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Can single-step dilatation technique in pediatric percutaneous nephrolithotomy be an effective alternative to stepwise dilatation?

Pediatrik perkütan nefrolitotomide tek aşamalı dilatasyon tekniği, aşamalı dilatasyona efektif bir alternatif olabilir mi?

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Abstract

Aim: The most important stage of percutaneous nephrolithotomy (PNL), which is an effective and reliable method in the treatment of large and complex kidney stones, is to create a suitable and effective tract after the accessory is provided. For this purpose, different techniques such as Amplatz, baloon and Alken dilators have been described. We aimed to compare the efficacy and safety of single-step Amplatz dilatation technique with stepwise Amplatz dilatation technique in pediatric PNL patients.

Methods: This is a retrospective cohort study. We evaluated the data from 75 PNL operations performed on 72 pediatric patients in our center within the last decade. The data from single-step dilation technique patient group (group 1, n: 41) and the stepwise dilatation technique patient group (group 2, n: 34) was compared in terms of durations of fluoroscopy and surgery, stone-free and complication rates, pre and postoperative hematocrit levels and blood transfusions rates.

Results: There was no significant difference between the groups in terms of demographic data, mean stone burden, duration of surgery, decrease in hematocrit, blood transfusion rates, stone-free rate and complication rates. The median fluoroscopy durations of group 1 and group 2 were 120 and 220 seconds, respectively. Duration of surgery and fluoroscopy were significantly shorter in the single-step dilatation group

Conclusion: PNL is a safe and effective procedure for pediatric stone diseases. Performing this procedure with a single-step dilatation technique ensures that children are less exposed to radiation.

Keywords: Single-step dilatation, Nephrolithiasis, Percutaneous nephrolithotomy, Fluoroscopy

Öz

Amaç: Büyük ve kompleks böbrek taşlarının tedavisinde etkili ve güvenilir bir yöntem olan perkütan nefrolitotomi (PNL) ameliyatının en önemli aşaması akses sağlandıktan sonra uygun ve efektif bir traktusun oluşturulmasıdır. Bu amaçla Amplatz, balon ve Alken dilatatörler gibi farklı teknikler tariflenmiştir. Biz pediatrik PNL ameliyatlarında single step Amplatz dilatasyon tekniğinin etkinlik ve güvenilirliğini aşamalı Amplatz dilatasyon tekniği yapılan hastalar ile karşılaştırmayı amaçladık.

Yöntemler: Bu çalışma retrospektif kohort çalışmasıdır. Son on yılda merkezimizde 72 pediatrik hastaya uygulanan 75 PNL ameliyatının verileri değerlendirildi. Single step dilatasyon tekniği (Grup 1, n:41) ile aşamalı dilatasyon tekniği (Grup 2. n:34) yapılan hastaların floroskopi ve cerrahi süreleri, taşsızlık ve komplikasyon oranları, ameliyat öncesi ve sonrası hematokrit seviyeleri ile kan transfüzyon oranları karşılaştırıldı.

Bulgular: Gruplar arasında hastaların demografik verileri, ortalama taş yükü, operasyon süresi, hematokritte azalma, kan transfüzyonu ihtiyacı, taşsızlık oranı ve komplikasyon oranları açısından anlamlı farklılık görülmedi. Grup 1 ve Grup 2 medyan floroskopi süreleri sırasıyla 120 ve 220 saniye olarak saptandı. Single step dilatasyon grubunda ameliyat ve floroskopi süreleri anlamlı olarak daha kısa olduğu saptandı.

Sonuç: PNL, çocuk taş hastalıklarında uygulanan güvenli ve etkili bir prosedürdür. Bu prosedürün tek adımlı dilatasyon tekniği ile yapılması çocuk hastaların daha az radyasyona maruz kalmasını sağlamaktadır.

