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Mini— versus standard percutaneous nephrolithotomy for treatment of pediatric renal stones: is smaller enough?

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Keywords
Pediatric; Percutaneous nephrolithotomy; Percutaneous renal surgery; Urolithiasis; Mini-PCNL

Abbreviations
PCNL, percutaneous nephrolithotomy; SPCNL, standard percutaneous nephrolithotomy; MPCNL, mini—percutaneous nephrolithotomy; SFR, stone-free rate; KUB, kidney ureter and bladder radiography

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Summary

Introduction
Miniaturized percutaneous nephrolithotomy (PCNL) has gained increased popularity owing to efforts in recent years to lower peri-operative morbidity while maintaining a high stone-free rate (SFR).

Objective
The outcomes of pediatric renal stones treated by mini-PCNL (MPCNL) versus standard PCNL (SPCNL) were retrospectively assessed.

Study design
A retrospective data analysis of 134 consecutive patients younger than 17 years who underwent PCNL between January 2014 and July 2018 was performed. The patients were categorized into two treatment groups depending on the tract size and instruments used. Seventy-five patients were treated by SPCNL using adult instruments via a 22—26 Fr tract, and 59 patients were treated by MPCNL using pediatric instruments via a 16—20 Fr tract.

Results
A total of 134 children (SPCNL = 75; MPCNL = 59) underwent PCNL and subsequent evaluation. Patient demographics and stone characteristics were comparable between the two groups. The mean stone size ranged from 1.9 ± 1.162 cm in the MPCNL group to 2.2 ± 1.424 cm in the SPCNL group, and the overall SFR was 89.5% in the MPCNL group and 94.7% in the SPCNL group. When comparing the common characteristics, no significant difference was found between the two surgical access regarding the mean operative duration, SFR, incidence of peri-operative complications, and the rate of bleeding requiring a blood transfusion. Conversely, the mean postoperative hemoglobin decrease was significantly lower in the MPCNL group relative to the SPCNL group, at 0.354 ± 0.299 g versus 0.568 ± 0.332 g, respectively ($P = 0.001$). In addition, the mean duration of hospitalization was significantly lower in the MPCNL group than in the SPCNL group, at 1.91 ± 1.154 days compared with 2.41 ± 1.14 days, respectively ($P = 0.014$).

Discussion
Herein, the authors report the first systematic review of the first center in the locality treating this cross section of patients. This review reveals that the use of these smaller instruments can deliver a strong safety profile while achieving good stone clearance. As an alternative to decreasing the peri-operative morbidity associated with SPCNL, MPCNL can be conveniently used without affecting the outcomes of the procedure. It is a safe and feasible procedure for maximal clearance of stones and should comprise the treatment of choice—regardless of age—for experienced endourologists.

Conclusion
MPCNL represents a valuable way of treating simple and complex renal stones in children, with an operative time, SFR, and overall complication rate comparable with those of SPCNL. Mini-PCNL resulted in shorter hospitalization and fewer hemoglobin drops.

Table Operative and postoperative characteristics

Variables	MPCNL	SPCNL	*P*-value
Hospital stay (days), mean (SD)	1.91±1.154	2.41±1.14	0.014
Operative and postoperative complication, *n* (%)	11 (18)	22 (29)	
Blood transfusion, *n* (%)	1 (1.69)	4 (5.3)	0.389
Postoperative fever, *n* (%)	9 (15.5)	14 (18.9)	0.609
Postoperative transient hematuria, *n* (%)	1 (1.69)	4 (5.3)	0.257
Mean postoperative Hg drop (g/l ±SD)	0.354 ± 0.299	0.568 ± 0.332	0.001
Stone clearance (PCNL single session), *n* (%)			
Complete clearance	51 (89.5)	71 (94.7)	0.513
Stone residual	6 (10.5)	4 (5.3.0)	

SPCNL: standard PCNL; MPCNL: mini-PCNL; PCNL: percutaneous nephrolithotomy; SD: standard deviation.

