Percutaneous nephrolithotomy in children in different age groups: data from the Clinical Research Office of the Endourological Society (CROES) Percutaneous Nephrolithotomy Global Study

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What's known on the subject? and What does the study add?

- Without age being a limiting risk factor, recent reports have shown that almost any version of percutaneous nephrolithotomy (PCNL) can be safely applied in children. As there has been no standardisation in the age categorisation of children, there are inconsistencies among the age subgroups in the current literature.
- To achieve a standard terminology and thus a common language, the World Health Organization age classification criterion was used in the present study. Based on the findings, we can suggest that PCNL can be applied safely and effectively in children in different age groups.

Objectives

- To present the overall results of paediatric percutaneous nephrolithotomy (PCNL) compared with adults.
- To present the indications, complications and outcomes of patients treated in the participating centres in the PCNL Global Study, as categorised in different age groups.

Patients and Methods

- The Clinical Research Office of the Endourological Society (CROES) Study was conducted from November 2007 to December 2009, and included 96 centres and >5800 patients.
- All children aged ≤14 years in the PCNL Global Study database were the focus of the study.

Results

- In all, 107 children aged ≤14 years were included in the analysis.
- The PCNL procedure was conducted in 13 patients (12.1%) in the supine position; tubeless PCNL was performed in 15 patients (14%); and balloon dilatation was preferred in 22 patients (20.5%). The overall mean operative duration was 97.02 min; blood transfusion rate, fever and stone-free rates were 9%, 14% and 70.1%, respectively.
- A comparison of the paediatric PCNL cases according to age groups showed no statistically significant differences between the subgroups for patient characteristics, co-morbidities, renal anomalies, or previous surgical history.
- In the evaluation of the operative details, the mean sheath size and nephrostomy tube size were larger in school-age children than the preschool children ($P = 0.01$ and 0.002, respectively). There was a difference in the preferred methods for confirming stone-free status, with ultrasonography preferred more in preschool children ($P < 0.001$).
- The PCNL procedure position, puncture site, dilatation method, postoperative tube application, and surgical outcomes were comparable in school- and preschool-age children. While operative details showed some differences between children and adults, the surgical outcomes were comparable.

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Conclusions

- A considerable number (45.7%) of the paediatric patients had a previous history of stone intervention.
- Based on the findings of the present study, we can suggest that PCNL can be applied safely and effectively in children in different age groups.
- Outcomes appear comparable with those in adults for the success and complication rates, in the presence of substantial indications, appropriate equipment and adequate experience.

Keywords

percutaneous nephrolithotomy, stone, children, percutaneous, PCNL, age, supine

Introduction

Despite the fact that stone disease in children shows wide geographic variations, it has increased in incidence worldwide in children of all ages [1–4]. While comparatively, only a small portion of the patients in urology clinics represent paediatric urolithiasis, the most effective treatment for these patients is of utmost importance due to the high risk of stone recurrence in this group. The treatment chosen must not impair the development and function of the growing kidney. The main concerns in children are to minimise the extent of radiation exposure and the need for retreatment and, if the latter does become necessary in the future, to not limit or preclude any possible treatment options.

Over time, many standardised adult stone disease treatment options, with their proven efficacy and safety, have been used for treating children, as evident in a multitude of reports. Similarly, percutaneous nephrolithotomy (PCNL), first applied in adults, was later improved with refinements in instrumentation and technology; these improvements, together with the increased experience of endoscopic surgeons, have enabled PCNL to emerge as one of the standard treatment options in paediatric cases [5]. Furthermore, with age no longer such a limiting risk factor, recent reports have shown that almost any version of PCNL can be applied safely in children [5–9].