Anahtar kelimeler: Tek aşamalı dilatasyon, Böbrek taşı, Perkutan nefrolitotomi, Floroskopi

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Introduction

The main goal of urinary stone treatment in children is to provide maximum stone-free rate with minimally invasive approach. Percutaneous nephrolithotomy (PCNL) was first used for the treatment of kidney stones in pediatric patients in 1985 and has since become the first treatment option with stone-free rates of 86.9-98.5%, especially in the treatment of large and complex kidney stones [1]. Although PCNL has advantages such as rapid postoperative recovery period, high stone-free rates, no reduction in renal function due to scarring, and no inhibition of renal growth, it may still cause serious complications such as high radiation exposure, organ injury, hemorrhage and sepsis [2]. Considering the 5-year recurrence rate of 55%, these children undergo a serious radiation exposure throughout the diagnosis and treatment processes [3].

Establishing an access tract is an important step in PCNL and may be accomplished using Amplatz dilators (semirigid polyurethane fascial dilators), Alken dilators (telescopic metal coaxial dilators), balloon dilators, and one-shot dilators [4]. In order to decrease radiation exposure and shorten the processing time in adult patients, single step dilatation technique was defined and studies about its effectiveness have been published [5]. To the best of our knowledge, there are no studies in the literature that have used this technique in pediatric patients.

In this study, we aimed to compare the data of pediatric patients who underwent PCNL by using single step dilatation technique or phased dilatation technique. We also evaluated the suitability of single step dilatation technique as a safe and effective method of dilatation in pediatric patients.

Materials and methods

Data source and patient selection

This is a retrospective cohort study. Following the approval of the İzmir Tepecik Research and Training Hospital ethics committee (File Number and Date: 2018 / 7-7, 28.06.2018) we retrospectively evaluated 72 pediatric patients (44 males, 28 females) that underwent 75 PCNL procedures in our clinic between May 2008 and March 2018. The PCNL surgery was performed for the treatment of staghorn stones, upper urinary tract stones larger than 2 cm, lower-pole stones larger than 1 cm, and stones resistant to extracorporeal shock waves. Patients were divided into 2 groups. The patients who underwent single-step dilatation technique were assigned into group 1 and the patients who underwent stepwise dilatation technique formed group 2. The groups were compared in terms of pre-, post-, and intra-operative variables. Prior to the procedure, all patients underwent general physical examination to evaluate any systemic diseases and a detailed medical history form including a body mass index (BMI) was filled.

Kidney, ureter and bladder X-ray, ultrasonography, and, when needed, a spiral non-contrast tomography were used to evaluate the renal anatomy and stone localization before PCNL. According to the radiological data, stones were classified as opaque and non-opaque. The terms “simple” or “complex” were used to easily identify the localization of stones [6]. Kidney stones localized only in the calyx or pelvis were defined as simple stones, while staghorn stones, pelvic stones, and stones that fill one or more calyxes were defined as complex stones. The stone burden was approximated by combining the measurements of width and length in mm^2, as measured on x-ray (KUB) or CT in cases with non-opaque stones. In cases with multiple stones, each stone was measured separately and the total value was considered as the total stone burden. In staghorn stones, the total stone burden was calculated by measuring the area of each stone piece in the pelvis and calyxes.

The operation time was accepted as the time from the first puncture to the insertion of the nephrostomy tube. Fluoroscopic imaging time during the operation, number of accesses, access sites, tract size, and the presence of perioperative complications were recorded. In this study, two days after the procedure x-rays of the urinary system or ultrasound (for non-opaque stones) were used to evaluate residual fragments. Operation success was defined as being stone-free or having residual stone fragments of 4 mm or less. Patients with stone fragments smaller than 4 mm were evaluated as having clinically insignificant residual fragments (CIRF), while patients with stones > 4 mm were considered as having residual fragments.