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Introduction

Renal stone disease in children is uncommon, and it is associated with clinical management difficulties owing to the size of the urinary tract and the high rate of recurrence [1,2]. The introduction of new technologies over the past two decades has reformed the course of renal stone disease management in children [3]. The most recent American Urological Association guidelines for the treatment of stones in children recommended PCNL as a reasonable treatment option for renal stones exceeding 2 cm [4]. Percutaneous nephrolithotomy (PCNL) has become a well-proven standard procedure for treating renal stones, achieving a high stone-free rate (SFR) of 90% or higher in recent studies 5—9], with no anatomical or functional renal damage regardless of age or equipment diameter [7,10].

Miniaturized PCNL has achieved expanded acceptance in recent years as an attempt to reduce peri-operative morbidity while simultaneously providing a high SFR [1,11]. The inference of applying smaller sheaths is that the smaller the PCNL tract, the less harm is inflicted onto the renal parenchyma. Consequently, there would be lower associated morbidity, lower intra-operative blood loss and need for blood transfusions, reduced demand for post-operative analgesia, and shorter hospitalization time, without alteration of therapeutic efficacy [12—14]. Nonetheless, its potential superiority in safety and effectiveness when compared with conventional PCNL remains controversial [15].

In the present clinical analysis, the authors evaluated the relative effectiveness and safety of mini-PCNL (MPCNL) compared with standard PCNL (SPCNL) in treating renal stones in various pediatric age-groups.

Patients and methods

We performed a retrospective data analysis of 134 consecutive patients younger than 17 years who underwent PCNL performed by a single surgeon at our institution between January 2014 and July 2018. The patients were categorized into two treatment groups depending on the size of the tract and instruments used: 75 patients were treated by SPCNL using adult instruments via a 22—26 Fr tract, and 59 patients were treated by MPCNL using pediatric instruments via a 16—20 Fr tract. Stone size, location, density, and number were not considered for inclusion or exclusion.

The pre-operative evaluations included full medical history, complete physical examination, urinalysis, urine culture, renal function testing, complete blood count, coagulation profile, abdominal ultrasonography, and kidney, ureter, and bladder radiography (KUB). Intravenous urography or non-contrast computerized tomography was performed to evaluate the relation of the colon and surrounding structures to the kidney, especially in previously operated (open renal stone surgery) cases and in cases of complex renal calculi where more than one tract may have been needed.

Children with positive urine cultures were treated pre-operatively with appropriate antibiotics for 7—10 days, and sterilization of urine was confirmed by urine culture before the procedure. The stone burden was measured by multiplying the two largest dimensions on pre-operative radiography, and the stone complexity was classified according to the Guy's stone score [16] (see Appendix 1).

All PCNLs were performed under general anesthesia using prophylactic intravenous antibiotics. A four- or five-Fr ureteral catheter was inserted in the lithotomy position. For opacification of the pelvicalyceal system, the patients were turned to the prone position, and under fluoroscopic guidance, percutaneous access was established. Tract formation was performed by serial coaxial dilatation using Teflon-coated telescopic dilators, and afterward, using Amplatz sheaths, 16—20 Fr was selected for the MPCNL group, whereas 22—26 Fr was chosen for the SPCNL group. An 18-Fr slender nephroscope (RZ Medizintechnik GmbH, Tuttlingen, Germany) without an external sheath was used for the SPCNL group, and a 12-Fr mini-nephroscope (RZ Medizintechnik GmbH, Tuttlingen, Germany) was used for the MPCNL group. A pneumatic lithotripter was used for disintegration of the stones. All calyces were routinely checked at the end of the procedure, and to reach calyces inaccessible through rigid nephroscopy, a 15-Fr flexible nephroscope (Karl Storz, Tuttlingen, Germany) was used to examine and remove stone fragments. Stone-free status was confirmed using both fluoroscopy and endoscopic examination (rigid and flexible nephroscopy). The number and location of access points, blood loss, duration of hospitalization, stone burden according to the Guy's score, stone clearance, and complications were recorded. On completion of the procedure, a Foley catheter was placed in the bladder, a 14- to 16-Fr nephrostomy was left *in situ* in all cases, a double-J stent (DJS) was inserted in cases of patients with infected stones, pelvis calyceal injuries, and extravasations. Each patient remained in the hospital overnight and underwent KUB investigation in the morning of postoperative day 1 to assess residual stone burden. When urine was clear and patients were deemed stone free, the nephrostomy tube and urethral catheter were removed on postoperative day 1, and the patient was discharged home when absence of urine leakage or fever was confirmed.

