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ORIGINAL PAPER

Which factors affect the success of pediatric PCNL? Single center experience over 20 years

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Summary

***Objective:** We aimed to investigate the impact of surgeons' experience on pediatric percutaneous nephrolithotomy (PCNL) outcomes.*
***Materials and methods:** Between June 1997 and June 2018, 573 pediatric patients with 654 renal units underwent PCNL for renal stone disease by senior surgeons. Data were divided into two groups, group-1 (n = 267), first ten years period, group-2 (n = 387); second ten years period.*
***Results:** Mean ± SD age of patients was 7.6 ± 4.9 (1-17) years. The stone-free rates (SFR) assessed after 4 weeks were 74.9% vs. 83.4% in group-1 vs. group-2, respectively (p = 0.03). The mean operation time, fluoroscopy time, and the number of patients requiring blood transfusion significantly decreased in group 2 (100.4 ± 57.5 vs. 63.63 ± 36.3, 12.1 ± 8.3 vs. 8.3 ± 5.4, and 24.3% vs. 2.9%; p < 0.001, p < 0.001, and p = 0.002 in group-1 versus group-2, respectively). On multivariate analysis, increasing stone size increased operation time (p < 0.001), fluoroscopy time (p < 0.001), intraoperative and postoperative blood transfusion rates (p = 0.006 and p = 0.018, respectively), and hospital stay (p = 0.002) but was not associated with change of glomerular filtration rate (GFR) (p = 0.71). Sheath size also correlated with increased fluoroscopy time (p < 0.001), operation time (p < 0.001), intraoperative blood transfusion (p < 0.001) and hospital stay, but sheath size did not affect postoperative blood transfusion (p = 0.614) or GFR change (p = 0.994).*
***Conclusions:** The percutaneous nephrolithotomy (PCNL) is a minimally invasive procedure and is well accepted because of its lower complication rate and high efficiency for pediatric patients. Stone and sheath size are predictive factors for blood loss and hospital stay. During 20 years, our fluoroscopy time, operation time, blood loss, and complication rates decreased, and stone-free rate increased.*

KEY WORDS: *Pediatric; Percutaneous; Urinary calculi; Endourology.*

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INTRODUCTION

Pediatric stone-disease is widespread in developing countries and Turkey (1). The surgical management of stone disease has changed because of technological advances in recent years. For renal stones smaller than 2 cm, extracorporeal *shock wave lithotripsy* (SWL) and *retrograde intrarenal surgery* (RIRS) are the treatments of choice in children (2). Additionally, over the last two decades, *percutaneous nephrolitotomy* (PCNL), with low complications and high success rates, has become the standard treatment of choice for kidney stones > 2 cm and is an alternative procedure for stone size between 1-2 cm at lower pole (2, 3).
PCNL is an effective and safe procedure in pediatric patients (4-7). Nevertheless, serious complications such as bleeding requiring transfusion, organ injuries, pneumothorax, infection, and sepsis, still have been reported for this procedure (7). There are a few factors identified as affecting complications, including stone size, sheath size, number of punctures, presence of hydronephrosis, and prolonged operation time (8, 9). Recent studies of stone disease treatment showed increased success rates, and also decreased complication rates in association with increase of expertise in high volume centers (7, 8).
In this retrospective study, we aimed to evaluate the impact of surgeons' experience on complication rates, success rates, and the management of complications along a period of more then 20 years.

MATERIALS AND METHODS

Between June 1997 and June 2018, 573 pediatric patients with a total of 654 renal units underwent PCNL for renal stone disease. The patients with bilateral kidney stones were treated with staged procedures. All patients were assessed preoperatively with excretory urography, renal ultrasound, and/or non-enhanced spiral computerized tomography, and urine was collected for culture analysis before surgery. Written informed consent was achieved for all participants. After approvel by *Cukurova University Ethics Committee*, June 2018/78, preoperative data were obtained, including gender, age, operation time, sheath size, laterality, stone burden, hematocrit, and serum creatinine. The stone burden was calculated by the stone surface area formula.
Intraoperative and postoperative data were obtained including pre/postoperative variation of *glomerular filtration rate* (GFR) (calculated with Cockcroft Gault equations), drop of hemoglobin levels, transfusion rate, complications according to the Clavien classification, operative time, length of hospital stay and *stone-free rate* (SFR) (10, 11).