Other variables included in the analysis were age, gender, change in the serum creatinine level, stone size and feature. In this study, the blood loss estimation was measured by calculating changes in hematocrit and hemoglobin values (difference between last and first Htc/Hb values). The first Htc/Hb was considered as the values obtained preoperatively, while the last Htc/Hb value was considered as obtained 48 hours after the operation. Patients who underwent blood transfusion were evaluated separately. The indications for blood transfusion were the evidence of hemodynamic instability and the postoperative Htc values below 30%. Other variables pertaining to complication rates, nephrostomy removal time, and length of hospitalization were also evaluated. The postoperative complications were evaluated according to the modified Clavien classification.

Surgical technique

Under general anesthesia, an open-ended 5 or 6 F ureteral catheter was placed in the lithotomy position using a cystoscope and the bladder was drained with a Foley catheter. The patient was then brought to the prone position. The surgical field was wiped with povidone iodine and covered with sterile pediatric percutaneous cover. The radiation source C-arm fluoroscopy device was placed under the table. After the contrast agent was injected retrogradely from the ureter catheter, the collector system access was achieved with the guidance of biplanar fluoroscope with an 18-gauge Chiba (Boston Scientific, Natick, MA, USA) needle and triangulation or bull-eye technique. After access was established, a 0.038-inch hydrophilic guide wire (Sensor™ Guide Wire, Boston Scientific, Natick, MA, USA) was placed in the collector system. Under the guidance of the sensor, the tractus was formed by stepwise or single-step dilatation with Amplatz dilators. Amplatz sheath (Boston Scientific) was positioned in the renal collecting system, based on each patient’s body size and hydronephrosis status. In stepwise dilatation technique, tract dilatation was achieved with 6, 10, 14, 18 and 20/26/30 Fr Amplatz dilators up to the target

sheath size and planned appropriate Amplatz sheath (18, 20, 26 or 30 F) was placed. Meanwhile, in the single-step dilation technique, a planned Amplatz sheath (18, 20, 26 or 30 F) was placed by itself directly into the kidney via a sensor guide together with the Amplatz dilatators. The PCNL procedures were performed using 17 or 24 F rigid (Karl Storz) nephroscope. The stone crushing process was mostly carried out using ultrasonic lithotriptors. Pneumatic lithotriptor and holmium YAG laser were used when needed. At the end of the procedure, 14 Fr reentry Malecot catheter was placed in all patients. Four experienced surgeons who have completed at least 50 PCNL procedures on adults performed all pediatric PCNLs.

Statistical analysis

In the study, depending on the assumptions, descriptive statistics such as mean (standard deviation) or median (minimum-maximal) were used for numerical variable, while frequency (n) and percentage (%) were used for categorical data. If the parametric test assumptions were met, the Student t-test was used for analysis of the difference between the numerical values of single-step vs stepwise groups, while Mann-Whitney U Test was used if the parametric test assumptions were not met. A two proportion z-tests was used to determine whether there was a difference between the groups in terms of the incidence of categorical variables and the effect of those categorical variables on groups was evaluated either by Pearson chi-square test or Fisher-Freeman-Halton exact test, depending on the hypothesis. For all tests, Type I error probability was determined as $\alpha = 0.05$.

Results

The results of 72 pediatric patients (28 females and 44 males; mean age 9 years) who underwent 75 PCNL for kidney stones during the study period were included in this study. Three of the patients underwent bilateral PCNL procedures. The most common presenting symptom was abdominal or flank pain in 51 (71 %) patients. The other common symptoms were hematuria in 40 (55.5 %) patients and fever in 12 (16.6 %) patients. The results of the study were divided into two groups according to the dilatation technique. Group 1 consisted of 41 (54.7%) patients that were treated with single-step technique, while group 2 consisted of 34 patients (45.3%) that underwent stepwise dilatation technique. The body mass index of the groups was 18.7 (10.2-26.8) and 15.79 (11-32.6), respectively, and was significantly different between the groups (P=0.005). The mean stone burden was 420 (78-2475) and 382.5 (78-1760) mm^2 in groups 1 and 2, respectively (P=0.182). Detailed demographic data including previous treatments of the patients according to groups are shown in Table 1. Median operation time was 85 (24-155) min in group 1 and 90 (40-155) in group 2 (P=0.167). Fluoroscopy time was 120 (60-380) and 220 (60-600) seconds in groups 1 and 2, respectively (P<0.001). The stone-free rates were 73.2 and 67.6% in groups 1 and 2, respectively; which was not significantly different between the groups (P=0.226). When CIRF was included, stone-free rates were 80.5 and 85.2% in groups 1 and 2, respectively. Operation data are summarized in Table 2.

