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ORIGINAL PAPER

Comparison of the results of pediatric percutaneous nephrolithotomy with different sized instruments

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Abstract We aim to compare the outcomes, including the morbidity and success rates in children undergoing percutaneous nephrolithotomy (PCNL) using different sized devices. According to the size of instruments used during surgery, three different groups (ultra-mini-PCNL, mini-PCNL and adult size PCNL) were composed and the outcomes were compared between the groups. PCNL was applied to 225 renal units of 220 children, including 5 patients with bilateral kidney stones. Percutaneous nephrolithotomy was performed using adult instruments (24 F) in 82 renal units, using pediatric instruments (18 F) in 89 and using minimal-size instruments (9.5 F) in 50. One-hundred and twenty-four girls and 96 boys with a mean age of 8.33 (<17) years were assessed. Stone-free rates were 78 % in group 1 ($n = 39$) using 9.5 F nephroscope, 75.8 % in group 2 ($n = 69$) using 18 F nephroscope and 71.4 % in group 3 ($n = 60$) using 24 F nephroscope. Time to access the collecting system, operative time, duration of nephrostomy and average postoperative hospital stay did not differ between the groups. However, mean hematocrit drop and stone burden were significantly lesser in ultra-mini-PCNL group. There was no significant difference in the complication rates between the groups, according to the modified Clavien classification system. As the important complication of PCNL, bleeding seems to be associated with diameter of dilatation, calibre of nephroscopes and stone burden. To reduce the certain complications, pediatric type of instruments is suitable but the use of adult instruments and techniques may achieve equal results.

Keywords Kidney calculi · Percutaneous nephrolithotomy · Pediatrics · Instrument type

Introduction

Pediatric urolithiasis is a significant health problem and there is an increase in incidence due to the change in lifestyle, dietary habits and obesity. Urinary system stones' prevalence was detected as 11.1 % and it was stated that our country is among endemic countries [1]. Anatomical and metabolic abnormalities, malnutrition and racial factors are known to be the most important risk factors for the high incidence and recurrence of urolithiasis [2].

Surgical treatment can be used when the stones are larger or more complex and unbroken by extracorporeal shock wave lithotripsy (ESWL). The metabolism of children has less tolerance for bleeding, which can cause an anxiety for surgeon. Therefore, minimally invasive techniques have become more important in the treatment of urolithiasis in pediatric age group. European Association of Urology (EAU) guidelines recommend that percutaneous nephrolithotomy (PCNL) is the primary treatment option in children with kidney stones >2 and >1 cm lower pole calyx stones [3]. The stone-free rate is between 73 and 96 % with PCNL in the literatures [3, 4]. There are many factors, such as the anatomy of kidney, stone burden and localization, affecting the success rate of PCNL [5, 6]. The disadvantages of PCNL in children are probable renal damage, radiation exposure, and the risks of major complications

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like sepsis and bleeding. To decrease the possibility of such complications, the nephroscopes' sizes began to be reduced. However, a few centres have reported their experiences in PCNL with different sized instruments in children [7–9].

In this study, we compared the outcomes including the morbidity and success rates among the different groups of pediatric patients undergoing PCNL using adult-sized instruments (24 F), mini-PCNL (18 F) and ultra-mini-PCNL (9.5 F).

Materials and methods

This retrospective study, which was approved by the Research and Publication Ethics Boards in Malatya/Turkey, was conducted in two urology clinics to review the medical data of 220 children (225 renal units), up to the age of 17 years, who underwent PCNL between August 1999 and April 2015. The data collected from two different centers where the operations have been performed by different surgeons. But the protocols (evaluation, surgical technics and postoperative follow up) were the same. The patients who were treated with different protocol were excluded from this study. Almost all of the stones <2 cm except lower calyx stones were firstly evaluated for SWL; however, the stones, which were estimated as so hard in radiological evaluations or unbroken by SWL, were treated with PCNL. Preoperative patient histories, physical examinations and routine laboratory tests, including urine analysis, urine culture, blood urea, serum creatinine, complete blood cell count and coagulation tests, were evaluated. To determine the size and location of the stones for planning of the treatment, abdominopelvic ultrasound, plain abdominal films and intravenous urography were used before surgery. In the patients, who were suspected to have renal and colon abnormalities or allergies of the contrast medium and the patients with non-opaque stones, computerized tomography was done. In the patients, who had a delayed in the excretion phase of intravenous pyelography, renal scintigraphy was done. Patients with abnormal renal morphology such as horseshoe kidney were excluded from the study. Besides, the patients with missing data were not included.