While reporting the efficacy and reliability of the paediatric PCNL procedure, authors prefer to categorise patient outcomes according to different age groups. Moreover, in the reports about the different PCNL techniques, such as bilateral simultaneous or tubeless PCNL, successful applications have been reported together with a comparison of the different equipment used in similar and different age groups (subgroups) [5–9]. The categorisation of the results by age groups would be more appropriate in multicentre studies conducted with a wide range of patients. Multicentre studies facilitate the comparison of results across centres, while representing a large number of patients, different geographic locations and a wider range of population groups. The classification according to age groups and presentation of surgical outcomes in light of this classification are necessary, as this will enable a closer scrutiny of the data presented.

The Clinical Research Office of the Endourological Society (CROES) was established as a unit within the Endourological Society responsible for organising, structuring and facilitating a global network for endourological research. CROES, with the prospective PCNL Global Study it initiated, has established the world's largest database in the field of PCNL, including the largest accumulation of clinics, authors and patients. With the study results including >5800 patients, CROES has compiled a series of articles on PCNL indications, complications and outcomes [10–12]. By providing an opportunity to understand the current status of paediatric PCNL cases treated in 96 centres within a 'real-life' scenario, the study offers new insights into PCNL and a thorough review of the relevant literature. The present manuscript presents the overall results of paediatric PCNL, in addition to the indications, complications and outcomes of patients treated in the participating centres in the CROES PCNL Global Study, as categorised in different age groups.

Patients and Methods

The present article, a part of the CROES PCNL Global Study, evaluates the PCNL results in children. The study was conducted between November 2007 and December 2009, including 96 centres and >5800 patients. Information about the data collection methods, study organisation, steering committee, inclusion criteria, and data analysis were described elsewhere in previous CROES reports [10–12].

All children aged ≤14 years in the CROES PCNL Global Study database are within the scope of the present study. Using the WHO age classification, the primary aim was a comparison of the pre-school- and school-age children. Indication for PCNL was based on the size and type of stone. PCNL procedures were conducted according to local clinical guidelines and practice.

Overall patient characteristics, urine analysis, PCNL procedure position, tract dilatation methods, sheath size, blood loss, operative duration, stone burden, postoperative stent and/or nephrostomy tube, methods for confirming stone-free status, prior stone surgery, and complications were analysed. For each surgical procedure, operative duration was recorded as the time from the first puncture to the completion of the stone removal. The stone-free rate was defined as the patient being stone-free for 30 days during the postoperative period; secondary treatments were not considered in the stone-free rate analysis. Perioperative complications were compared according to modified Clavien classification system [13].

After a general evaluation of PCNL results in children, cases were further divided into three age categories based on the WHO classification as: infants (≤1 year), young children (2–4 years) and school-age children (5–14 years). For the purpose of comparison of PCNL results between adults and children, patients were divided as 0–14 years of age and ≥15 years.

While infants were designated as a separate group in the results, in view of their limited number, they were combined into the group of young children for the purpose of statistical analysis. The overall paediatric PCNL results were compared with the outcomes in adult cases from those participating centres having at least one paediatric PCNL case.

Further analyses were performed to compare the three groups of children to determine differences in patient characteristics, previous surgical history, surgical details, and outcomes. Means and standard deviations (SDs) were calculated for the continuous variables, while proportions (percentages) were calculated for the categorical variables. Chi-square and one-way ANOVA tests were used to test for statistical significance (with a level of 0.05) in the differences between groups in categorical and continuous variables, respectively.

Results

Overall Evaluation

Among the 5803 cases in the CROES PCNL global database, 107 children aged ≤14 years were included in the analysis. Of the 96 centres participating in the study, 24 (25%) had conducted paediatric PCNL. According to age categorisation of the 107 cases, six were infants, 29 young children, and 72 school-age children (Fig. 1). The mean (SD) age of the cases included in the overall evaluation was 7.07 (3.98) years, with a male dominance (64.4%; Table 1). Of the 107 children, PCNL was performed on six (5.6%) children with stones in anatomical kidney abnormalities (horseshoe kidney [five, 4.7%], ectopic kidney [one, 0.9%]; Table 2). One child had co-morbid conditions as noted in

Fig. 1 Age group classification of children who underwent PCNL.

