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Effects of the stone density on the outcome of percutaneous nephrolithotomy in pediatric population

Pediatrik popülasyonda taş dansitesinin perkütan nefrolitotomi sonuçlarına etkisi

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Abstract

Aim: The measurement of the stone densities of urinary system calculi in Hounsfield units (HU) using non-contrast computed tomography (NCCT) provides information regarding the composition and hardness of the stones. This study aims to evaluate the effects of stone HU values on the percutaneous nephrolithotomy (PCNL) outcomes in pediatric stone disease patients.

Methods: In this retrospective cohort study, the records of 57 pediatric patients, who had undergone PCNL between 2010 January and 2018 May, were evaluated. Demographic data, stone characteristics, peroperative changes, outcomes, and complications were obtained from patient records. The patients were divided into two groups based on their HU values: the low HU group (HU ≤1000) and the high HU group (HU >1000).

Results: A total of 61 PCNL operations were performed on 57 pediatric patients. Overall median stone size was 420 mm^2 – 475 mm^2 (78-2475) and simple/complex stone rate was (52.4%) / 29 (47.5%). A total of 38 patients were examined using NCCT prior to the operation. Twenty-two of the patients had an HU value ≤1000, whereas 16 had an HU value>1000. There were no statistically significant differences between the low and the high HU groups in terms of the duration of procedure, fluoroscopy time, success rates, and complications.

Conclusion: PCNL surgery is an effective method for the treatment of large and complex stones in the pediatric population. We determined that in pediatric patients who were evaluated using NCCT prior to PCNL the stone HU values of did not influence PCNL success.

Keywords: Hounsfield unit, Kidney stone, Percutaneous nephrolithotomy, Pediatrics

Öz

Amaç: Kontrastsız bilgisayarlı tomografi (BT) kullanılarak, üriner sistem taşlarının Hounsfield ünitesi (HU) ölçümü ile, taşların dansiteleri hakkında bilgi verir. Bu çalışmada, pediatrik taş hastalığı olan hastalarda taş HU değerlerinin perkütan nefrolitotomi (PCNL) sonuçları üzerindeki etkileri değerlendirildi.

Yöntemler: Bu retrospektif kohort çalışmasında, Ocak 2010 ve Aralık 2018 tarihleri arasında PCNL uygulanan 61 pediatrik hastanın kayıtları değerlendirildi. Hasta kayıtlarından tüm hastaların demografik verileri, taş özellikleri, peroperatif değişiklikleri, sonuçları ve komplikasyonları tarandı. Operasyon öncesi BT çekilen çocuk hastaların taş yapıları, HU değerlerine göre iki gruba ayrıldı: düşük HU grubu (HU ≤1000) ve yüksek HU grubu (HU >1000).

Bulgular: 61 pediatrik hastaya toplam 65 PCNL operasyonu uygulandı. Tüm hastaların medyan taş boyutu 420 mm^2 – 475 mm^2 (78-2475), basit / kompleks taş oranı 36 (%55,3) / 29 (%44,6) idi. Operasyon öncesi BT kullanılan toplam 38 hasta incelendi. Hastaların 22'sinde HU değeri ≤1000 iken, 16'sında HU değeri >1000 idi. Düşük ve yüksek HU grupları karşılaştırıldığında, gruplar arasında işlem süresi, floroskopi zamanı, başarı oranları ve komplikasyon oranları açısından istatistiksel olarak anlamlı fark saptanmadı.

Sonuç: Pediatrik popülasyonda uygulanan PCNL ameliyatı, büyük ve kompleks taşların tedavisi için etkili bir yöntemdir. PCNL'den önce BT kullanılarak değerlendirilen pediatrik hastalarda, taş HU değerlerinin PCNL başarısını etkilemediğini belirledik.