Surgical technique

The patients with sterile urine underwent PCNL with antibiotic prophylaxis which was carried out via parenteral administration of second generation cephalosporins. In lithotomy position, 6 F open-end catheter was inserted into the ureter via a pediatric cystoscope under general anesthesia, and then prone position was given to the patient. Before

Fig. 1 Nephroscopes with different diameters (24 F nephroscope, 18 F nephroscope and 9.5 F nephroscopes)

percutaneous access to the urinary tract using 19-G needle obtained under biplanar fluoroscopic guidance, patients' gonads were protected from X-rays using gonad shields. The tract was dilated with Amplatz dilators over a guide wire, 12 F for 9.5 F nephroscope (ultra-mini-PCNL) (Karl Storz, Germany), 20 F for 18 F nephroscope (mini-PCNL) (Wolf, Germany) and 26 F for 24 F nephroscope (Karl Storz, Germany) which were used according to the patient's age, body mass, caliceal dilatation and the size of the calculi (Fig. 1). Pneumatic lithotripsy was used for stone fragmentation. Whether there were the residual fragments was confirmed under the direct vision of nephroscope and fluoroscopy during the operation. To buffer bleeding, a 10–22 F Malecot or Foley catheter was placed according to the dilatation size. A DJ stent was intraoperatively inserted in whom there was the residual fragment requiring postoperative ESWL and/or uretero-pelvic stenosis occurred due to stone irritation. The patients were protected from hypothermic reactions during the surgery.

To evaluate residual stone and any pathology of the pelvicalyceal system occurred during surgery, plain abdominopelvic radiography was used on the first postoperative day. If there are signs of obstruction in the ureteral drainage of urine after clamping of nephrostomy tube, we performed antegrade pyelogram. Even though there is no a consensus in children, the stone piece of smaller than 4 mm was considered clinically insignificant residual fragment (CIRF). The nephrostomy tube was generally clamped at 48 h after the PCNL and was removed if there was no pain, fever or urine leakage. Size of the instruments, stone size and burden, number and location of the renal tracts, complications,

duration of nephrostomy and hospitalization time were compared as pre- and postoperative evaluation factors in this study.

Statistical analysis was performed using SPSS, version 23 (SPSS Inc., Chicago, IL, USA) and given as median (min–max) and frequencies with percentages. Normality was evaluated using the Shapiro–Wilk test. Kruskal–Wallis, Pearson Chi square and Mann–Whitney *U* test were appropriately used for statistical analyses. Multiple comparisons were carried out by Mann–Whitney *U* test with Bonferroni correction. Significance was considered $p < 0.05$.

Results

A total of 220 children (96 boys and 124 girls; mean age 8.33 years) with 225 renal units underwent PCNL for renal stones were included this study. One-hundred and twenty procedures were performed on the right side and 105 on the left side. The mean body weight was 21.6 kg (range 5.2–61 kg) and mean patient height was 110.5 cm (range 60–168 cm). The most common presenting symptom was abdominal or flank pain in 169 (76.8 %) patients. The other common symptoms were hematuria in 126 (57.2 %) patients and fever in 28 (12.7 %) patients. Thirty-one and 26 of the patients had previous ESWL and PCNL treatments, respectively, and 22 patients had a history of spontaneous stone passage before the surgery.