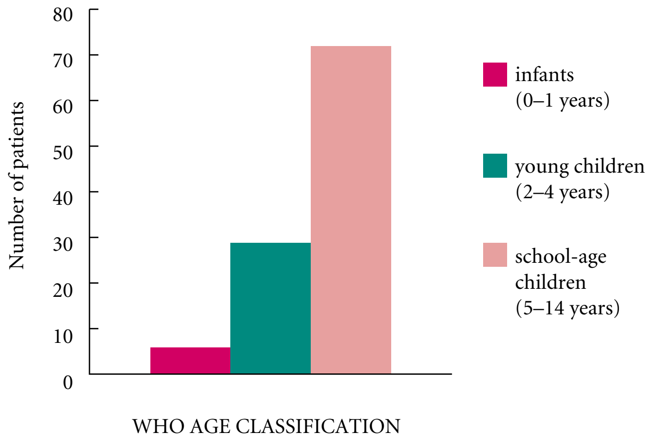

Table 2. A considerable number (49, 45.7%) of patients had undergone previous PCNL, extracorporeal shockwave lithotripsy (ESWL), pyelolithotomy, ureteroscopy, or nephrostomy for stone disease. Of the stones treated, 26.5% were staghorn stones, showing a similar incidence to the staghorn incidence in adults. PCNL procedure was conducted in 13 patients (12.1%) in the supine position, and supine PCNL was attempted in eight centres. Balloon dilatation was preferred in 22 patients (21.8%), and multiple accesses were needed in 11 patients (10.3%; Table 3). In all, 14 patients (13.2%) underwent tubeless PCNL. In most of the patients, pneumatic lithotripter was preferred; however, ultrasonic, laser, electrohydraulic, and combined lithotripters were also used. Lithotripter types, together with their employment frequency in the subgroups, are given in Table 3. The method for confirming stone-free status postoperatively in most of the patients was plain abdominal radiograph of the kidneys, ureters and bladder (KUB; 81.3%); ultrasonography (US) or CT was preferred in only a small portion of the patients (Table 3).

The overall mean (SD, range) operative duration was 97.1 (54.3, 25–300) min. The blood transfusion, fever and stone-free rates were 9.3%, 14% and 70.1%, respectively. Further treatment procedures were required in 21 patients: ureteroscopy in two, second-look PCNL in nine, SWL in nine, and other options in one. Retreatment information according to age subgroups is summarised in Table 4.

Evaluation According to Different Age Groups

The results of the analysis comparing paediatric PCNL vs adult PCNL with corresponding *P*-values are given in Tables 1–4. A subgroup analysis of paediatric PCNL is presented in each table, comparing PCNL in young children (including infants) vs in school-age children.

In the comparison of adult and paediatric cases, adult cases from the 24 centres having at least one paediatric PCNL

Table 1 Comparison of patient characteristics and previous surgical history among children and adults who underwent PCNL.

Characteristic	Children vs adults			Preschool- (incl. infants) vs school-aged children		
	Children (0–14 years)	Adults (>15 years)	*P*	Preschool (incl. infants) age (0–4 years)	School age (5–14 years)	*P*
N	107	2666		35	72	
Mean (SD) age, years	7.1(4.0)	47.9	–	2.6 (1.1)	9.2 (2.9)	–
Sex, n/N (%):						
Male	69/107 (64.5)	1577/2665 (59.1)	0.269	23/35 (65.7)	46/72 (63.9)	0.853
Female	38/107 (35.5)	1090/2665 (40.9)		12/35 (34.3)	26/72 (36.1)	
Mean (SD) stone burden, mm^2	272.0 (255.2)	338.5 (311.8)	0.060	265.9 (266.2)	275.0 (251.6)	0.755
Previous stone-related surgery, n/N (%):						
PCNL	14/107 (13.1)	390/2641 (14.8)	0.629	3/35 (8.6)	11/72 (15.3)	0.334
ESWL	15/107 (14.0)	535/2651 (20.2)	0.117	3/35 (8.6)	12/72 (16.7)	0.257
Pyelolithotomy	6/107 (5.6)	275/2647 (10.4)	0.109	2/35 (5.7)	4/72 (5.6)	0.973
URS	7/107 (6.5)	242/2648 (9.1)	0.358	1/35 (2.9)	6/72 (8.3)	0.282
Nephrostomy	7/106 (6.6)	181/2614 (6.9)	0.898	3/35 (8.8)	4/72 (5.6)	0.527
Positive urine cultures, n/N (%)	7/105 (6.7)	396/2570 (15.4)	0.014*	2/34 (5.9)	5/72 (7.0)	0.823