No conflict of interest declared.

Additionally, we divided the data into two groups. In group-1, PCNL was performed in the first ten years period (1997-2007); in group-2, PCNL was performed in the second ten years period from 2008 to the present.

Surgical technique

All procedures were performed by four experienced surgeons who had been working for at least 20 years in our clinic and staff surgeons under supervision of mentors. All patients received prophylactic antibiotics preoperatively during anesthesia induction. After the placement of a 5 Fr ureteral open-end catheter, patients were positioned in a prone position with proper constructional support by silicone rolls. The pelvicalyceal system was visualized by injecting the radiographic contrast dye through the ureteric catheter. The collecting system was punctured with a needle under fluoroscopy, a guidewire was inserted, and then the urinary tract was dilated with metal or Amplatz dilatators. After placement of an 18-30 Fr sheath, a 15Fr-19Fr rigid nephroscope or 9.5 Fr rigid ureteroscope was inserted into the collecting system. Stones were fragmented with a pneumatic lithotripter or laser and retrieved with rigid or flexible forceps or graspers. A 10 Fr nephrostomy tube was left in place if needed. We preferred the tubeless technique for selected cases such as those with short operation time, a single puncture for a tract, undamaged pelvicalyceal system, no major bleeding or residual stones at the end of the procedure.

On the second postoperative day, the patient underwent antegrade pyelography, or the nephrostomy tube was clamped if there was no residual fragment or extravasation detected by imaging. Then, the nephrostomy tube was extracted. Patients were discharged after drainage from the nephrostomy tract was stopped. If the drainage from the nephrostomy tract continued longer than seven days, it was defined as prolonged drainage, and we inserted a double J stent. When drainage was stopped for several days, patients were discharged.

Follow up

The first visit for follow up was done at 4-6 weeks after discharge, including urinalysis, metabolic examination of 24-hour urine specimens, and urinary ultrasonography. Stone free rates (SFR) were evaluated at 4 week follow. We reported the result as a failure in presence of any asymptomatic residual stone fragment > 4 mm at 4 week follow up. We confirmed the result by using intravenous urography in the first-year period and non-enhanced computerized tomography in the second ten years period.

Statistical analysis

SPSS, version 20.0, was used to perform statistical analysis. The Kolmogorov Smirnov test was used in the numerical computations provided the assumption of a normal distribution. For comparing the categorical measurements between the groups, the chi-square test was used. Mann-Whitney U, chi-square, ANOVA, and logistic regression were used for multivariate analysis. Statistical significance was defined as a p-value of less than 0.05.

RESULTS

Demographic data

Five hundred seventy-three pediatric patients with 654 renal units were evaluated in the study. The mean ± SD age of patients was 7.6 ± 4.9 years. The mean stone burden was 371.8 ± 459.4 (95% CI: 343.0-415.5) mm^3. There were 343 (52.5%) renal units with a single calyceal stone and 311 (47.5%) patients with multiple calyceal or staghorn stones. SFR was found 81.4% (n = 533). The mean hospital stay was 4.6 ± 4.2 days. In our practice, the usual hospital course for PCNL is 3-4 days in pediatric patients, but 173 (26.4%) patients stayed longer (7 to 27 days) due to leakage drainage, bleeding, infections, or other complications (Table 1).

Operative outcomes

On multivariate analysis, the perioperative parameters such as fluoroscopy time, bleeding, and operation time were associated with stone size and sheath size.

Increasing stone size increased operation time ($p < 0.001$), fluoroscopy time ($p < 0.001$), intraoperative and postoperative blood transfusion rate ($p = 0.006$ and $p = 0.018$, respectively), and hospital stay ($p = 0.002$) but was not associated with GFR change ($p = 0.71$).

Sheath size also correlated with th parameters and increased fluoroscopy time ($p < 0.001$), operation time ($p < 0.001$), intraoperative blood transfusion ($p = 0.002$) and hospital stay, but sheath size did not affect postop-

Table 1.
Demographic data of patients.

	Value
No. of patients	654
Age (years)[a]	7.6 ± 4.9
Gender[b]	
M	167 (62.5%)
F	100 (37.5%)
Laterality[b]	
Left	326 (49.8%)
Right	328 (50.2%)
Site of stone[b]	
Single calyx	343 (52.5%)
Multiple calyces	311 (47.5%)
Operation time[a]	78.3 ± 49.0
Stone free rate[b]	533 (81.4%)

[a]Data was presented as mean ± SD; [b]Data was presented as n (%).