The mean stone burden was 1.747 ± 0.521 cm^2. The most frequent location of the stones was middle calyx (46.2 %), followed by lower calyx (18 %). Properties of the stones and access calyces are shown in Table 1. Patients were evaluated in three groups according to the size of the nephroscopes used. In group 1, 49 (22.3 %) patients were operated by 9.5 F nephroscope (ultra-mini-PCNL); in group 2, 89 (40.4 %) patients by 18 F nephrosscope (mini-PCNL); in group 3, 82 patients (37.3 %) by 24 F nephroscope (adult size PCNL). The mean stone burden, which was 1.261 ± 0.26, 1.667 ± 0.67 and 2.089 ± 0.11 cm^2 in groups 1, 2 and 3, respectively, was significantly different between the groups ($p < 0.001$). In group 1, the mean tract size was significantly lower than that in groups 2 and 3 ($p < 0.001$).

As shown in Table 1, there was not any major complication and death in our patient group. There was no significant difference in the complication rates between the groups, according to the modified Clavien classification system (Table 1). Some complications were pain, urine leakage after removal of the nephrostomy tube, postoperative fever and bleeding. The mean hematocrit drop in group 1 (0.821) was significantly lower when compared with other two groups (1.732 and 1.936) ($p < 0.001$); nevertheless, only one patient in group 2 and two patients in group 3 required blood transfusions.

The stone-free rates were 78, 75.8 and 71.4 % in the ultra-mini, mini and adult size PCNL groups, respectively; however, there was no significant difference between the groups ($p = 0.678$). The mean duration of nephrostomy was 3.14 (2–5) days, and in comparison of the groups no meaningful differences were found ($p = 0.445$). Tubeless PCNL was performed in 7 patients in group 1 and in 2 patients in group 2. Twenty-five patients had a double J stent in addition to the nephrostomy tube during the operation. Four patients (1 in group 1, 1 in group 2 and 2 in group 3), who had urinary drainage persisted for more than 24 h after removal of the nephrostomy tube, had a double J stent on 2nd day of nephrostomy tube removing due to plenty drainage and carried for a month averagely. The mean duration of hospitalization was 5.19, 5.22 and 5.68 ± 0.91 days for groups 1, 2 and 3, respectively, and there was no meaningful difference between the groups ($p = 0.357$).

Discussion

Urinary system stone disease is generally a rare condition in pediatric age group, but it is endemic in Turkey [10]. An epidemiological study conducted in Turkey reported the incidence of urinary system stone disease as 14.8 %, whereas these rates are known to be lower in America [11]. Stone disease has a high risk of recurrence and is frequently associated with environmental and dietary factors, anatomic and metabolic abnormalities or infectious diseases in children [12]. Due to these reasons, the treatment of pediatric stone disease is important, and ESWL, PCNL and flexible ureteroscopy have become the main methods in appropriate indications. The most of the stones have been treated with ESWL since 1980s, but in course of time this treatment method becomes limited to the stones <2 cm with the success rate of 75–80 % [13].

In 1985, Woodside and colleagues reported the first PCNL outcomes in children [14]. The effectiveness and safety of PCNL as a minimal invasive treatment method have been proven; however, some severe complications like bleeding requiring transfusion, organ injuries, pneumothorax and sepsis can occur [4, 5].

Dilatation of the percutaneous tract with smaller calibre dilators and using smaller sized nephroscopes can reduce the morbidity and mortality rates via reducing the damage of the renal parenchyma [7–9].

Renal access with 24–30 F access sheaths accepted in adult PCNL surgery, but this has not been standardized in children yet. On the other hand, in the previous studies, it was reported that the dilation with 24–30 F dilators does not cause significant morbidity in pediatric age groups [15]. Bleeding is one of the most frequent and serious