As shown in Table 3, no major complications or deaths were seen in our patient groups. There were no significant differences in complication rates between the groups. Some complications observed in the groups were pain, urinary leakage after removal of the nephrostomy tube, postoperative fever, bleeding, and pneumothorax. The mean hematocrit decline in group 1 (3.26) was not significantly different from that of the group 2 (2.65) (P=0.416). However, blood transfusions were needed for 1 patient in group 1 and 2 patients in group 2. In two patients (1 from each groups), urinary drainage persisted for more than 1 day after removal of the nephrostomy tubes, therefore Double J stents were consequently inserted in these patients. Two patients in group 2 underwent ureterorenoscopy because of renal colic attack following nephrostomy tube removal. The ureteral catheter was placed after removing stone pieces that fell into the ureter. The ureter catheters were removed at the 1st postoperative day. One patient from group 2 that had supracostal access developed pneumothorax following the removal of the nephrostomy tube and tube thoracostomy had to be performed for treatment.

There was no significant difference in creatinine levels between the groups (P=0.835). The mean duration of nephrostomy in groups 1 and 2 were 2 (1-3) and 2 (0-6) days, respectively, and there was no statistically significant difference between the groups (P=0.645).

Stone analysis was available for 32 procedures and revealed calcium oxalate in 19 (59.3%), uric acid in 7 (21.8%), struvite in 4 (12.5%), and cystine in 2 (6.3%).

Table 1: Demographic data of the patients

Characteristics	Group 1 Single-step n:41	Group 2 Stepwise n:34	*P*-value
Age, years Median (min-max)	9.1 (3-17)	8.3 (1-17)	0.182[a]
Female/male ratio, n	18 (43.9%)/ 23 (56.1%)	11 (32.4%)/ 23 (67.6%)	0.307[b]
BMI kg/m2 Median (min-max)	18.77 (10.2-26.8)	15.79 (11-32.6)	0.004[a]
Stone location, n/%			
Simple	22 (53.7%)	20 (58.8%)	0.654[b]
Complex	19 (46.3%)	14 (41.2%)	
Stone size, mm2 Median (min-max)	420 (78-2475)	382.5 (78-1760)	0.182[a]
Stone side R n/% L n/%	21 (51.2%)/ 20 (48.8%)	13 (38.2%)/ 21 (61.8%)	0.261[b]
Previous ipsilateral stone treatment, %			
None	34 (82.9%)	32 (94.1%)	0.164[c]
PCNL	4 (9.8%)	1 (2.9%)	
Open renal surgery	3 (7.3%)	1 (2.9%)	
History of ESWL	5 (12.2%)	8 (23.5%)	0.197[b]

BMI: Body Mass Index, ESWL: Extra shock wave lithotripsy a: Mann-Whitney U Test, b: Pearson Chi-square Test, c: Fisher-Freeman-Halton Exact Test

