PEDIATRIC UROLOGY

Original Article

Effectiveness and complications of mini-percutaneous nephrolithotomy in children: one center experience with 232 kidney units

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Cite this article as: Baydilli N, Tosun H, Akınsal EC, Gölbaşı A, Yel S, Demirci D. Effectiveness and complications of mini-percutaneous nephrolithotomy in children: one center experience with 232 kidney units. Turk J Urol 2020; 46(1): 69-75.

ABSTRACT

Objective: To evaluate the efficacy and complications of mini-percutaneous nephrolithotomy (PCNL) surgery using 14-20 Fr access sheaths in pediatric patients, as well as the results of postoperative stone analysis and metabolic urine analysis.

Material and methods: We retrospectively evaluated the records of 206 pediatric patients (232 kidney units) who underwent mini-PCNL for kidney stones in our clinic between February 2011 and December 2018. We evaluated the demographic characteristics, complications, stone-free rates, and the results of chemical analysis and urinary metabolic analysis.

Results: The age ranged from 9 months to 16 years. The mean age was 5.1±3.9 years, and the median age was 3.5 years. The median stone burden was 200 mm^2 (min: 100; max: 1600). Kidney stones were most commonly located in the pelvis in 118 (50.9%) patients, followed by lower calyceal stones in 42 (18.1%) and multiple calyceal stones in 38 (16.4%) patients, respectively. While the success of mini-PCNL was 80.6% after the first session, this rate increased to 87.9% after auxiliary treatments. The total complication rate was 12.9% according to modified Clavien classification. A postoperative stone analysis showed that calcium oxalate had the highest frequency with 61.1% of patients, followed by cystine stone with 21.3% of patients. Metabolic urine analysis revealed no abnormalities in 42.8% of patients. The most common metabolic abnormality was hyperoxaluria (32%), followed by hypercalcuria (19.6%).

Conclusion: Mini-PCNL is a safe and effective procedure with reasonable complications for the treatment of pediatric kidney stones. All kinds of multidisciplinary efforts are required to remove kidney stones completely in pediatric patients.

Keywords: Children; kidney stones; minimally invasive surgery; percutaneous nephrolithotomy.

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Submitted: 30.07.2019

Accepted: 25.09.2019

Available Online Date: 14.11.2019

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Available online at www.turkishjournalofurology.com

Introduction

Pediatric urinary stone disease is an important health problem with an increasing incidence and morbidity all over the world, especially in developing countries.[1] Unlike in adults, urinary stone disease in children should be evaluated carefully as it may recur frequently in later years due to underlying metabolic anomalies or an anatomical disorders. Furthermore, "clinically insignificant residual fragments," which is an expression used after treatment of kidney stones in adult patients, is not suitable for pediatric patients. This is because residual stones <4-5 mm in size, which are considered clinically insignificant, may cause symptoms in pediatric patients and may require surgical intervention. Therefore, it is very important to achieve a complete stone-free condition with surgical procedures in pediatric patients. In addition, it is of great importance to choose minimally invasive methods that will not interfere with kidney development and its function.[2] The latest European Association of Urology guidelines recommend percutaneous nephrolithotomy (PCNL) as the first-line treatment for pelvic stones >2 cm and lower calyceal stones >1 cm in children.[3] The relatively large size of standard PCNL (24-30Fr) equipment for small kidneys in pediatric patients leads to an increase in complications, especially bleeding. This has led to the need for miniaturization (mini) of the PCNL equipment for pediatric patients utilizing technological advances.

Turk J Urol 2020; 46(1): 69–75
DOI:10.5152/tud.2019.19158

Thus, the methods using smaller access sheaths such as mini-PCNL (14-22Fr), ultra-mini PCNL (11-14Fr), super-mini-PCNL (10-14Fr), and micro-PCNL (4.8 Fr) have become widely used.[4-6] In this study, we evaluated the efficacy and complications of mini-PCNL surgery using 14 to 20 Fr access sheaths in pediatric patients, as well as the results of postoperative stone analysis and metabolic urine analysis.