Anahtar kelimeler: Hounsfield ünit, Böbrek taşı, Perkutan nefrolitotomi, Pediatri

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Introduction

Stone disease is a significant health problem for the pediatric population, especially in countries such as Turkey, where the stone disease is endemic [1]. Due to high recurrence rates, minimally invasive treatments that offer high stone-free success rates such as shock-wave lithotripsy (SWL), retrograde intrarenal surgery (RIRS), and percutaneous nephrolithotomy (PCNL) have priority over open surgery in the treatment of stone disease in the pediatric patients [2]. In their guidelines on pediatric urology, the European Association of Urology recommends PCNL surgery as the primary treatment for pediatric staghorn stones, kidney pelvic stones larger than 2 cm, and lower pole kidney stones larger than 1 cm [3]. On the other hand, the risk of PCNL resulting in potential renal damage, potential complications such as hemorrhage, and the associated radiation exposure may cause concerns for both the surgical team and the parents. However, latest publications report that this surgery can be safely performed with high success and low complication rates even in pre-school children [4,5].

The measurement of the stone densities of urinary system calculi in Hounsfield units (HU) using non-contrast computed tomography (NCCT) provides information regarding the composition and hardness of the Stones [6]. Numerous studies investigating adult and pediatric patients have shown that there is a relationship between the stone density and SWL success. [7-10]. The effect of this value on the outcomes of RIRS and PCNL performed on adult patients has also been evaluate [11-13]. However, to the best of our knowledge, the direct effect of Stone density on the outcome of PCNL surgery performed on children has not been evaluated to date. In this study, we aimed to investigate the effects of HU values on surgical outcomes and complications by evaluating patients in various age groups, who had undergone PCNL surgery due to kidney stones and who had undergone preoperative NCCT examinations.

Materials and methods

Following the ethics committee's approval (Tepecik Training and Research Hospital, 2018/7-7, 06/28/2018) we retrospectively evaluated records of patients of ages 0-18, who had undergone PCNL operations at our urology clinic between the dates January 2010 and May 2018. We selected 57 pediatric patients. All patients were evaluated preoperatively with kidney ureter bladder (KUB) x-ray and ultrasound (USG) of the urinary system. Patients who had suspicious or inconclusive USG results, presented with kidney anomalies on urinary USG, had staghorn and semi-staghorn calculi, and had non-opaque stones, were examined with NCCT. Nineteen patients without indication for NCCT or who did not undergo NCCT were excluded from the study. Overall, 38 pediatric patients that had indications for and undergone NCCT were included in the study. The patients were divided into two groups based on their HU values: the low HU group (HU $\leq$ 1000) and the high HU group (HU $>$ 1000). Moreover, patients were divided into three groups according to their age and comparisons of these age groups were also conducted. All patients were evaluated by pediatric and anesthesia teams. Demographic data, Stone characteristics, preoperative, peroperative, and postoperative changes, surgical outcomes, and complications were acquired from patient records. Full blood count, serum creatinine levels, bleeding profiles, complete urinalysis results, and urine cultures were evaluated preoperatively. Those who had sterile urine cultures were approved to surgery. Those who had resistant infections were started on antibiotherapy prior to and following the surgery. The NCCT with a 64 multislice CT device (Aquilion, Toshiba Medical Systems, Tokyo, Japan) was performed preoperatively on patients who had indications for NCCT. The region of interest (ROI) and the HU value were calculated automatically from the picture archiving and communication system (PACS). Stones were classified as opaque or non-opaque based on radiological data. Stone localization was determined as upper, middle, lower, lower calyx, and pelvis. Stone size was measured by multiplying the largest width and length of the stone. For patients who had multiple stones in their urinary system, stone size was calculated by measuring each stone and calculating the sum of individual stone sizes. In our study, the Stone was classified as non-complex if it had an isolated pelvic, upper calyceal, middle calyceal, or lower calyceal localization, and as complex if there were partial or complete staghorn calculi and if stones were localized in the renal pelvis with additional presence in any calyx. Hydronephrosis was classified according to the Society for Fetal Urology grading system as none-mild or moderate-severe [14].

