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ORIGINAL ARTICLE

Percutaneous nephrolithotomy in children

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Abstract

Introduction The high success rates of percutaneous nephrolithotomy (PCNL) in the clearance of large renal calculi has made it a primary mode of surgical management in adults. Similarly, in children too PCNL has been gaining ground and the indications for the same are on the rise. We retrospectively evaluated the safety and efficacy of this technique, in children below 18 years of age.

Materials and methods We retrospectively reviewed the inpatient, outpatient records, imaging films of all children with renal stones undergoing PCNL at our hospital.

Results During the study period, 123 children underwent 129 PCNL at our centre for renal calculi. The mean age was 11.06 years and 87 (70.73%) of the children were males. The size of the stones varied from 15 to 37 mms in the longest diameter. A complete staghorn was noted in six (4.65%) and a partial staghorn in nine (6.97%) children. Supine PCNL was performed in 21 (16.2%) children and remaining 102 (83.7%) children underwent PCNL in prone position. The mean drop in haemoglobin was 1.24 gm%. Stone clearance was achieved in 122 (94.5%) children. Post-operatively four (3.1%) children needed blood transfusions due to excessive bleeding.

Conclusions Refinements in percutaneous access techniques, miniaturization of instruments, and technologic advances in energy sources for lithotripsy have led to improvement of outcomes and have lowered the morbidity rates in children following PCNL. It is a safe and effective means of clearing large volumes of renal calculi with minimal morbidity.

Keywords Percutaneous nephrolithotomy · Children · Renal calculi · Morbidity

Introduction

Percutaneous nephrolithotomy (PCNL) has established itself as a safe and effective procedure in the management of large stone burdens in adults. Concerns regarding the use of large instruments in children, damage to renal parenchyma and associated effects on renal function, exposure to radiation with the use of fluoroscopy and complications such as bleeding and sepsis had made Pediatric Urologists hesitant to use this procedure initially [1]. As experience accumulated over period of time, PCNL has been presently used as either a monotherapy or in combination with shockwave lithotripsy (SWL) as a sandwich therapy in children, achieving stone-free rates ranging from 68 to 100% [1–3]. Currently, there exists no International consensus regarding the indications for PCNL in children. Similar to that in adults, the indications for PCNL in children include large upper tract stone burden (> 1.5 cm), lower pole calculi larger than 1 cm, concurrent anatomic abnormality impairing urinary drainage and stone clearance, or known cystine or struvite composition [4, 5].

The Clinical Research Office of the Endourological Society (CROES) conducted a study between November 2007 and December 2009, that included 96 centres and > 5800 patients. Of these, 107 children aged ≤ 14 years who underwent PCNL were analysed. 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%,

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respectively. 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 being more preferred in the preschool children ($P < 0.001$) [6]. The authors concluded that PCNL could be applied safely and effectively in children of all age groups, and the outcomes were comparable with those in adults including success and complications. In this paper we have retrospectively reviewed our series of children who underwent PCNL and analysed the success rate, complications and biochemical composition of the renal stones.

Materials and methods

With permission obtained from the University/Institutional ethical committee, we retrospectively reviewed the inpatient, outpatient records, imaging films of all children with renal stones undergoing PCNL at our hospital (Figs. 1 and 2). Age, gender, symptoms and clinical findings were noted. Similarly, the imaging films were accessed and analysed. The indications for surgery, positioning of the patient, instruments used and blood loss was noted. Blood transfusion rate, complications such as fever, post-operative bleeding and infections were noted. Stone free rates, residual calculi and adjuvant procedures were also noted.