Material and methods

We retrospectively evaluated the records of 206 pediatric patients (232 kidney units) who underwent mini-PCNL for kidney stones in our clinic between February 2011 and December 2018. The study was approved by the Erciyes University Ethical Committee (Internal Review Board approval number: 2019/550). Indications for mini-PCNL included lower pole stones >1 cm, kidney stones >2 cm, and stones that were unresponsive to shock wave lithotripsy (SWL) or that could not be removed due to calyceal anatomy. Written consent was obtained prior to the surgery after a verbal interview between the doctor and the patient and the legal guardian. In the postoperative period, kidney stones were evaluated using kidney urinary bladder radiography (KUB), ultrasonography (USG), and abdominal tomography, when necessary. Patients with positive preoperative urine culture results were treated with appropriate antibiotic therapy and operated after obtaining sterile urine culture results. Intravenous ceftriaxone was used for preoperative prophylaxis in all patients. The size of the stone was measured in mm^2 by multiplying the long edge and the right-angled edge. In multiple stones, all of the stones were measured, and the total size was obtained. In this study, we evaluated the demographic characteristics, complications, postoperative stone-free rates, and the results of chemical analysis and urinary metabolic analysis. The diagnosis of hypercalciuria was established when the amount of calcium in the urine exceeded 4 mg/kg/24 h. However, cystinuria was diagnosed when the 24 h urinary excretion of cystine was >0.5 mmol/1.73 m^2. Normal urinary citrate excretion was accepted as >1.6 mmol/1.73 m^2/24 h. Normal daily excretion of oxalate in the urine was accepted as <0.5 mmol/1.73m^2/24 h, whereas this value was <1.1 mg/kg/24 h for uric acid. The normal value for tubular phosphate reabsorption was accepted as 4.1±0.6 mg/dL (1.32±0.19 mmol/L)/glomerular filtration rate.[7]

Surgical technique

All mini-PCNL procedures were performed under general anesthesia and in prone position. In the lithotomy position, an open-ended ureter catheter (5 Fr) was inserted retrogradely into the pelvis of the kidney under fluoroscopic guidance. The gonads were shielded from radiation through the use of a lead shield. Under fluoroscopic guidance, an 18-gauge Chiba needle (Boston Scientific, Natick, MA, USA) was used to enter the kidney calyx that was most suitable for the position and size of the stone. In general, the posterior calyx of the lower pole was preferred to access the urinary system. After reaching the urinary system, a 14Fr, 16Fr, or 20Fr access sheath was used based on the patient's age and stone size, and it was positioned over a 0.035-inch guidewire using an Amplatz dilator. The temperature of the irrigation fluid (0.9% NaCl) was maintained between 24°C-26°C to prevent hypothermia. A 7.5 Fr cystoscope (Olimpus, Germany) or a 12 Fr pediatric nephroscope (Karl Storz, Germany) was inserted through 14 Fr and 16 Fr Amplatz sheaths, and a 17 Fr pediatric nephroscope (Karl Storz, Germany) through a 20 Fr Amplatz sheath. Holmium:YAG laser was used frequently, and pneumatic lithotripter was used when necessary. All the disintegrated stones were removed by forceps, baskets, or irrigation fluid. In the postoperative period, 10 Fr to 12 Fr Nelaton catheters or 14 Fr re-entry catheters were used as nephrostomy tubes for urinary diversion.

Patient follow-up

Postoperative complete blood count was performed only in patients where it was deemed necessary. The Foley catheter was removed on the first postoperative day if the patient had no hematuria. The nephrostomy tube was removed on the second or third postoperative day if the patient had no hematuria, fever, or leakage of urine. Complications were evaluated using the modified Clavien classification.[8] The stone-free condition was evaluated by KUB on the 1st postoperative day and by KUB and USG at the 1st and 3rd months. Detection of a residual stone of any size by imaging methods was accepted as treatment failure. Abdominal tomography was used only when necessary to prevent unnecessary radiation exposure in the assessment of kidney stone recurrence. In the postoperative period, patients were referred to the pediatric nephrology department with the results of the stone analysis. Metabolic analysis of urine was performed.

Statistical analysis

Using the Statistical Package for the Social Sciences statistical package version 15.0 (SPSS, Inc.; Chicago, IL, USA), data were analyzed. Data are given as median (percentiles 25%-75%), and frequencies as percentages. In addition, data with normal distribution were expressed as the mean±standard deviation and with non-normal distribution as a median (25^{th}-75^{th} quarters).