Surgical technique: All PCNL operations were performed under general anesthesia. Prior to induction, patients were administered single-dose second-generation cephalosporin intravenously based on weight. First, in the lithotomy position, a 5F open-ended ureteral catheter was inserted to the ureter on the surgical side with cystoscopy and was affixed onto the Foley catheter. The patient was then placed in the prone position. The urinary system was accessed using an 18 Gauge Chiba (Boston Scientific, Natick, MA, USA) needle with the 'triangulation' or 'eye of the needle' technique along with fluoroscopy. Access location was recorded as below (infracostal) and above (supracostal) the 12th rib. Following access, a 0.038-inch hydrophilic guidewire (SensorTM Guide Wire, Boston Scientific, Natick, MA,USA) was advanced into the kidney. Stepwise or one-shot dilatation was performed with Amplatz dilators under the guidance of the sensor. PCNL procedures were performed using 20/24/30 Fr Amplatz sheaths (Amplatz sheat, Boston Scientific) and 17F rigid (Karl Storz) or 24F nephroscopes. Stone fragmentation was performed using an ultrasonic lithotriptor (Swiss LithoClast Master). At the end of the procedure, all patients had 14F nephrostomy catheters placed. Operative time (time period between the first kidney puncture and insertion of the nephrostomy tube) and fluoroscopy time were recorded. Foley catheters were removed on the 1st postoperative day. The nephrostomy catheter was removed on the 2nd postoperative day in patients who had clear urine and presented no complications. Postoperative complications were evaluated based on the modified Clavien grading system. 15 Complication rates associated with different age groups were also compared according to the Clavien grading system. Patients who manifested urine drainage in the nephrostomy tract for longer than 48 hours, had a double J stent inserted under general anesthesia. Stone-free states and residual fragments (>4mm) were evaluated by using KUB x-ray performed on the 2nd postoperative day for opaque stones, and using urinary USG of the urinary system for non-opaque stones.

Statistical Method: For quantitative variables in the study, descriptive statistics were presented as mean (standard deviation) or median (min-max) based on assumptions, while the categorical data were presented as frequency (n) and percentages (%). If the parametric test assumptions regarding whether or not there is a difference between the HU <1000 and HU >1000 groups in terms of quantitative variables were satisfied, the Student's t-test was used, and if they were not satisfied, the Mann-Whitney U test was used. If the parametric test assumptions regarding whether or not there were any differences between age groups were not satisfied, the related analysis was performed using the Kruskal-Wallis test. For both the HU groups and the age groups, the effects of categorical variables on the groups were evaluated using the Pearson Chi-square Test, Fisher's Exact Test, or the Fisher-Freeman-Halton Exact Test based on the assumptions. For all tests, the probability of a Type I error was considered α=0.05.

Results

Our study evaluated 61 PCNL operations performed on 57 pediatric patients. Patients' age, gender, body mass index (BMI), stone characteristics, presence of previous SWL and stone surgery, hydronephrosis grades, peroperative-postoperative properties, and complication rates have been summarized in Table 1. Three patients who underwent PCNL had solitary kidneys and one patient had a double collecting system. Two patients had bilateral stones and underwent multiple PCNL operations in separate sessions. In addition, two other patients underwent a second PCNL session on the previously operated side, due to residual stones after the first session of PCNL. Comorbidities included thalassemia major in one patient and congenital visual impairment in another patient. NCCT scans were performed prior to the operation for a total of 38 patients who were to undergo PCNL. Twenty-two of the patients had an HU value ≤1000 (low HU group), whereas 16 had an HU value >1000 (high HU group). There were no statistically significant differences between the low and high HU groups in terms of age, stone size, duration of procedure, fluoroscopy time, success rates, individual incidences of grade 1, grade 2, grade 3, and grade 4 complications, and days of nephrostomy, and hospitalization (Table 2).

Patients were assigned to three groups based on age, group 1 (Ages 0-5), group 2 (Ages 6-12), and group 3 (Ages 13-18). The patients' characteristics, peroperative data, complication rates, and stone-free rates were compared with regard to their age groups (Table 3).