Table 2: Operative data of the patients

Characteristics	Group 1 Single-step	Group 2 Stepwise	*P*-value
Duration of the procedure, min; median (min-max)	85 (24-155)	90 (40-155)	0.167[a]
Fluoroscopy time, sec; Median (min-max)	120 (60-380)	220 (60-600)	<0.001[a]
Access n(%)			
Infracostal	33 (82.5%)	28 (82.4%)	0.987[b]
Supracostal	7 (17.5%)	6 (17.6%)	
Success, n/%			
SF	30 (73.2%)	23 (67.6%)	0.226[c]
CIRF (<4mm)	3 (7.3%)	6 (17.6%)	
RF	8 (19.5%)	5 (14.7%)	
Hemoglobin decrease Mean (SD)	1.06 (1.097)	0.88 (0.939)	0.470[d]
Hematocrit decrease Mean (SD)	3.26 (3.304)	2.65 (2.867)	0.416[d]
Difference in creatinine (pre vs postop) Median (min-max)	-0.1 (-1.20-0.30)	-0.1 (-0.50-0.10)	0.835[a]
Days of nephrostomy Median (min-max)	2 (1-3)	2 (0-6)	0.111[a]
Days of hospitalization Median (min-max)	1(1-10)	2(1-5)	0.222[a]

a: Mann-Whitney U Test, b: Pearson Chi-square Test, c: Fisher-Freeman-Halton Exact Test, d: Student's t Test, SD: Standard deviation

Table 3: Comparison of the rate of complications between the groups according to the modified Clavien classification

Clavien grade	Group 1 Single-step n:41	Group 2 Stepwise n:34	*P*-value
G1 total, n (%)	2 (4.8)	4 (11.7)	
Fever	1	2	
Pain	1	2	
G2 total, n (%)	3 (7.3)	2 (5.8)	
Blood transfusion	1	2	
UTI	2	0	
G3b Total, n (%)	1 (2.5)	4 (11.7)	
DJ for urinary leakage	1	1	
URS	0	2	
Pneumothorax	0	1	
Total, n (%)	6 (14.6)	10 (29.4)	0.122[a]

UTI: Urinary tract infection, DJ: Double J stent, URS; Ureteroscopy a: Two-Proportion z Test

Discussion

In recent years, a significant increase has been detected in the incidence of pediatric stone disease. The reason for this increase may be the ever-increasing sedentary lifestyle (TV, PC games and immobile life preferences, etc.) and the growing fast food consumption (salt consumption, excess weight, etc.) [7].

The main concerns in pediatric stone disease are the presence of underlying metabolic and anatomical disorders, the possible side effects of various treatment options on the developing kidney, and most importantly, high recurrence rates and exposure to radiation during a long-term follow up [8]. Since it was first introduced to pediatric cases by Woodside JR in 1985, PCNL has been a reliable and minimally invasive treatment option in the treatment of stones larger than 2 cm, large and complex stones, or kidney stones resistant to extracorporeal shock wave lithotripsy (ESWL) treatment [9]. Exposure to radiation during this procedure is a serious concern for both the surgical team and children, who are more susceptible to radiation poisoning. Frattini et al. [10] have defined a single-step dilatation technique that aims to reduce both the operative time and radiation exposure in adult patients.

After kidney access has been achieved, balloon dilatation, alkaline dilatators or Amplatz dilators can be used to create a suitable tract. Although some studies have shown that there is no significant difference between the use of balloon dilatators and Amplatz dilators for dilatation of the tract, there are studies that indicate that the stepwise use of Amplatz dilators can shorten both the duration of surgery and fluoroscopy time [11,12]. The use of balloon dilators for tract dilatation has been limited in Turkey due to high cost. Amirhassani et al. [4] showed that in adults, compared to the stepwise technique, a single-step dilatation technique shortened the operation time and fluoroscopy time. Suelozgen et al. [5] evaluated 932 adult patients who underwent PCNL and reported that single-step dilation technique was effective and safe. We could not find any studies comparing the stepwise Amplatz dilatation technique with single-step dilatation technique in pediatric patients. In our study, we found that both the operation time and the fluoroscopy time were significantly lower in the pediatric patient from single-step dilatation group compared to the stepwise dilatation group. We believe that this result is very important in showing that the single-step dilatation method can reduce pediatric patients' exposure to radiation. At the same time, it is known that performing PCNL under ultrasound guidance in pediatric patients reduces exposure to radiation during the access phase and also results in less injury to neighboring organs [13].