Results

There were 206 pediatric patients and 232 kidney units undergoing mini-PCNL surgery. Of the patients, 119 (57.8%) were male, and 87 (42.2%) were female. The age ranged from 9 months to 16 years. The mean age was 5.1±3.9 years, and the median age was 3.5 years. In these patients, 119 (51.3%) left kidney units and 111 (47.8) right kidney units were operated. Two patients with bilateral kidney stones underwent bilateral mini-PCNL surgery in the same session. The median stone burden was 200 mm^2 (min: 100; max: 1600). Kidney stones were most commonly located in the pelvis in 118 (50.9%) patients, followed by lower calyceal stones in 42 (18.1%) and multiple calyceal stones in 38 (16.4%) patients, respectively. Staghorn stones were detected in 21 (9.1%) kidney units. Only 2 patients required the use of a second access sheath in the same session. In 8 (3.4%), 149 (64.2%), and 75 (32.3%) patients, 14 Fr, 16 Fr, and 20 Fr access sheaths were used, respectively. The median duration of the operation was 77.5 (min: 20; max: 240) minutes, while the duration of fluoroscopy was 5 (min: 1; max: 24) minutes. The median duration of nephrostomy was 2 (min: 1; max: 8) days, and the median duration of hospital stay was 3 (min: 1; max: 15) days. While the success of mini-PCNL was 80.6% after the first session, this rate increased to 87.9% after auxiliary treatments. The patient characteristics are summarized in Table 1.

Table 1. Demographic data of patients

	n=232 kidney units
Age (years)	3.5 (2-8)
Gender	
Male	119 7.8)
Female	87 (42.2)
Side	
Right	111 7.8)
Left	119 1.3)
Bilateral	2 (0.9)
Size of dilatation (Fr)	
14	8 (3.4)
16	149 4.2)
20	75 (32.3)
Localization of stone	
Upper calyx	6 (2.6)
Middle calyx	7 (3.0)
Lower calyx	42 18.1)
Pelvis	118 (50.9)
Multiple calyx	38 (16.4)
Staghorn	21 (9.1)
Number of accesses (1 access/2 accesses)	230 (99.1)/2 (0.09)
Duration of operation (min)	77.5 (60-100)
Stone burden (mm^2)	200 (100-300)
Duration of scopy (min)	5 (3-8)
Drop in hemoglobin (mg/dl)	0.8 (0.1-1.3)
Blood transfusion	5 (2.2)
Duration of nephrostomy (days)	2 (2-3)
Length of stay (days)	3 (2-4)
Stone-free rate after mini-PCNL (%)	80.6
Stone-free rate after auxiliary treatments (%)	87.9

Data given as n, (%), and median (25th-75th quarters).

The total complication rate was 12.9%, according to modified Clavien classification. The rate of Grade 2 complications was 8.1%, while the rate of Grade 3 complications was 4.7%. None of the patients had life-threatening complications. Blood transfusion was required only in 5 (2.1%) patients (Clavien Grade 2). Because of urinary tract infection, 14 (6%) patients received intravenous antibiotic therapy in the postoperative period (Clavien Grade 2). After the removal of the nephrostomy tube, 7 patients had a leakage of urine at the access site and underwent double-J stents under anesthesia (Clavien Grade 3B). During the operation, 1 patient developed avulsion of the pelvis of the kidney and therefore underwent ureterocalicostomy in the same session (Clavien Grade 3B). Due to urinary bleeding, 1 patient developed clot retention and thus underwent percutaneous cystostomy catheterization under anesthesia (Clavien Grade 3B). After the operation, the balloon of the urethral catheter could not be removed in 1 patient, and the balloon was detonated with a suprapubic needle under anesthesia and then removed (Clavien Grade 3B). During surgery, 1 patient developed abdominal distension due to saline infiltrated into the peritoneum and underwent peritoneal drainage catheterization in the same session (Clavien Grade 3B). Complications are summarized in Table 2.

A postoperative stone analysis showed that calcium oxalate had the highest frequency with 63 (61.1%) patients, followed by cystine stone with 22 (21.3%) patients. The results of the stone analysis are summarized in Table 3.