*URS, ureterorenoscopy; *Statistically significant.*

Table 2 Comparison of co-morbidities and anatomic kidney abnormalities between children and adults.

Characteristic	Children vs adults			Preschool- (incl. infants) vs school-aged children		
	Children (0–14 years)	Adults (>15 years)	*P*	Preschool age (incl. infants) (0–4 years)	School age (5–14 years)	*P*
N	107	2666		35	72	
Renal anomalies, n/N (%):						
None	97/103 (94.2)	2419/2526 (95.8)	0.190	33/34 (97.1)	64/69 (92.8)	0.631
Ectopic kidney	1/103 (1.0)	13/2526 (0.5)		0/34 (0.0)	1/69 (1.4)	
Horseshoe kidney	5/103 (4.9)	57/2526 (2.3)		1/34 (2.9)	4/69 (5.8)	
Malrotation	0/103 (0.0)	37/2526 (1.5)		0/34 (0.0)	0/69 (0.0)	

case were included in the comparison. The total sample size was 2773, which included 107 children and 2666 adults. Patient characteristics and previous surgical history were comparable between children and adults except for preoperative positive urine cultures. Preoperative positive urine culture was higher in the adult group (6.7 vs 15.4%, $P = 0.014$; Table 1). While a considerable percentage of adult patients had co-morbidities, one child had cardiovascular disease ($P < 0.001$; Table 2). For operative details, the mean dilatation method, mean sheath size, mean nephrostomy tube size, and methods for confirming stone-free status were different between children and adults (Table 3); however, the surgical outcomes were comparable (Table 4).

On categorising the paediatric PCNL cases according to age groups, there were no statistically significant differences between the subgroups for patient characteristics, co-morbidities, renal anomalies, or previous surgical history (Tables 1, 2). Of the six infants, two had had nephrostomy tubes placed before PCNL with stone disease diagnosis.

Evaluation of the operative details (Table 3) showed that the mean sheath size and nephrostomy tube size were larger in school-age children than in the preschool children (P = 0.01 and 0.002, respectively). There was a difference in the preferred methods for confirming stone-free status, with US preferred more in preschool children ($P < 0.001$). The PCNL procedure position, puncture site, dilatation method, postoperative tube application, and surgical outcomes were comparable in school- and preschool-age children (Tables 3, 4).

Discussion

SWL and interventional treatment options for stone disease in children often necessitate general anaesthesia or i.v. sedation; hence, stone relief in a single session is of high priority. Although SWL is recommended in children for kidney stones of <1.5–2 cm, concerns include the necessity of further shock treatments, low stone-free rates after single-session monotherapy, frequent retreatment sessions, and increased risk of postoperative obstruction [3,14,15]. Moreover, some evidence exists about renal vessel vasoconstriction, renal tubular injury and sub-capsular haematoma caused by cavitations and shear forces due to increasing kilovoltage [16]. Depending on the intensity of

Table 3 The operative details of children who underwent PCNL.