Table 1: Patient, stone characteristics and peroperative, postoperative outcomes

Parameter	Value
Patients, n	61
Renal units operated, n	65
Median age, years (min-max)	12 (2-18)
Mean (SD), years	11.5 (5.5)
Gender, n (%)	
Female	26 (42.6%)
Male	35 (57.3%)
Median BMI, kg/m2 (min-max)	18.54 (10.1-32.6)
Laterality: n (%)	
Right	28 (43%)
Left	37 (56.9%)
Median stone size, mm^2 (min-max)	420 (78-2475)
Mean (SD), mm2	680.1 (561.2)
Stone complexity, n (%)	
Simple	36 (55.3%)
Complex	29 (44.6%)
Stone opacity	
Opaque	62 (95.3%)
Nonopaque	3 (4.6%)
Previous stone interventions, n (%)	
None	48 (73.8%)
Ipsilateral SWL	8 (12.3%)
Ipsilateral PNL	5 (7.6%)
Ipsilateral open surgery	4 (6.1%)
Hydronephrosis degree, n (%)	
None-Mild	31 (47.6%)
Moderate-Severe	34 (52.3%)
Median operative time, mins. (min-max)	90 (24-155)
Mean (SD), mins	84.8 (29.5)
Median scope time, secs. (min-max)	120 (60-1220)
Mean (SD), secs	172.7 (172.2)
Sheath size, n (%)	
<22 Fr	31 (47.6%)
>22 Fr	34 (52.3%)
Accesses, n (%)	
Single	58 (89.2%)
Multiple	7 (10.7%)
Access number, Mean (SD)	1.1 (0.3)
Access, n (%)	
Infracostal	55 (84.6%)
Supracostal	10 (15.3%)
Hgb Preop-Postop, Mean (SD)	1.1 (1.1)
Hematocrit Preop-Postop, Mean (SD)	3.2 (3.2)
Median duration of nephrostomy, days (min-max)	2 (1-3)
Mean (SD), days	1.7 (0.5)
Median hospitalization days (min-max)	2 (1-10)
Mean (SD), days	2.7 (2.1)
Result, n (%)	
Stone-free	55 (84.6%)
Residual stone	10 (15.3 %)
Complications, n, (%)	
Grade 1	6 (9.2%)
Grade 2	5 (7.6%)
Grade 3	3 (4.6%)
Grade 4	0
Overall complication rates	14 (21.5%)

SD: Standard deviation, BMI: body mass index, Fr: French, SWL: shock-wave lithotripsy, PCNL: percutaneous nephrolithotomy, Hgb: Hemoglobin

Table 2: Comparison of the results according to HU groups

Characteristics	HU<1000 N=22	HU>1000 N=16	*P*-value
Age,			0.968[a]
Mean (SD), years	11.77 (5.8)	12 (4)	
Median age, years (min-max)	15 (3-18)	16 (4-18)	
Gender, n (%)			0.171[b]
Female	11 (50%)	5 (31.2%)	
Male	11 (50%)	11 (68.7%)	
Median stone size, mm^2 (min-max)	506 (238-2475)	412 (238-1760)	0.639[a]
Site of Stone location, n/%			0.832[b]
Simple	9 (40.9%)	6 (37.5%)	
Kompleks	13 (59.1%)	10 (62.5)	
Duration of the procedure, minutes Mean (SD)	89.09 (27.344)	95.133 (27.299)	0.518[c]
Median fluoroscopy time, seconds (min-max)	120 (75-600)	120 (60-380)	0.598[a]
Tract size, n (%)			0.832[b]
<22 Fr	9 (40.9%)	6 (37.5)	
>22 Fr	13 (59.1%)	10 (62.5%)	
Median days of nephrostomy (min-max)	2 (1-3)	2 (1-2)	0.987[a]
Median days of hospitalization (min-max)	1 (1-8)	2 (1-6)	0.065[a]
Success, n/%			0.871[b]
Stone Free	19 (86.3%)	13 (81.2%)	
Residual Stone	3 (13.6%)	3 (18.7%)	
Modified Clavien classification system, n/%			0.160[d]
Grade 0	19 (86.3%)	12 (75%)	
Grade 1	1 (4.5%)	2 (9.5%)	
Grade 2	1 (4.5%)	1 (4.8%)	
Grade 3	1 (4.5%)	1 (9.5%)	
Overall complication rates	3 (13.6%)	5 (25%)	

SD: Standard deviation, HU: Hounsfield Unit, Fr: French, [a] Mann-Whitney U Test, [b] Pearson Chi-square Test, [c] Student's t Test, [d] Fisher-Freeman-Halton Exact Test