Table 2.
Complications causing prolonged hospital stay.

	Group 1 (1997-2007)	Group 2 (2008-2018)	p value
Infection and fever	26 (9.7%)	15 (3.8%)	0.02
Leakage drainage	10 (3.7%)	11 (2.8%)	0.52
Requiring stenting	6 (2.2%)	7 (1.8%)	0.69
Colon perforation	2 (0.7%)	1 (0.2%)	0.79
Collecting system perforation	1 (0.3%)	4 (1.0%)	0.34
Bleeding	78 (29.2%)	22 (5.6%)	< 0.001
Requiring blood transfusion	65 (24.3%)	11 (2.8%)	< 0.001
Transcathateter angiography	2 (0.7%)	1 (0.2%)	0.36

All data was presented as n (%).

erative blood transfusion (p = 0.614) or GFR change (p = 0.994). Furthermore, prolonged operation time increases fluoroscopy time (p < 0.001), intraoperative and postoperative blood transfusion (p < 0.001 and p = 0.008, respectively), and hospital stay (p < 0.001), but not associated with GFR change (p = 0.55).

Stone size and sheath size were not associated with postoperative changes of GFR. SFR was correlated with operation time (B: -0.013, p = 0.02) (Table 3). Table 4 shows the comparison of the outcomes of two subgroups of patients treated in two different period of time using different-sized instruments. Mean operation time, fluoroscopy time, and blood transfusion rate were significantly lower in group-2 (p < 0.001, p < 0.001, and p = 0.002, respectively). However, stone volume and sheath size also significantly decreased in group-2 (p < 0.001). SFR were 74.9% and 86.4% in group-1 and group-2, respectively (p = 0.03).

Reoperation rates were 18 (6.7%) *versus* 11 (2.9%) in group-1 *vs.* group-2, respectively (p = 0.01). There was no significant change between preoperative and postoperative mean GFR in both groups (2.51 ± 0.2 mL/min and 3.83 ± 0.3 mL/min; p = 0.584, p = 0.536 in group-1 and group-2, respectively).

The most common complications were low-grade complications, grade I (21.3%), and grade II (29.6%). Grade I and II complications were significantly higher group-1 than group-2 (p = 0.001 and p < 0.001). Grade III-a and III-b complications were seen in 16 (2.4%) and 5 (0.7%) patients, respectively, and there was no significant difference between groups (p = 0.45, p = 0.34).

Table 3.
Multivariate analysis of SFR compared to demographic and perioperative parameters.

	Unstandardized coefficients			95% Confidence interval	
	B	Std. error	p	Lower	Upper
Age	.047	.056	.399	.939	1.170
Gender	-.024	.300	.936	.543	1.756
Laterality	-.264	.301	.380	.426	1.385
Weight	-.017	.014	.226	.956	1.011
Stone size	-.001	.001	.108	.998	1.000
Operation time	-.013	.006	.021	.976	.998
Fluoroscopy time	.000	.000	.781	.999	1.001
Sheath size	.079	.070	.259	.944	1.241
Constant	1.367	1.614	.397		

**Depended variable was SFR.*

Table 4.
Difference characteristics of two chronological groups.

	1997-2007 (n = 267)	2008-2018 (n = 387)	p value
Age (years)[a]	8.5 ± 4.9	6.9 ± 4.7	
Gender[b]			
M	167 (62.5%)	210 (54.2%)	
F	100 (37.5%)	177 (45.8%)	
Sideb			
Left	128 (47.9%)	198 (51.1%)	
Right	139 (52.1%)	189 (48.9%)	
Stone sizea (mm^2):	480.8 ± 380.0	295.8 ± 196.5	p < 0.001
Sheath sizea:	27.87 ± 2.8	24.41 ± 2.6	p < 0.001
GFR change (mg/dl):	2.6 ± 0.2	3.8 ± 0.3	p = 0.425
Serum creatinine changea (mg/dl):	0.013 ± 0.0	0.001 ± 0.0	p = 0.717
Operation timea (min):	100.4 ± 57.5	63.63 ± 36.3	p < 0.001
Fluoroscopy timea (min):	12.19 ± 8.3	8.31 ± 5.4	p < 0.001
Hemorrhage requiring transfusionb:	65 (24.3%)	11 (2.9%)	p = 0.002
Stone free rates[b]			
SF	200 (74.9%)	323 (83.4%)	p = 0.03
Failure	64 (24.2%)	56 (14.8%)	
Nephrostomy removal time (day):	2.93	2.57	p = 0.133
Postoperative Complications:			
Clavien Dindo[b]			p = 0.842
1	39 (14.6%)	26 (6.7%)	p = 0.001
2	69 (25.8%)	15 (3.8%)	p < 0.001
3[a]	8 (2.9%)	8 (2.0%)	p = 0.45
3[b]	1 (0.3%)	4 (1.0%)	p = 0.34
4[a]	2 (0.7%)	1 (0.2%)	p = 0.36
5	0	0	