Metabolic urine analysis revealed no abnormalities in 24 (42.8%) of 56 patients. The most common metabolic abnormality was hyperoxaluria (32%), followed by hypercalcuria (19.6%). The results of metabolic urine analysis are shown in Table 4.

Discussion

Although pediatric kidney stone disease is rare in developed countries (1%-5%), its incidence can reach up to 30% in developing countries.[9,10] For years, SWL that is still the first-line treatment for urinary stone disease, mini-PCNL, micro PCNL, and retrograde intrarenal surgery (RIRS) has been safely and effectively used for the treatment of pediatric kidney stones. RIRS is the secondary treatment option for stones <2 cm and a less invasive method to remove kidney stones compared with PCNL. However, an important problem was the inability to obtain access to the ureter in approximately half of the cases. For this

Turk J Urol 2020; 46(1): 69-75
DOI:10.5152/tud.2019.19158

Table 2. Classification of surgical complications according to modified Clavien system

	n, (%)
Grade 1 (Any deviation from the normal postoperative course without the need for pharmacological treatment or surgical, endoscopic, or radiological intervention)	NA
Grade 2 (Requiring pharmacological treatment with drugs other than such allowed for Grade 1 complications)	19 (8.1)
Intravenous antibiotic treatment due to urinary tract infection	14 (6)
Bleeding requiring transfusion	5 (2.1)
Grade 3A (Requiring surgical, endoscopic, or radiological intervention, but not under general anesthesia)	0
Grade 3B (Requiring surgical, endoscopic, or radiological intervention under general anesthesia)	11 (4.7)
Insertion of a J stent due to urine leakage from the nephrostomy site	7 (3)
Ureterocalicostomy surgery due to pelvic avulsion	1 (0.4)
Percutaneous cystostomy due to clot retention	1 (0.4)
Detonation and removal of the unrecovered Foley catheter balloon under anesthesia	1 (0.4)
Development of distention as a result of leakage of saline into the peritoneum during surgery and consequent drainage catheterization by laparotomy	1 (0.4)
Grade 4 A (Life-threatening conditions with single-organ dysfunction)	0
Grade 4 B (Multiple organ dysfunction and life-threatening conditions)	0
Grade 5 (Death)	0

NA: not available

Table 3. Results of stone analysis

(n=103 kidney units)	n, (%)
Calcium oxalate	63 61.1)
Cystine	22 21.3)
Calcium oxalate, uric acid	5 (4.8)
Calcium oxalate, ammonium urate, carbonate apatite	6 (5.8)
Citruvite, calcium oxalate, carbonate	1 (0.9)
Citruvite, calcium oxalate, carbonate apatite	2 (1.9)
Xanthine	1 (0.9)
Carbonate apatite	2 (1.9)
Ammonium urate	1 (0.9)

Table 4. Results of metabolic urine analysis

(n=56 kidney units)	n, (%)
Normal	24 (42.8)
Hyperoxaluria	11 (19.6)
Hypercalcuria	6 (10.7)
Hyperoxaluria, Hyperuricosuria	3 (5.3)
Hyperoxaluria, Hyperuricosuria, Hypercalcuria, Hypomagnizuria	2 (3.5)
Hyperuricosuria	4 (7.1)
Hyperphosphaturia	1 (1.7)
Hypercalcuria, Hyperuricosuria	1 (1.7)
Hyperoxaluria, Hypercalcuria	1 (1.7)
Hyperoxaluria, Hyperuricosuria, Hypercalcuria	1 (1.7)
Hypomagnesuria	1 (1.7)
Hypocitraturia	1 (1.7)