The outcomes compared between both groups comprised SFRs, operative durations, peri-operative complications, blood transfusion rates, postoperative hematocrit changes, and length of hospital stay. Success was defined as complete removal of the patient's stone without the need for an auxiliary procedure or without residual stone fragments, regardless of size. The first follow-up evaluation was performed 10—14 days after the operation (at the time scheduled for DJS removal). Subsequent evaluations were performed if the patient had residual fragments at 6 weeks and 3 months after operation (chance of spontaneous clearance of the stones fragments), with renal ultrasonography supplemented with abdominal KUB, if necessary. The overall SFR was calculated at 3 months after operation.

Data were analyzed using the Statistical Package for Social Sciences (SPSS version 21). The chi-squared test of association was used to compare proportions. When the expected count of $>20\%$ of the cells of the table decreased to less than five, Fisher's exact test was used. Student's *t*-

test was used to compare the means of the two groups. *P*-value of ≤0.05 was considered statistically significant. Univariate analyses were performed to detect any significant association between each of the dependent and independent variables. The 95% confidence interval was also calculated.

Results

One hundred thirty-four patients younger than 17 years underwent PCNL (SPCNL = 75; MPCNL = 59). The MPCNL group included 31 males (52.5%) and 28 females (47.5%), with a mean age of 6.91 years. The SPCNL group included 51 males (68%) and 24 females (32%), with a mean age of 6.20 years. Patient demographics and stone characteristics were comparable between the two groups. Detailed patient demographics and pre-operative variables are summarized in Table 1.

The mean stone size ranged from 1.9 ± 1.162 cm (MPCNL) to 2.2 ± 1.424 cm (SPCNL). The overall SFRs (single session) were 89.5% in the MPCNL group and 94.7% in the SPCNL group. However, there was no statistically significant difference between the two groups ($P = 0.513$). Comprehensive operative variables and outcomes are outlined in Table 2.

When comparing the common characteristics, we found no difference between the two surgical access regarding the mean operative duration, SFR, the incidence of peri-operative complications, and the rate of bleeding requiring blood transfusion.

Despite a higher number of multitract interventions in the MPCNL group, the incidence of bleeding and blood transfusion was nonetheless low, with only one patient in the MPCNL group and four patients in the SPCNL group requiring blood transfusions ($P = 0.38$). The mean post-operative decline in hemoglobin was significantly lower in the MPCNL group relative to the SPCNL group, at 0.354 ± 0.299 g versus 0.568 ± 0.332 g, respectively ($P = 0.001$). In addition, the mean duration of hospitalization was significantly lower in the MPCNL group than in the SPCNL group, at 1.91 ± 1.154 days versus 2.41 ± 1.14 days, respectively ($P = 0.014$).

As shown in Table 2, neither major complications, including death, were observed in the patient groups nor a statistically significant difference was found in complication rates between the two groups. Twenty-two (29%) patients had peri-operative complications in the SPCNL group compared with nine (18%) patients in the MPCNL group, which failed to reach statistical significance. Most of these complications were minor (Clavien grade I and II), and all were managed conservatively. Fever (temperature >38 °C) occurred in nine (15.5%) patients in the MPCNL group and fourteen (18.9%) patients in the SPCNL group ($P = 0.609$). All cases were successfully managed by appropriate antipyretics and antibiotics.

Discussion

Pediatric renal stone disease is more prone to recurrence, and its incidence is increasing worldwide in all age-groups [17]. In addition to the advancements in instrumentation and technology, the growing skills of urologists have rendered PCNL a well-proven method for treating renal stones in children requiring surgical intervention [1].

Mini-PCNL has gained increased popularity as there has been an effort in recent years to lower peri-operative morbidity while maintaining a high SFR [1,11]. The concept of using smaller instruments through smaller diameter sheaths arose from the reasoning that the smaller the PCNL tract, the less harm is inflicted onto the renal parenchyma; consequently, associated morbidity is lowered without compromising therapeutic efficacy [11,22,23]. A variety of endoscopes have been used by various authors for stone fragmentation and removal using access sheath sizes ranging from 11 Fr to 20 Fr [10,18–23].