Table 3: Comparison of the results according to groups

Total cases, n (%)	Group 1 n=13 (21.3%)	Group 2 n=17 (27.8%)	Group 3 n=31 (50.8%)	*P*-value
Age, years				-
Mean (SD)	3.8 (1)	8.8 (2)	16.6 (1.3)	
Median (min-max)	4 (2-5)	8 (6-12)	17 (13-18)	
Gender, n (%)				<0.001[b]
Female	9 (69.2%)	9 (52.9%)	6 (52.9%)	
Male	4 (30.7%)	8 (47%)	25 (47%)	
Median stone size, mm^2 (min-max)	158 (78-2475)	375 (120-1564)	345 (126-1760)	0.055[a]
Stone complexity, n (%)				0.510[b]
Simple	9 (60%)	8 (47%)	19 (57.5%)	
Complex	6 (40%)	9 (52.9%)	14 (42.4%)	
Median operative time, mins. (min-max)	90 (25-125)	95 (50-155)	87.5 (24-155)	0.509[a]
Median scope time, secs. (min-max)	140 (60-220)	123 (77-600)	120 (60-1220)	0.575[a]
Sheath size, n (%)				0.032[b]
<22 Fr	11 (73.3%)	9 (50%)	11 (34.3%)	
>22 Fr	4 (26.6%)	9 (50%)	21 (61.7%)	
Median Hgb Preop-Postop, (minimum-maksimum)	0.8 (-0.2-2.10)	1 (-1.0-2.80)	1.4 (-0.9-4.8)	0.363[a]
Median Hematocrit Preop-Postop, (minimum-maksimum)	2.8 (0.8-6.8)	3.4 (-3.0-8.4)	4.2 (-4.60-11.2)	0.846[a]
Median duration of nephrostomy, days (min-max)	2 (1-3)	2 (1-2)	2 (1-3)	0.712[a]
Median hospitalization days (min-max)	1 (1-3)	2 (1-4)	1 (1-10)	0.315[a]
Result, n (%)				0.842[b]
Stone Free	13 (86.6%)	15 (88.2%)	28 (84.8%)	
Residual Stone	2 (13.3%)	2 (11.7%)	5 (15.1%)	
Complications, n, (%)				
Grade 1	1 (6.6%)	3 (17.6%)	2 (6%)	
Grade 2	2 (13.3%)	0	3 (9%)	-
Grade 3	0	3 (17.6%)	0	
Grade 4	0	0	0	
Overall complication rates	3 (20%)	6 (35.2%)	5 (15.1%)	-

SD: Standard deviation, HU: Hounsfield Unit, Fr: French, Hgb: Hemoglobin, [a] Mann-Whitney U Test, [b] Pearson Chi-square Test

Discussion

In regions that are endemic for stone disease, such as Turkey, pediatric stone disease is a significant health problem due to its high recurrence rate and the associated need for lifelong follow-up. A study done on pediatric stone disease patients reported a five-year recurrence rate of 55% after urinary stone surgery [15]. The need for repeated surgical interventions due to this high recurrence rate have highlighted the importance of minimally invasive treatments (SWL, RIRS, PCNL). The role of these procedures in the treatment of kidney stones has been established by guidelines and our daily practice. As our clinic is the referral center for Stone surgery in our area, we encounter stones with high stone burdens and complex stones more frequently.

Various studies have shown that SWL treatment is safe and effective in the treatment of kidney stones. Although SWL is a minimally invasive treatment option, its requirement for general anesthesia and radiation exposure over repeated sessions make up its most important disadvantages. Moreover, the success rate associated with this treatment method decreases with stone size, presence of multiple stones, and high stone complexity [16,17]. It has been stated that PCNL is more effective for these types of stones, and pediatric stone-free rates that vary between 67% and 100% in patients with large stones have been reported in the literature [18-22]. Ozden et al. [19] reported a success rate of 73.6% in their study where they applied PCNL monotherapy on 53 pediatric renal patients, who had a mean stone size of 654.0 (92.4). In our study, the mean stone size of our patients was 683 (564.8) and our stone-free rate was determined as 85.2%, paralleling the literature. We think that the experience of the surgeon has greater importance in the case of pediatric stone disease patients with high stone burden and complex stones in particular.