Characteristic	Children vs adults			Preschool- (incl. infants) vs school-aged children		
	Children 0–14 years	Adults >15 years	P	Preschool age (incl. infants) 0–4 years	School age 5–14 years	P
N	107	2666		35	72	
Patient position, n/N (%):						
Prone	94/107 (87.9)	2413/2662 (90.6)	0.332	29/35 (82.9)	65/72 (90.3)	0.270
Supine	13/107 (12.1)	249/2662 (9.4)		6/35 (17.1)	7/72 (9.7)	
Dilatation method, n/N (%):						
Telescopic	79/101 (78.2)	1378/2512 (54.9)	<0.001*	29/35 (82.9)	50/66 (75.8)	0.410
Balloon	22/101 (21.8)	1134/2512 (45.1)		6/35 (17.1)	16/66 (24.2)	
Mean (SD) sheath size, F	22.9 (4.6)	28.5 (4.2)	<0.001*	21.2 (4.7)	23.7 (4.4)	0.010*
Postoperative nephrostomy, n/N (%)	92/106 (86.8)	2406/2647 (90.9)	0.153	30/35 (85.7)	62/71 (87.3)	0.817
Mean (SD) nephrostomy tube size, ?	14.8 (3.4)	17.6 (5.2)	<0.001*	13.4 (2.9)	15.5 (3.4)	0.002*
Postoperative stent, n/N (%)	38/107 (35.5)	1249/2654 (47.1)	0.018*	10/35(28.6)	28/72(38.9)	0.295
Assessment of stone-free status, n/N (%):						
CT	7/104 (6.7)	480/2483 (19.3)	<0.001*	1/35 (2.9)	6/69 (8.7)	<0.001*
US	10/104 (9.6)	44/2483(1.8)		9/35 (25.7)	1/72 (1.4)	
KUB	87/104 (83.7)	1959/2483 (78.9)		25/35 (71.4)	65/72 (89.9)	
Stone fragmentation methods, n/N (%):						
None	4 (3.8)	153 (5.8)	0.039	1 (2.9)	3 (4.2)	0.966
US	13 (12.3)	477 (18.2)		5 (14.3)	8 (11.3)	
Laser	14 (13.2)	208 (7.9)		5 (14.3)	9 (12.7)	
Pneumatic	61 (57.5)	1312 (49.9)		20 (57.1)	41 (57.7)	
Electrohydraulic	2 (1.9)	18 (0.7)		1 (2.9)	1 (1.4)	
US + pneumatic	12 (11.3)	460 (17.5)		3 (8.6)	9 (12.7)	

**Statistically significant.*

Table 4 The surgical outcomes of children who underwent PCNL.

Characteristic	Children vs adults			Preschool- (incl. infants) vs school-aged children		
	Children 0–14 years	Adults >15 years	P	Preschool age (incl. infants) 0–4 years	School age 5–14 years	P
N	107	2666		35	72	
Mean (SD) operative duration, min	97.1 (54.3)	89.4 (49.0)	0.155	105.3 (51.5)	93.0 (55.5)	0.262
Blood transfusion, n/N (%)	10/107 (9.3)	202/2641 (7.6)	0.518	3/35 (8.6)	7/72 (9.7)	0.847
Fever, n/N (%)	15/107 (14.0)	311/2646 (11.8)	0.477	4/35 (11.4)	11/72 (15.3)	0.590
Stone-free rates, n/N (%):						
All assessment methods	75/107 (70.1)	2028/2650 (76.5)	0.124	26/35 (74.3)	49/72 (68.1)	0.509
CT	4/7 (57.1)	286/480 (59.6)	0.896	1/1 (100.0)	3/6 (50.0)	0.876
US	6/10 (60.0)	28/44 (63.6)	0.829	5/9 (55.6)	1/1 (100.0)	0.829
KUB	62/87 (71.3)	1557/1959 (79.5)	0.065	20/25 (80.0)	42/62 (67.7)	0.252
Re-treatment methods, n/N (%):						
None	86/107 (80.4)	2225/2650 (84.2)	0.624	31/35 (88.6)	55/72 (76.4)	0.470
URS	2/107 (1.9)	24/2650 (0.9)		1/35 (2.9)	1/72 (1.4)	
PCNL	9/107 (8.4)	227/2650 (8.6)		1/35 (2.9)	8/72 (11.1)	
ESWL	9/107 (8.4)	152/2650 (5.7)		2/35 (5.7)	7/72 (9.7)	
Other	1/107 (0.9)	16/2650 (0.6)		0/35 (0.0)	1/72 (1.4)	