[a]Data was presented as mean ± SD; [b]Data was presented as n (%).

Complications and management

The most common complication was bleeding in both groups (29.2% and 5.6% in group-1 and group-2, respectively). Rates of hemorrhages requiring transfusions were significantly different between the two groups (24.3% and 2.9% in group-1 and group-2, respectively, p = 0.02). Three patients underwent angiography for severe bleeding after the procedure, and a ten-year-old child underwent embolization for a pseudoaneurysm of the kidney. Twenty-six (9.7%) children in group-1 and fifteen (3.8%) in group-2 had a fever after PCNL (p = 0.07). Patients took different antibiotic regimens after a positive urine culture.

Twenty-one patients were followed up for prolonged drainage after removal of the nephrostomy tube. Thirteen patients, six (2.2%) in group-1 and seven (1.8%) in group-2, required double-J stenting. One patient required stenting for perirenal urinoma that resolved spontaneously. Collecting system perforations were seen in five patients, one (0.3%) in group-1 and four (1.0%) in group-2. Three patients had a long-staying nephrostomy tube from four to seven days, which was extracted after no extravasation was demonstrated at anterograde pyelography. Two cases required open surgery, one underwent pyeloplasty for damaged ureter-pelviv junction (UPJ) and the other underwent a primary repair of the renal pelvis.

Two (0.7%) patients in group-1 and one (0.2%) in group-2 had a colon perforation. One of them was treated with open surgery and a colostomy by the pediatric surgeon. The colostomy was closed after three months when anastomosis was done successfully. Two patients were treated conservatively, by withdrawal of the nephrostomy tube outside the kidney into the colon as a percutaneous colostomy tube and by insertion of a double-J ureteral stent for separating nephron-colic communication. Patients took intravenous broad-spectrum antibiotics and total parenteral nutrition. After 7-10 days, the patients started receiving oral feeding. The tube was removed after complete healing of the colon. One month after, the J stent was extracted under control of retrograde pyelography. One child underwent nephrectomy for a non-functioning kidney that was not producing urine in the postoperative days. Histopathological evaluation revealed xanthogranulomatous pyelonephritis.

Discussion

Pediatric stone disease is an important issue, and the critical point for preventing recurrence and relative complications after surgery is stone clearance. There still is not a consensus on describing stone-free rates. SFR varied in the studies due to the differences between pediatric and adult kidney anatomy, variable stone size, use of different-sized instruments, and inclusion or exclusion of *clinically insignificant residual fragment* (CIRF) cases. A recent study by *Çıtamak et al.* presented their results at four years intervals over 17 years, and stone-free rates were 73.5%, 68.1%, 75.5%, and 74.0%, with no significant difference among the groups ($p = 0.65$) (12). Our study showed that our increasing clinical experience and use of small instruments incresed SFR after pediatric PCNL.

Our SFR was significantly higher in group-2 than group-1 and reoperation rates were similar into groups. Similar to our study, *Yadav et al.* study reported that stone-free rates were increased over 15 years from 84.6% to 89.9% (13).

The early pediatric PCNL series were performed using adult-size instruments. The improvements in the devices and techniques of PCNL facilitated urologists to perform this procedure (14, 15). In our study, the mean sheath size decreased from 28 Fr to 24 Fr over the years. Bilen et al. compared three different sized nephroscope, and stone-free rates were 69.5%, 80%, and 90% in the 26Fr, 20Fr, and miniperc groups, respectively ($p < 0.005$).