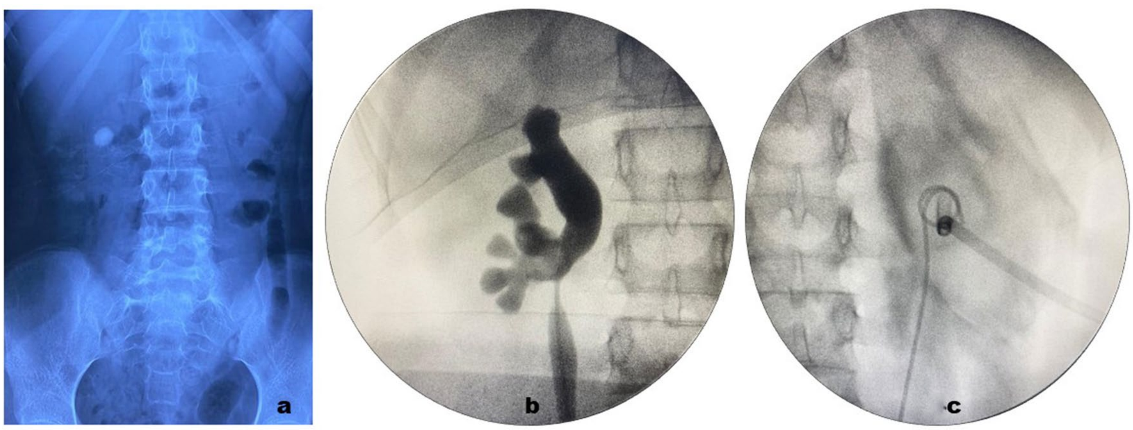

Fig. 1 **a** Plain X-ray KUB shows a 13 mm calculus in the Rt. kidney in a 15 yrs. old girl. **b** Shows pre-PCNL Rt. retrograde pyelography. **c** Shows complete clearance of stone following PCNL

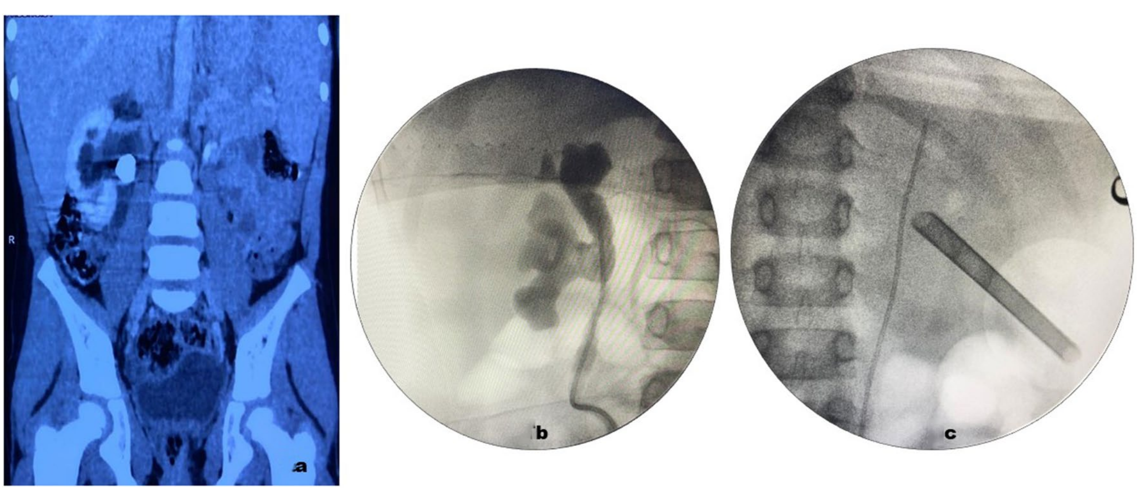

Fig. 2 **a** CT scan shows a 14 mm Rt. renal calculus in a 9 yrs. old boy. **b** A pre-PCNL Rt. retrograde pyelography. **c** Shows complete clearance of stone following PCNL

Positioning of the patient

All PCNL procedures were performed under general anaesthesia. Initially the child was positioned in a lithotomy position and an initial cystoscopy was done. The affected side was catheterized using a 3/5 Fr open ended ureteric catheter and a retrograde uretero-pyelography was performed. The open-ended ureteric catheter was left in place for use during the PCNL procedure. For children undergoing PCNL in prone position, the children were turned prone. In children who were planned to undergo supine PCNL, the patients were positioned in the typical Galdakao-modified supine Valdivia (GMSV) position, with the leg of the side to be operated extended and the contralateral one well abducted (Fig. 3).

