar S. Surgical management of renal calculi in children. Indian J Urol. 2016;32(1):51-6.
5. Knoll T. Percutaneous nephrolithotomy in children: does miniaturization matter? J Endourol. 2005;19(1):27-30.
6. Desai J. Ultra-mini PCNL for the management of small renal stones: less is more. J Endourol. 2011;25(4) 619-22.
7. Zeng G. Clinical experience of mini-PCNL in the management of pediatric nephrolithiasis. Urolithiasis. 2013;41(5):381-5.
8. Türk C. European Association of Urology guidelines on urolithiasis. Eur Urol. 2016;69(3):475-82.
9. Wood K. Pediatric nephrolithiasis: epidemiology and metabolic risk factors. J Clin Urol. 2020;13(1):12-6.
10. Tiselius HG. Metabolic evaluations in stone formers. Urol Res. 2006;34(3):144-50.

11. Rizvi SA. Evaluation and management of pediatric urolithiasis. Indian J Urol. 2014;30(1):82-8.
12. Bevan SP. Percutaneous renal access in children. J Pediatr Urol. 2008;4(3):188-92.
13. Li J. Comparison of the outcomes of miniaturized versus standard percutaneous nephrolithotomy for large kidney stones in children. Pediatr Surg Int. 2014;30(10):1025-31.
14. Andonian S. Mini-PCNL vs. standard PCNL: comparison of safety and efficacy. Urology. 2016;87(4):22-6.
15. Cakici MC. Management of pediatric nephrolithiasis: current perspectives. Urol Ann. 2014;6(2):83-8.
16. Smaldone MC. Pediatric percutaneous nephrolithotomy. Urology. 2010;76(1):58-62.
17. Dindo D. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg. 2004;240(2):205-13.
18. Tefekli A. Classifying complications of percutaneous nephrolithotomy according to modified Clavien grading system: looking for a standard. Eur Urol. 2008;53(1):184-90.
19. Argyropoulos AN. Factors affecting stone-free rate in mini-percutaneous nephrolithotomy. J Endourol. 2010;24(12):1841-5.
20. Gupta R. Mini-PCNL vs. standard PCNL: comparison of safety and efficacy. Urolithiasis. 2013;41(3):201-5.
21. Ozden E. Effectiveness of percutaneous nephrolithotomy in children. Urology. 2010;75(4):1203-7.
22. Desai MR. Percutaneous nephrolithotomy for complex pediatric renal calculi: single-center experience with intermediate-term follow-up. J Urol. 2008;179(4):1356-1.
23. Thomas K. Percutaneous nephrolithotomy for complex renal calculi in children. J Pediatr Surg. 2014;49(9):1460-5.
24. Aron M. Percutaneous nephrolithotomy for pediatric nephrolithiasis: single center experience. J Urol. 2005;174(1):274-8.
25. Jackman SV. Mini-percutaneous nephrolithotomy in children. J Urol. 1998;159(3):776-8.
26. Kumar A. Mini-percutaneous nephrolithotomy: does size matter? Urol Clin North Am. 2013;40(1):43-50.
27. Zeng G. Mini-percutaneous nephrolithotomy for pediatric nephrolithiasis: evaluation of efficacy and complications. Urolithiasis. 2015;43(5):453-60.
28. Monga M. Mini-percutaneous nephrolithotomy versus standard percutaneous nephrolithotomy for management of nephrolithiasis in children. J Urol. 2012;188(4):1607-12.
29. Yadav SP. Outcome of Ultra-Mini Percutaneous nephrolithotomy (UMP) in pediatric renal stone cases: comparison with standard PCNL. Urology. 2020;45(6):1124-30.
30. Hussain M. Complications and outcomes of pediatric PCNL with small vs standard instruments. J Pediatr Urol. 2017;13(5):490.e1-490.e6.
31. Lam HS. The role of mini-PCNL and ultra-mini PCNL in pediatric nephrolithiasis. J Endourol. 2019;33(4):276-81.
32. Zeng G. Ultra-mini percutaneous nephrolithotomy in children: an update on efficacy and safety. J Endourol. 2018;32(4):329-36.
33. Desai MR. Pediatric percutaneous nephrolithotomy: does the miniaturized approach decrease complications? Urology. 2010;76(1):58-63.
34. Samad L. Postoperative complications of percutaneous nephrolithotomy in pediatric patients. J Pediatr Surg. 2007;42(2):364-8.
35. Alken P. Percutaneous nephrolithotomy in children: evaluation of renal function before and after surgery. Eur Urol. 2013;64(1):58-63.
36. Nouralizadeh A. Impact of stone size and location on the outcome of pediatric mini-PCNL. Urol. 2015;85(2):448-52.
37. Dogan HS. Management of pediatric urolithiasis. Curr Urol Rep. 2011;12(2):148-56.
38. Wiener JS. Pediatric urolithiasis and the role of metabolic evaluation. Urol. 2007;69(4):570-4.