While NCCT scans are commonly used prior to PCNL surgery in adult patients, their use in the case of pediatric patients causes concerns for the physician and the parents due to radiation exposure. However, studies have shown that NCCT performed prior to PCNL facilitates the planning stage and access, especially in cases of high stone burden and complex stones [23-25]. Moreover, it was reported to provide advantages relating to the prediction of certain major complications such as a retrorenal colon [23]. At our clinic, we supplement USG with NCCT as an imaging method in cases of suspicious or inconclusive USG results, kidney anomalies on USG, staghorn and semi-staghorn calculi, and non-opaque stones. Moreover, by conducting the preoperative NCCT, we can calculate the HU values of the stones and obtain information about stone densities before the operation. Although different cut-off values have been used in studies investigating the relationship between stone density and SWL success (1000> HU and 600> HU), it has been demonstrated clearly that lower stone densities are connected to increased SWL success rates [7-10]. On the other hand, Ito et al. [11] have demonstrated the relationship between the HU value and the effectiveness of the stone fragmentation in RIRS. This study has also reported that in stone sizes of 20 mm and below both maximum and mean HU values were determinative for the duration of operation. However the relationship between the success of PCNL performed on adults and stone density is contended in the literature [12,13]. In their study, Gucuk et al. [12] reported that in contrast to SWL, lower Stone densities (HU <677.5) translated to a 2.65 fold increase in the residual stone rate following PCNL. They explained this by suggesting that lower-density stones became more non-opaque and were less visible under fluoroscopy during surgery, resulting in an increase in residual stones. On the other hand, another study determined that stone HU ratios (1000> HU-HU <1000) did not affect post-PCNL stone-free rates but the hardness of the stone prolonged the operative duration and fluoroscopy time[13]. We determined that the HU ratios of our pediatric patients did not affect PCNL success, and while the high density group with a stone density >1000 manifested longer operative durations, there were no statistically significant differences.

In line with the technological advances that took place in recent times, the shift from open surgery to minimal invasive surgery required the surgical tools to decrease in size. The reduction in sheath size lead to a decrease in blood transfusion rates [26,27]. Celik et al. [28] grouped pediatric patients in their study based on the size of the nephroscopes they used during the PCNL procedure. They reported that patients they operated using pediatric nephroscopes manifested a statistically lower fall in hematocrit values. However, although studies report decreased rates of hemorrhage in association with the decrease in sheath and nephroscope sizes, there are also studies that suggest that using adult type instruments on this age group does not increase the rate of general complications [26-29]. Adult type instruments also possess advantages due to being readily available at every center and allowing faster stone clearance during surgery in patients with higher stone burdens. In our pediatric cases, we selected dilatation sets, sheaths, and nephroscopes based on the patient's age, BMI, and stone burden.

Various studies attest to the safety and effectiveness of PCNL surgery for patients in all age groups ranging from newborn to late adolescence [4,5]. In their study, Mahmud et al. [4] performed PCNL on 29 children between the ages 0-5. In their study the median stone size was 23.6 mm (13-60 mm).

They reported a 6% complication rate and a stone-free rate of 60% in the third month following the PCNL. In another study, they performed PCNL on 20 patients between the ages 0-5 [5]. Median stone size was 33 mm (20-46 mm). They achieved a stone-free rate of 79.1% and reported an overall complication rate of 15.38%. In our study, the overall complication rate in the 0-5 age group was 23% (all the complications were grade 1 and grade 2) and the stone-free rate was determined as 84.6%. No statistical differences were determined with regard to overall complication rates and stone-free rates of PCNL surgery performed on the 0-5 age group and the other age groups. While the rate associated with the use of sheaths smaller than 22F is 73.3% for the 0-5 age group, this rate is 32.3% for patients in the 13-18 age range. The variability of this rate across age groups also demonstrated statistical significance.

One of the strengths of our study is that it is one of the very few studies that investigated the relationship between HU and success in PCNL cases. Additionally, the absence of a statistical difference between pediatric patients in the different age groups and HU groups with regard to stone size and stone complexity, which are known to affect PCNL success, can be considered another strength. The limitations of our study can be listed as being based on retrospective data, involving heterogeneity in sheath and nephroscope sizes used within age groups during PCNL operations and including a relatively low number of patients.

In conclusion, PCNL surgery is a minimally invasive treatment method that can be safely and effectively used on pediatric patients that have complex stones and high stone burdens. Based on the data from our retrospective study, we determined that stone HU values of pediatric patients who were examined using NCCT prior to PCNL did not influence operative durations, fluoroscopy times, and PCNL success. The technological advances of our time brought a gradual decrease in the size of surgical equipment used in PCNL surgery. We believe that the reduction in size of surgical equipment and increased experience in performing PCNL surgeries facilitates successful performance of this operation on every age group with increased reliability.

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