URS, ureterorenoscopy.

the SWL, evidence for increasing hypertension and diabetes mellitus risks in the long-term is argued [17]. Since the first paediatric series reported by Woodside et al. [5] in 1985, PCNL has become an established technique in children as monotherapy or as part of a multimodal approach for children with large stone burden. Over the last two decades, the miniaturisation of equipment and refinement in technology have enabled their usage in children, causing a decline in the preference for SWL by both surgeons and parents and a steady increase in the endoscopic stone treatment options. However, urologists still have some concerns about PCNL due to possible long-term renal damage, small kidney size, relatively large instruments, radiation exposure, and risk of major complications, e.g. bleeding. Furthermore, the complexity of the surgical technique, such as accessing the pelvi-calyceal system, might be difficult considering the hypermobility of the small kidney. Despite the fact that no major complications have been mentioned in paediatric PCNL reports, it must not be forgotten that PCNL is a potential morbid procedure and can be accompanied by life- threatening bleeding and sepsis, as reported in some adult series. These concerns increase with a decrease in age in children, as young children are more fragile and have lower body reserves. Hence, while evaluating the results of paediatric PCNL, age groups should be differentiated.

In this respect, we evaluated the 107 paediatric cases aged ≤14 years derived from the global PCNL database. Earlier reports about paediatric case series with appropriate indications made in a single centre or in two to three centres showed comparable stone-free and complication rates for PCNL with those for adult PCNL. In some of those reports, in compliance with the general acceptance norm in paediatric departments, the age limit for the inclusion of patients in the studies was ≤16 years [6,18,19]. As there has been no standardisation in the age categorisation of children, there are inconsistencies among the age subgroups in the current literature. In addition to calendar age, using age groups or age classifications can provide a reasonable middle ground between the presentations of data by single years of age. Focusing on different age groups of children permits regrouping the data in conformity and facilitates linkage and comparability of data from different sources, over time, and within and among different subject areas regarding paediatric urolithiasis. To achieve a standard terminology and thus a common language in the studies, we used the WHO classification criteria. Cases were divided into three age categories as: infants (≤1 year), young children (2–4 years) and school-age children (5–14 years). As the number of infants was insufficient for statistical analysis, they were combined with the group of young children.

Despite the wide range of the patients included in the PCNL Global Study, the number of paediatric cases was relatively small, constituting only 1.8%. Only results of patients aged ≤14 years were included in the analysis. Increasing the upper age limit to 16 years would certainly increase the number of the patients in the present series. The small number of subjects may be explained in part by the comparably small number of paediatric cases in urology departments, urologists' timidity about indications for PCNL in children, and/or the referral of patients to certain centres specialised in paediatric stone treatment. Information about the frequency of paediatric cases in urology centres in which PCNL is among the routine procedures is not provided in the relevant literature. Further analysis of the PCNL Global Study results will give detailed insights into the indication range and the application frequency in the participating centres and geographic regions for paediatric PCNL cases. On the other hand, worldwide studies defining the true incidence and/or prevalence of stone disease in children remain insufficient. Results of the studies, limited in number [20–24], indicate that paediatric kidney stone cases are rare when compared with adults. Moreover, the younger the age, the more distinctive is this rarity [20]. Although paediatric kidney stones are encountered rarely, the increasing incidence reported is a matter of concern.