Table 1 Patients' pre-operative characteristics.

Variable	Mini-PCNL	Standard PCNL	*P*-value
Number of patients	59	75	
Age (y), mean (range)	6.91 ± 4.982 (1–15)	6.20 ± 4.138 (1–16)	0.376
Gender (M/F), n (%)	31(52.5)/28(47.5)	51(68)/24(32)	0.16
Previous stone-related surgery	8 (13.8%)	11 (14.7)	0.886
Stone size (cm), mean (SD), median	1.9 ± 1.162, 2	2.2 ± 1.424, 2	0.188
Stone complexity			
Single stone	22 (37.3)	30 (40.1)	
Multiple stone	26 (44.1)	31 (41.3)	
Partial staghorn	6 (10.2)	6 (8)	0.492
Complete staghorn	5 (8.5)	8 (10.7)	
GSS, n (%)			
1	20 (34.5)	30 (40)	
2	27 (46.6)	31 (41.3)	0.439
3	8 (13.8)	6 (8)	
4	3 (5.2)	8 (10.7)	
Pre-operative creatinine (mg/dl)	0.056 ± 0.206	0.05 ± 0.275	0.878

PCNL: percutaneous nephrolithotomy; GSS: Guy's stone score; SD: standard deviation.

Table 2 Operative and postoperative characteristics.

Variables	MPCNL	SPCNL	*P*-value
Operative duration (min), mean (SD)	41.53 ± 10.597	37.52 ± 6.747	0.073
Hospital stay (days), mean (SD)	1.91,±1.154	2.41,±1.14	0.014
Punctures, *n* (%)			
Single puncture	52 (88.1)	74 (98.7)	0.001
Multiple punctures	7 (11.9)	1 (1.3)	
No. of procedures without insertion of the JJ stent, n (%)	12 (20.7)	17 (22.7)	0.477
Operative and postoperative complication, *n* (%)	11 (18)	22 (29)	
Blood transfusion, *n* (%)	1 (1.69)	4 (5.3)	0.389
Postoperative fever, *n* (%)	9 (15.5)	14 (18.9)	0.609
Postoperative transient hematuria, *n* (%)	1 (1.69)	4 (5.3)	0.257
Sepsis	0	0	
Pleural injury	0	0	
Colon injury	0	0	
Mortality	0	0	
Urinoma	0	0	
Prolonged urine leakage (≥24 h)	0	0	
Surgical complications according to the modified Clavien grading system:			
Grade 1	5 (8.5)	10 (13.3)	
Grade 2	6 (10.2)	12 (16.0)	0.362
Grade 3	0	0	
Grade 4	0	0	
Mean postoperative Hg drop (g/l ±SD)	0.354 ± 0.299	0.568 ± 0.332	0.001
Mean postoperative creatinine (mg/dl ±SD)	0.8210 ± 0.1733	0.8120 ± 0.1700	0.763
Stone clearance (PCNL single session), *n* (%)			
Complete clearance	51 (89.5)	71 (94.7)	0.513
Stone residual	6 (10.5)	4 (5.3)	

MPCNL: mini-PCNL; SPCNL: standard PCNL; PCNL: percutaneous nephrolithotomy; SD: standard deviation.

In the current literature, the rate of stone clearance in children undergoing SPCNL has been reported to range from 50% to 98% [22–27]. Mini-PCNL has become increasingly popular in recent years, with stone clearance reported as 80–85% after a single session of MPCNL as monotherapy [17,26,27]. In the present study, MPCNL in children did not evince a significant difference in the stone clearance rate compared with SPCNL (89.5% versus 94.7%). Despite the very limited comparative data published so far, the study results corroborate those of studies conducted by Ünsal et al. [25], Guven et al. [26], Celik et al. [28], Jones et al. [29], Tanriverdi et al. [30], Altintas et al. [31], and Ozden et al. [32], who achieved nearly identical rates of stone clearance using instruments of varying sizes (SPCNL vs. MPCNL). However, Bilen et al. [14] reported stone clearance to be higher in the MPCNL group than in the SPCNL group.