Table 1 Comparison of the results according to groups

	Total	Group 1 (9.5 F) (ultra-mini-PCNL)	Group 2 (18 F) (mini-PCNL)	Group 3 (24 F) (adult size PCNL)	*p* value
Total cases	220	49 (22.3 %)	89 (40.4 %)	82 (37.3 %)	
Renal units	225	50	91	84	
Side (right:left)	120:105	28:22	47:44	45:39	0.731
Bilateralite		1	2	2	
Age (years) (mean)	8.33 ± 4.34	6.67[a]	9.52	10.8	<0.001
Sex distribution (male:female)	96:124	18:31	43:46	44:40	0.871
Weight (kg) (mean ± SD)		25.5 ± 10.08[a]	32.55 ± 8.90	35.33 ± 10.35	<0.001
Height (cm) (mean ± SD)		120.50 ± 18.30[a]	131.10 ± 11.65	129.45 ± 22.40	<0.001
Mean size of stone (cm^2) (mean ± SD)		1.261 ± 0.26[b]	1.667 ± 0.67	2.089 ± 0.11	<0.001
Presenting symptoms					
Abdominal or flank pain (*n*)	169 (76.8 %)	17	75	77	
Hematuria (*n*)	126 (57.2 %)	38	67	21	
Fever (*n*)	28 (12.7 %)	19	9	–	
Site of stone					0.442
Upper calyx (*n*)	3	0	0	3	
Middle calyx (*n*)	104	17	51	36	
Lower calyx (*n*)	45	22	11	12	
Pelvis (*n*)	42	9	19	14	
Multiple calyx (*n*)	28	2	9	17	
Staghorn stone (*n*)	3	0	1	2	
Access					0.241
Upper calyceal (*n*)	3	0	0	3	
Middle calyceal (*n*)	160	21	71	68	
Lower calyceal (*n*)	52	29	13	12	
Multiple calyceal access (*n*)	10	0	7	3	
Complications					
Clavien I	11	2	4	5	0.601
Clavien II	6	1	1	4	0.282
Clavien > II	0	0	0	0	
Hematocrit drop (mean)	1.22 ± 2.89	0.821[b]	1.732	1.935	<0.001
Difference in creatinine (mean)	0.02 ± 0.18	0.018	0.024	0.028	0.786
Result					0.612
CIRF *n* (%)	40	9 (18)	13 (14.3)	17 (20.3)	
Stone-free *n* (%)	168	39 (78)	69 (75.8)	60 (71.4)	0.678
Residual stone	17	3 (6)	7 (7.7)	7 (8.33)	
Duration of nephrostomy (day) (mean ± SD)	3.14	3.11 ± 0.34	3.18 ± 0.39	3.10 ± 0.45	0.445
Hospitalization (day) (mean ± SD)		5.19 ± 1.24	5.22 ± 1.85	5.67 ± 2.15	0.357

[a] Significantly different from group 2

[b] Significantly different from group 2 and group 3

complications during or after PCNL. Bleeding as an important factor that influences both patient mortality and PCNL success can be associated with larger renal access and larger calibre nephroscopes [9]. On the other hand, some studies conducted in pediatric age group were reported that smaller access using smaller calibre instruments had similar results with regard to the complications like bleeding [7, 9, 16]. Although nephroscope size and method of entry are still debated condition in the pediatric PNL, in generally, the dilation up to 24 F is accepted in the pediatric PCNL according to some authors [17, 18]. In our study, bleeding was more distinct with 24 F nephroscope. The use of 9.5 F nephroscope (ultra-mini-PCNL) significantly decreased the drop in hematocrit level when compared

with other groups ($p < 0.001$). Blood transfusion rates in pediatric patients have been reported to be affected by the calibre of the instruments used, stone burden and operative times [6, 7]. In our current study, 1 patient in group 2 and 2 in group 3 received blood transfusions, whereas none of the children in group 1 required transfusion. On the other hand, the stone burden was significantly less in ultra-mini-PCNL group, in which hemorrhage was significantly less than the other groups. The operation duration was shorter in the group that had lower stone burden; also, this indirectly could cause less hemorrhage via reducing the operation difficulties.