In the relevant literature, the stone-free rate after PCNL monotherapy in children ranges between 67 and 100% [3]. The overall stone-free rate in children was 70.1% in the paediatric cases of the PCNL Global Study. The method for confirming stone-free status was primarily KUB, although CT was preferred in some patients. Considering the high success rates in previous reports, factors having an impact on this rate require further analysis. In this context, we have seen that although the basic methodology and instrumentation appear similar in adult and paediatric PCNL, performing paediatric PCNL requires strenuous effort and expertise. This is evident in the CROES Study, as there were only 107 paediatric cases out of 5800 cases worldwide. Based on clinical experience, it can be stated that urologists only dare to perform paediatric PCNL applications after they have gained a significant experience with adult cases. They begin with children with more optimal body structures and progress to younger children. Although the number of reports is insufficient, it is obvious that after conducting the initial paediatric PCNL cases, the increasing number of case experiences and related learning curve have an impact on the success rates. It is suggested that in the initial practice of paediatric PCNL, staging of the procedure in selected cases, such as a non-dilated system, associated infection or large stone burden, would help to decrease complications and increase the success rate of the procedure. Kroovand [25] proposed a two-session approach to minimise bleeding, with the initial session for establishing the percutaneous tract and a second session for calculus manipulation. Furthermore, US-guided puncture is suggested as a good alternative to fluoroscopy and carries the advantages of avoiding radiation, allowing a straight peripheral calyceal puncture and preventing visceral injury [26]. Although the decision about the method of access in PCNL depends on the experience of each surgeon and the clinical setting, a combination of US and fluoroscopy has inherent advantages over using fluoroscopy alone.

The current success rate of this treatment option, used as an alternative to open surgery and even in some cases for SWL, is still a matter of concern. Of the centres included in the CROES PCNL Study, only 25% had paediatric PCNL cases, and in 91.6% of them, the paediatric patient volume was <10 annually. Despite the fact that this condition is a limitation of the present study, it might point to the underlying reason for the relatively lower rate of success compared with previous paediatric PCNL reports. Nevertheless, the resulting consequence is that the scope of PCNL indications against SWL may only be broadened if PCNL becomes an appealing effective alternative applied in one step, with higher success rates. In addition, the consistent definition of 'stone-free status' after definitive therapy should be discussed. As every residual fragment is accompanied with poor outcomes in children, children need to become completely 'stone-free' [27]. KUB and US might sometimes be insufficient in detecting residual fragments, which necessitates CT imaging; however, radiation exposure and the requirement of anaesthesia limit the use of CT in children. In the first report of the CROES Study [10], CT use in detecting the stone-free rate was 14%. Possibly due to the above-mentioned considerations in children, this percentage was 6.5% in paediatric cases.

A significant proportion of children in the study had a previous history of stone intervention. Many adult and paediatric studies have shown that patients with previous stone intervention histories, whatever the previous treatment methods, have similar PCNL success and complication rates compared with those without an earlier intervention [28,29]. In 45% of the paediatric cases involved in the present study, there was a previous stone intervention history. This ratio was statistically comparable between preschool- and school-age children. In paediatric cases, with their high recurrence risk, this fact highlights the importance of a permanent single-session treatment of kidney stones in addition to the medical evaluation and close follow-up.

Compared with adults, the mean stone burden in paediatric cases was lower (272 vs 338.5 mm2); however, the difference was not significant statistically ($P = 0.06$). Two plausible reasons might be the similar stone size recommendations for interventional management in paediatric cases and the decreased statistical power of the data.