Total percentage of patients with hyperoxaluria, 32%. Total percentage of patients with hypercalcuria, 19.6%

reason, RIRS requires stenting before the surgery and performing the procedure in a second session. In addition, RIRS requires multiple sessions for full stone clearance in pediatric population.[11] PCNL is still the first-line surgical treatment for kidney stones >2 cm or lower pole stones >1 cm that do not respond to SWL.[3] With technological advances, the use of large access sheaths (28-30 Fr) using adult-type nephroscopes with a high risk of complications has been largely abandoned in the pediatric group. Instead, PCNL devices with a good image quality and smaller sheaths are now being produced. This has led to a safer application of PCNL in pediatric patients. Although there is no consensus as to which PCNL method (mini, ultra-mini, micro) will be chosen for which patient, the main factors that are often considered are the age of the patient and the location, size, and rigidity of the stone in the kidney (cystine stones, calcium oxalate mono hydrate stones). Wright et al.[12] summarized all PCNL methods (mini, ultra mini, micro) providing a brief description of each technique, necessary equipment, limitations, estimated costs, and blood transfusion rates. Their definitions can help us better understand the nomenclature.

After the study by Desai et al.[13], studies indicating that adult nephroscopes do not cause significant morbidity in children, do not lead to kidney scarring, and using a small-sized sheath do not provide an advantage are no longer valid.[14] Considering that a 24 F dilatation in the relatively small kidneys of children corresponds to 72 F in adults, the use of a small-diameter access sheaths in children is of great importance.

Current studies have shown that the amount of bleeding requiring transfusion increases in direct proportion with the diameter of the sheath, the number of accesses, and the duration of the operation.[15-17] In the literature, a multicenter study of 1205 patients performed on 9.5 Fr, 17 Fr, and 26 Fr nephroscopes investigating the complications of PCNL in pediatric patients reported that a sheath diameter ≥20 Fr significantly increased complications, especially bleeding.[17] The literature series on mini-PCNL reported complications ranging from 10.6% to 36.3%.[3,15-17] These complications include life-threatening conditions requiring an immediate surgical intervention (hydrothorax, colon perforation, bleeding requiring angioembolization, etc.), as well as conditions that can be resolved with medical treatment and follow-up, such as fever and urinary tract infection. Therefore, it can be life-saving that pediatric PCNL surgery centers be experienced with serious complications. In our study, the overall complication rate was 12.8%. The most common complications included urinary tract infection and urine leakage from nephrostomy site. The literature series on mini-PCNL have reported bleeding rates requiring transfusion of less than 10%.[3,17] The studies carried out by Zeng and Farouk discussed similar stone and sheath sizes as in our study. A study by Zeng et al.[18] on mini-PCNL including 331 children with a mean age of 7.8 years and a mean stone size of 2.3 cm reported a blood transfusion rate of 3.1%. However, Farouk et al.[19] reported a blood transfusion rate of 3.7% in children with a mean age of 6.4 years and a stone size of 1.5 cm, who underwent mini-PCNL. In our study, 5 (2.1%) patients required blood transfusion. Although bleeding is one of the most common complications of this procedure, the use of a single-entry site (only 2 patients required a second percutaneous access in the same session) and mostly a thin sheath (16 Fr) were considered to greatly contribute to the low need for blood transfusion in our study. In addition, it can be said that this prevents severe and life-threatening complications, which are categorized as Grades 4 and 5 in Clavien's classification. Only 11 (4.7%) patients had Grade 3B complications (complications requiring surgical, endoscopic, or radiological intervention, and general anesthesia). The majority of these patients, 63.6%, were patients who underwent J stents due to urine leakage from the nephrostomy site. However, it should be kept in mind that undesirable serious complications such as pelvic avulsion, colonic injury, hydrothorax, and sepsis can be seen even in the most experienced centers.[17,18,20] In our study, 3 patients had significant complications (pelvic avulsion, bladder globe due to clot, peritoneal extravasation) that required immediate surgery. Therefore, it may be life-saving that surgical centers of pediatric urinary stones manage complications immediately and carefully in pediatric patients with low tolerability.