This pooled analysis showed that although the operative time of the MPCNL group was longer than that of the SPCNL group, the difference failed to reach statistical significance; this is in accordance with studies conducted by Ozden et al. [32], Tanriverdi et al. [30], Bilen et al. [14], Celik et al. [28], and Unsal et al. [25]. The explanation for this difference could be attributed to the restricted visual field provided by miniature endoscopes and the limited irrigation flow when reducing the sheath diameter, ultimately affecting adequate visualization. In addition, the need to fragment the stones into smaller pieces for their removal through smaller tracts more extensively led to prolonged operative durations.

In the present study, analysis revealed that MPCNL resulted in significantly shorter hospital stays relative to SPCNL. Similar results were reported in a study conducted by Ozden et al. [32], whereas Tanriverdi et al. [30], Bilen et al. [14], Celik et al. [28], Altintas et al. [31], and Unsal et al. [25] found no significant difference regarding duration of hospital stay.

By reducing patient discomfort using a smaller, less traumatic nephrostomy tract and achieving lower perioperative morbidity, it may seem logical to have shorter durations of hospitalization with MPCNL.

In the present study, although it was observed that the patients who underwent SPCNL had more peri-operative complications, a higher rate of postoperative fever, and more bleeding and blood transfusions relative to patients who underwent MPCNL, the differences were not statistically significant. This is in accordance with published studies by Tanriverdi et al. [30], Celik et al. [28], and Altintas et al. [31]. However, despite reporting similar overall complication rates, Tanriverdi et al. [30], Bilen et al. [14], and Unsal et al. [25] found that hemoglobin decrease, bleeding during surgery, and blood transfusion rates were significantly higher in patients who underwent SPCNL than in patients who underwent MPCNL.

Applying a smaller sized tract in MPCNL may affect postoperative complications; however, this was not shown to be the case in the present study. On the other hand, the small tract used in MPCNL may result in a higher pressure in the collecting system, leading to pyelovenous or pyelosinus backflow with subsequent postoperative fever [33]; however, this was not shown in the present study.

Bleeding is a serious complication during both the intraoperative and postoperative period in pediatric patients, in which the tract size is one of the important determinants of blood loss during PCNL [34]. However, many studies have reported that smaller access and the use of smaller caliber instruments have similar results regarding complications, such as bleeding and renal scarring, in children [35,36].

In the present study, the decrease in the hemoglobin level was significantly lower in the MPCNL group. This is in accordance with other studies conducted by Ozden et al. [32], Bilen et al. [14], Unsal et al. [25], Altintas et al. [31], and Celik et al. [28], whereas Tanriverdi et al. [30] found no significant difference in the rate of bleeding, blood transfusions, and hemoglobin decrease.

As an alternative to decreasing the peri-operative morbidity associated with SPCNL, MPCNL can be conveniently used without affecting the outcomes of the procedure. It is a safe and feasible procedure for maximal clearance of stones, and it should be the treatment of choice for experienced endourologists, with no age-group restrictions.

The first and primary limitation of this study is that data were retrieved from a single institution. Second, we used KUB and ultrasound as radiological methods for evaluating stone-free status. Although computed tomography may be the best imaging modality to evaluate the presence and/or burden of stone after treatment, our aim was to minimize the use of radiation and the cost to the patient. Finally, we believe that more results should be addressed to improve this study, e.g., postoperative analgesia requirements, readmission rate, and binning of hospitalization length.

Conclusion

Mini-PCNL is as safe and effective as SPCNL in the management of simple and complex renal calculi in children, with comparable operative times, SFRs, and overall complications. Mini-PCNL resulted in a shorter duration of hospitalization and lower hemoglobin decrease.

Author statements

Ethical approval

None sought.

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None.

Competing interests

The authors declare no conflicts of interest.

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Appendix 1. Guy's stone score.

Guy's stone score	
Grade I	A solitary stone in the mid/lower pole with simple anatomy or a solitary stone in the pelvis with simple anatomy
Grade II	A solitary stone in the upper pole with simple anatomy or multiple stones in a patient with simple anatomy or any solitary stone in a patient with abnormal anatomy
Grade III	Multiple stones in a patient with abnormal anatomy or stones in a calyceal diverticulum or partial staghorn calculus
Grade IV	Staghorn calculus Any stone in a patient with spina bifida or spinal injury