The database did not capture any specific information about the experience of the operators, or about the number of surgeons operating on children that were not paediatric surgeons or of true paediatric surgeons performing endoscopic stone surgery. Nevertheless, the findings of the PCNL Global Study show that the PCNL techniques used in paediatric cases are very similar to those used in adults except for the instrument size. The difference in paediatric PCNL equipment is the miniaturisation of the surgical tools. There are rare studies claiming that adult equipment in PCNL is compatible for use in children. In one of these studies, the limitation of the small paediatric instruments in the extraction of large or multiple stones with multi-access PCNL in children aged <5 years was argued as their main shortcoming [9]. In such cases, although usage of adult-sized instruments in specific circumstances is considered appropriate, in many other studies, decreased blood loss has been reported with the use of smaller paediatric-sized instruments [7,30]. The smaller calibre percutaneous tract and nephroscope are considered to be less injurious to the kidney, and furthermore, under-dilate, avoid torturing, and increase manoeuvrability, all important considerations in preventing bleeding and renal trauma [8,9,31]. In the present study, the mean sheath size and nephrostomy tube size were appropriate for children. Although there were no significant differences between the age subgroups for operative details, the mean sheath size and nephrostomy tube size were larger in school-age children.

Despite the many papers advocating various adult PCNL techniques for safe use in children, paediatric PCNL procedure in the supine position has not been mentioned to date. According to the information obtained from the CROES database, supine-position PCNL was used in 13 cases, including one infant. Although only a few centres performed supine PCNL in a limited number of cases in this series, it appears that supine-position PCNL can also be applied safely in children when deemed suitable. Furthermore, the reports related with PCNL in children with anatomical kidney abnormalities are scarce. The two previous studies reported the results of eight and six children with special anatomical conditions [32,33]. In the present study, we report the results in seven children with anatomical kidney abnormalities who underwent PCNL.

The data obtained from the CROES Study show a significant decreased positive urine culture rate of 6.7% in paediatric cases compared with adults (15.4%). To our knowledge, there is no published information comparing adult and paediatric urine culture rates before endoscopic interventions. The underlying reasons, whether stemming from stone aetiology, metabolic reasons or infections, necessitate further analyses.

Our knowledge about paediatric PCNL complications is scarce compared with that available in adults. The most frequent complications reported are fever and blood transfusion requirement. The literature does not shed light on Clavien classification grade 4–5 complications in children [6,34]. The complications reported after PCNL range between fever and blood transfusion (2–49%, 0.4–23.9%, respectively) [3–9,35]. Bleeding during PCNL is comparable between children and adults [6,13,35,36], although some authors reported a high bleeding ratio in their experience using the instruments available in the early days of application of the PCNL procedure [37].

We did not find a report comparing adult and paediatric PCNL results using the same data within a single study.

The CROES database provides the unique opportunity to compare the PCNL results of adult and paediatric cases for the first time. The comparisons made have shown that the complication rates in paediatric cases were comparable to those in adults. Moreover, it has also shown that the staghorn stone ratio in children is similar, 'stone-free' rates are comparable and the mean operative duration is longer than in adults. The interpretation of the findings obtained from the present comparison of paediatric and adult cases necessitates future analyses.

While the overview of the study provides important knowledge about PCNL in children, there are limitations regarding the above-mentioned issues, e.g. the few patients, the experience of the surgeon, the selected units, and the treatment options. The CROES Study is an observational study, and such concerns originate from certain limitations inherent in observational studies. However, among the advantages of observational studies is that they reflect daily clinical practice more closely than randomised controlled trials.

In conclusion, based on the findings of the present study, PCNL is a safe and effective procedure in children in different age groups in the presence of substantial indications, appropriate equipment and adequate experience. Although the stone-free rate in children is within the range of earlier reports, it is at the lower end of the continuum. The paediatric PCNL results presented in the present study are a part of the global observational study and a first prospective audit data collection. Thus, further prospective well-designed clinical studies are necessary to answer the questions generated by the outcomes of the CROES Study about paediatric cases.

Conflict of Interest

None declared.

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Abbreviations: PCNL, percutaneous nephrolithotomy; CROES, the Clinical Research Office of the Endourological Society; KUB, plain abdominal radiograph of the kidneys, ureters and bladder; US, ultrasonography; (E)SWL, (extracorporeal) shockwave lithotripsy.