There is no consensus on the definition of stone-free rate in the literature for pediatric patients after ureteric or kidney stone surgery. Somani et al.[21] propose a simple classification to define levels of stone-free rate post treatment. According to their simple classification, our stone-free rate can be defined as "0 USG" and "0 X-ray." Some authors do not consider residual stones smaller than 3-4 mm, called clinically insignificant residual fragments, when calculating stone-free rates in PCNL.[18,22] Since these residual stones may become symptomatic and require intervention in pediatric patients, the detection of even a piece of stone of any size should not be interpreted as a stone-free condition. The study by Zeng et al.[18] on mini-PCNL, which included 331 children with a mean stone size of 2.3 cm, reported a stone-free rate of 80.4%, but described residual stones <4 mm as clinically insignificant residues. A series by Resorlu et al.[22] on mini-PCNL, including 106 pediatric patients with a mean stone size of 2.3 cm and a mean age of 9.6 years, reported a success rate of 83.9% for 93 patients with stone sizes >2 cm and 100% for 13 patients with stones <2 cm. However, they did not include patients with clinically insignificant residues in the success rate. In our study, the stone-free rate was calculated as 80.1%, excluding patients with clinically insignificant residues. This rate increased to 87.9% with additional interventions on residual stones. The literature series on mini-PCNL using 20 Fr and smaller sheaths have generally reported stone rates 75.8%-95%.[23-25]

In mini-PCNL, miniaturization of endoscopic devices has some disadvantages. Thin sheaths may lead to an increased intrarenal pressure due to insufficient fluid drainage, prolongation of the operation, and prevention of endoscopic vision, even with minimal bleeding. In addition, these sheaths may cause failure to obtain stones of sufficient size for stone analysis and may result in postoperative kidney colic and/or urine leaks from the nephrostomy site due to small fragments blocking the ureter. In our study, it can be said that the use of 16 Fr sheaths and the more frequent use of laser for fragmentation of stones increased the need for J stents (7 patients, 3%) due to urine leakage. Therefore, the size of the dilatation should be determined on the basis of the largest diameter at which the stones can be collected and the smallest diameter that will not cause any harm to the kidney, and thus a patient-based selection should be made. In our study, the median duration of the operation was reasonable with 77 minutes. However, this time was between 65 and 109 min in a series on mini-PCNL with a similar stone burden.[23]

Follow-up is as important as surgery to prevent recurrence of pediatric kidney stone disease. Therefore, an experienced pediatric

Turk J Urol 2020; 46(1): 69-75
DOI:10.5152/tud.2019.19158

nephrology team should evaluate the patient along with the results of the stone analysis and perform the necessary metabolic examinations.[26] In the literature, the association of at least one metabolic risk factor has been reported in 33%-95% of patients with pediatric kidney stone disease. These metabolic disorders can lead to an increase in urine concentration of metabolites such as calcium, phosphorus, oxalate, uric acid, and cystine. In contrast, some metabolic disorders may be related to the excretion of inhibitory agents that inhibit the formation of stones, such as citrate, magnesium, and pyrophosphate. Hypercalciuria is the major metabolic risk factor reported, with a rate of 34%-97%.[26] Hyperoxaluria is seen in pediatric kidney stone disease in approximately 2%-36% of patients. In our study, hypercalcuria was detected in 11 (19.6%) patients, and hyperoxaluria in 18 (32.1%) patients, among the patients included in the metabolic urine analysis.

The limitations to our study include its retrospective nature, failure to obtain stone samples in some patients during mini-PCNL, failure to perform metabolic urine analysis in some patients, and lack of data defined as Clavien Grade 1 that does not alter the course of treatment, such as fever, etc. In addition, abdominal tomography that is the current gold standard for confirming urinary stones used only when necessary to prevent unnecessary radiation exposure in the assessment of kidney stone recurrence. In fact, this can be regarded as a limitation in determining the actual stone-free rate.

In conclusion, mini-PCNL is a safe and effective procedure with reasonable complications for the treatment of pediatric kidney stones. All kinds of multidisciplinary efforts are required to completely remove stones in pediatric patients.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Erciyes University (number: 2019/550).

Informed Consent: Written informed consent was obtained from the parents of the patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – D.D., N.B. ; Design – N.B., H.T.; Supervision – D.D., E.C.A.; Resources – H.T., N.B.; Materials – A.G., S.Y., H.T.; Data Collection and/or Processing – A.G., S.Y., N.B.; Analysis and/or Interpretation – E.C.A., D.D., N.B., S.Y.; Literature Search – N.B., S.Y., E.C.A., H.T.; Writing Manuscript – N.B., S.Y., H.T.; Critical Review – N.B., H.T., E.C.A., A.G., S.Y., D.D.

Conflict of Interest: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

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