The authors emphasized that the 26Fr and 20Fr groups include more patients with semi-staghorn and staghorn calculi (16). A novel systematic review showed that the minimal invasive PCNL (micro-ultra mini) success rate ranged between 85-100% (17).

In our study, the total complication rate (Clavien I-IV) was 28.4%, and there was no significant difference between the two groups. Similar results were found in the CROES study which showed that the complication rate was 23.3% (7). Novel research showed the complications were decreased over the years (33.8%, 23.6%, 19.6%, and 11.5%, respectively, for every four years, $p < 0.001$) (12). In the literature, the studies compared PCNL complications in children using different instruments, and the complications were graded according to the modified Clavien system, and similar to our research, most of the complications were grade I and II (5, 18, 19). *Ozden et al.*, in a study of 100 patients using pediatric instruments, reported an overall complication rate of 25% (18). Another study by Guven et al. reported that the total complication rate was 29.1% ($n = 140$), and there was no significant difference between pediatric and adult instruments ($p = 0.52$) (5). Additionally, *Bilen et al.* also showed that complication rates were not significantly different in their study comparing three different sized instruments (16). *Mishra et al.* examined the outcomes of miniperc (MPCNL) *versus* standard conventional PCNL and concluded that the MPCNL is significantly superior to PCNL in bleeding and hospital stay time (19). Similar to our study, novel papers showed that recently presented small size percutaneous accesses, such as MPCNL and *micro percutaneous method* (Micro-PCNL), are safer than classic PCNL in children (2, 20). Our study demonstrated that there had been no significant change in the treatment of complications until today, but we became less invasive due to our increased knowledge of complications.

The most common complications were bleeding and fever. Types and frequencies of complications were similar to those in adults (8, 17, 21). *Zeren et al.* study showed correlation of intraoperative bleeding with operation time, sheath size, and stone size (8). Our research demonstrated that stone size and operation time correlated with intraoperative and postoperative blood transfusion. We also found that a larger sheath size is related to higher intraoperative blood transfusion rates and longer hospital stay. Similar to our study, *Altintaş et al.* study compared three different sheath sizes (17 Fr, 24 Fr, and 26 Fr) showing that sheath size was related to increased intraoperative bleeding although there was no significant difference of preoperative and postoperative creatinine levels ($p = 0.873$) (22). However, controversial to our study, the literature also reported that sheath size did not affect transfusion rates (12, 16, 23).

Fever was the second common complication in our study. Previous studies reported that the postoperative fever rate was approximately present in 29% (18, 21). *Bayrak et al.* reported that postoperative fever rates in their study, comparing children to adults, were 5.4% and 5.6%, respectively (24). *Çelik et al.* showed that postoperative fever rates were similar and reported rates of 5.9% and 6.8% using pediatric (18Fr) and adult-sized (24Fr) nephroscope, respectively (25).

In our study, postoperative fever rates were not significantly different in the two groups and similar to published literature.

Herein, we compared different-sized instruments and experience time and found that PCNL is an operator-dependent procedure, which improves its results, presumably due to increased operator experience and the involvement of a team with substantial prior knowledge. Furthermore, our results depend on advances to technology that shifted the management of stone disease to minimal invasive modalities.

We realized that we treated smaller stones in the second ten years period.

The main reasons for this finding are:

- Increasing of diagnosis of patients with small stone size due to the novel radiological tools and easier access to health care services.
- In our clinic, use of a ESWL machine that uses fluoroscopy for stone localization (with no ultrasound-guided ESWL machine around the region)
- Technological advancement with development of small instruments for urologic endoscopic procedures.

Limitations of the study included its retrospective nature and the absence of a metabolic evaluation and chemical analysis of the composition of the stone. The second significant limitation was insufficient data of follow up, especially on group-1 and no standardization of timing or use of imaging tools at follow up. Another limitation of the study was the performance of percutaneous procedures by more surgeons using different instruments at different periods being the experience of each surgeon a possible source of bias. However, a strenght of the study is that the data and results were obtained from a single large volume center.

Conclusions

Our study showed that the patient cohort became younger with smaller stone sizes over time.
Concordantly, the fluoroscopy time, operation time, blood loss, and complications rates were decreased, and stone free-rates were increased with use of smaller instruments. The stone and sheath size are major factors to predict blood loss and hospital stay.

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