PCNL success rate can be influenced by several factor, and stone-free and CIRF rates usually have been used for success assessment. Although in the pediatric age group, PCNL is difficult due to kidney size and large instruments; high stone-free rates (73–96 %) have been reported in the different pediatric PCNL series [5, 6]. The success rate of this surgery is almost similar in adults and pediatric population. In the current study, the total stone-free rate obtained regardless of the type of the instruments used was 74.6 %. Although the mean stone-free rate in group 1 (ulltra-mini-PCNL) was higher when compared with the other groups, the difference between the results obtained with pediatric type instruments was not significant in our study. Relatively less stone burden in group 1 could be the reason of higher success rate in this group. In parallel to our results, in a study conducted by Ünsal et al., the success rates obtained by pediatric and adult type nephroscopes were almost similar [8].

Although PCNL is an efficient minimally invasive method, it can result in some serious complications. There are some complicated classification systems, such as Clavien and Satava in the literature. Minor complication rates up to 83 % have been reported; however, major complications, such as sepsis and colon injuries, were rare in the previous studies [8, 20]. In the literature, the rate of postoperative fever and urinary infection was reported to be up to 29.3 [21, 22]. Bayrak et al. reported that the postoperative fever rates in children and adults were 5.4 and 5.6 %, respectively [23]. In our study, fever was seen in 6.1, 5.6 and 6.9 % of the patients using 9.5, 18 and 24 F nephroscopes, respectively; however, the difference between the groups was not significant ($p = 0.601$). The rate of urinary infection was 2.1, 1.1 and 4.8 % in groups 1, 2 and 3, respectively, and there was no significant difference between the groups ($p = 0.282$). In the literature, the rate of sepsis after surgery has varied between 0.3 and 4.7 % [19, 20]. The most important preventive measure to decrease the risk of sepsis is to sterilise patients' urine before surgery. Preoperative urinalysis and urine culture should be done in all patients; however, the patients with urinary infections should be operated after the treatment with an appropriate antibiotic. Kumar et al. reported that preoperative nitrofurantoin treatment for 1 week in adult patients reduced the risk of sepsis [24]. But, there has been no such study related to long-termed prophylactic antibiotics in pediatric patients. In our study, all patients had been treated with 50 mg/kg of ceftriaxone preoperatively.

In the previous studies, it has been reported that the tubeless PCNL in children resulted in the decrease in hospital stay and analgesia requirement [25]. In our study, we performed tubeless PCNL in 9 (4 %) patients, using 9.5 F (n 7) and 18 F (n 2) nephroscopes, in whom the stone burden was less and the operation duration was shorter. An adequate size nephrostomy tube was inserted in the rest of the patients (96 %). In our study, there was no significant difference in the duration of nephrostomy between the groups. While the duration of hospitalization was shorter in the patients using the 9.5 F nephroscope, there was no significant difference between the groups. In a previous study, Unsal et al. reported that there was no difference in the mean postoperative duration of hospitalization with different sizes of instruments [4].

The limitation of this study is that there is no chemical analysis due to the lack of data and it is retrospective. On the other hand, a large series in this study provides significant statistical assessment. Nevertheless, comparison of the results of pediatric PCNL with different sized instruments may be possible to provide a better assessment thanks to a well-designed, similar stone size and age distributions in the prospective study.

Conclusion

The aim of treatment in renal stone is to have a high success rate with minimal injury. Therefore, the treatment modality becomes important in children. There is no common consensus on usage of small calibre instruments regarding to causing less complications than adult-sized devices. Although this study is not a randomized trial, we found that the success rates obtained via using different instrument types (ultra-mini-PCNL, mini-PCNL and adult size PCNL) were similar. However, bleeding was significantly lower in ultra-mini-PCNL group, in which 9.5 F instruments were used. Bleeding appears to be related to stone burden, diameter of dilatation and calibre of instrument used. PCNL in children is a safe and practicable method for maximum clearance of stones. To reduce the certain complications of PCNL, smaller instruments can be conveniently used without affecting the success of this procedure.

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Compliance with ethical standards

This study was approved by the Research and Publication Ethics Boards in Malatya/Turkey.

Conflict of interest The authors declare that they have no competing interests and received no financial support for the research.

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