Frattini et al. [10] reported that stepwise dilatation technique was unsuccessful in two patients who had previously undergone open renal surgery, therefore suggested performing single-step dilation in those patients. However, both Sofikerim et al. [14] and Amjadi et al. [15] have reported that one-step dilatation technique provided easy access in the patients who underwent open renal surgery. They stated that this method is safe, associated with decreased radiation exposure in the patient and the surgical team, and can be applied as a standard treatment method of adult patients. In our study, the single-step dilation group included 2 patients who had previously undergone open renal surgery. An appropriate tract was established in these 2 patients with single-step technique and no further dilatation was required.

Hemorrhage has always been a major complication since the introduction of PCNL. While mild hemorrhages can be managed by conservative methods, moderate or severe hemorrhages may require transfusions. The rates of PCNL-related transfusions vary in pediatric patients. Fraser et al. [16] reported no hemorrhagic complications requiring transfusion, whereas Özden et al. [17] reported 24% transfusion rate in the first 25 patients and 10% in the next 28 patients. In the light of this data, they suggested that hemorrhage rates may decrease with the increase of clinical experience. In one study, stepwise and single-step dilatation patient groups were compared in terms of the effect of chosen technique on hemorrhage. Although the transfusion- requiring hemorrhage rates were lower in the single-step dilatation group, this difference was not statistically significant [18]. Desai et al. [19] reported that establishing more than one tract during PCNL and the diameter of those tracts being larger than 24 F were significant factors affecting the decrease in Hb values. It is suggested that a smaller tract diameter leads to less tissue displacement and less nephron damage. In addition to these factors, it is known that minor and careful manipulations during surgery may play an important role in the prevention of hemorrhages. In our study, a total of 3 patients had to undergo postoperative blood transfusions and the transfusion rate of the entire study population was 4%. Blood transfusion was performed in 1 patient in the single-step group and in 2 patients in stepwise dilatation group. The rates of transfusion requirement were lower in single-step dilation group compared to the stepwise dilation group, but as in aforementioned studies, the difference between groups was not statistically significant. In our study, the transfusion rates were lower than that in the literature. We believe that it was due to several factors, such as being able to establish a single tract in almost all patients, majority of the stones being simple in character, and having a highly experienced surgical team. We could not evaluate the effect of the tract diameter on hemorrhage because the tract numbers were equal in both groups and we did not do a sub-analysis of the groups in terms of tract diameters.

Postoperative fever and leakage around the nephrostomy tract are considered minor complications in pediatric PCNL patients [20]. In our study, 6 patients had postoperative fever and pain that responded to antibiotherapy and anti-inflammatory treatment. Although these minor complications were seen less frequently in the single-step group, this difference was not statistically significant.

In the literature, it is reported that the most frequently injured structures during PCNL, especially during entering near the 12th rib, are the pleura and the lungs [21]. In our study, 1 patient in the stepwise dilatation group (1.3%) developed hydropneumothorax requiring a chest tube insertion. This was probably due to the tract established between the 11th and 12th ribs. This patient recovered with the help of the chest tube drainage and was discharged without any further complications within 7 days.

PCNL operations have a very low mortality rate. No complications resulting in death have developed in our study.

Limitations

There are certain limitations in our study. The most basic of them are the retrospective design of the study and limited number of cases. The wide age range of patients, varying sheath sizes, the lack of a patient group that underwent balloon dilatation, the failure to perform sub-analysis of the factors affecting hemorrhage can be considered as other limitations.

Conclusion

PCNL surgery with single-step dilatation technique is safe, and can significantly reduce fluoroscopy time. The efficacy and reliability of this technique should be verified with further studies.

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