Percutaneous nephrolithotomy

Using bi-planar fluoroscopy an initial puncture into the collecting system was made. The calyx offering the most direct access to the stone was selected for puncture. A hydrophilic guide wire was passed through the needle into the collecting system and used for further dilatation of the tract using Teflon dilators as well as telescoping metallic dilators. A safety wire was always used. The tracts were dilated depending on the size of the nephroscope (10/15 Fr) for placement of an Amplatz sheath of 12/16 Fr inner diameter. After entering the system, the stone was identified and fragmented using either a pneumatic lithoclast or a holmium laser. Additional punctures were placed if required. Stone clearance was assessed by intra-operative fluoroscopy and endoscopy. At the end of the procedure, a 10/14 Fr nephrostomy tube was placed within the tract and clamped for 12 h or overnight. The following morning plain X-ray of KUB region and abdominal ultrasonography was done to ensure complete clearance. The nephrostomy was removed in the absence of residual significant stone fragments. The child was discharged 48–72 h after surgery. The child was called for follow-up after 2 weeks. The treatment success was defined as the child being free of any stone fragments (> 4 mm) by 30 days posttreatment.

Results

During the period Jan 2010 till Dec 2019, 123 children underwent 129 PCNL (6 bilateral) procedures at our centre for renal calculi. The mean age was 11.06 years and 87 (70.73%) of the children were males (Table 1). The symptoms included abdominal pain, fever with chills, vomiting and haematuria. Eight children (6.5%) had undergone interventions for urolithiasis previously which included SWL in 5 and ureteroscopy in 3. None of the children had any skeletal abnormalities.

All children had normal renal function (mean pre-op creatinine was 0.6 mg%, range (0.4–1.0 mg%). Pre-operative

Table 1 Demographics of children with Renal Calculi

	0–6 yrs	7–12 yrs	13–18 yrs	Total
Patients	10	86	27	123
Mean age	5.8 ± 0.42	11.79 ± 0.43	15.59 ± 2.25	11.06 ± 4.93
Male	8	61	18	87 (70.73%)
Female	2	25	9	36 (29.26%)
Previous interventions (ipsilateral)	–	2	1	3
Previous interventions (contralateral)	–	3	2	5

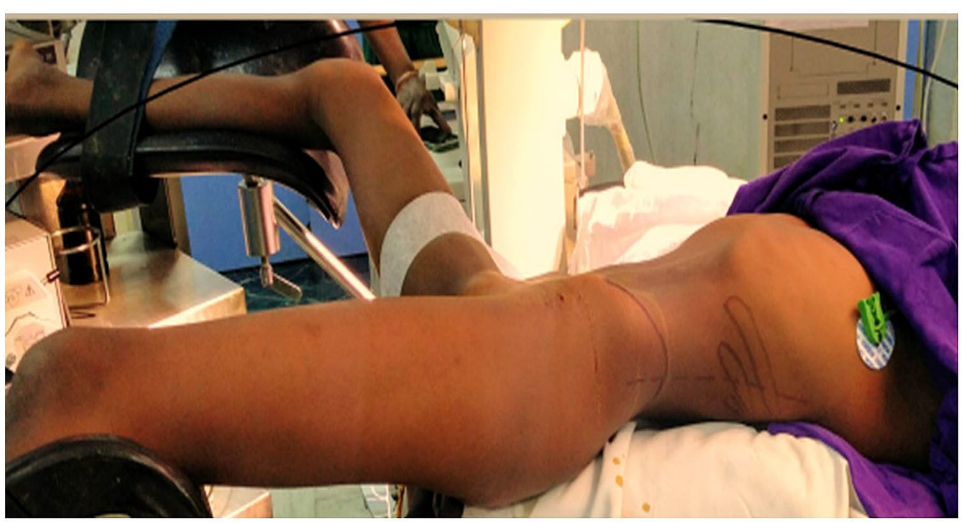

Fig. 3 Patients position in supine PCNL

evaluation in children included complete hemogram coagulation profile, renal function test, ultrasonography and computer tomography. Six children had bilateral renal calculi on imaging. The size of the stones varied from 15 to 37 mms in the longest diameter. The stone size (Table 2) in terms of square mm ranged from 170 to 870 mm^2. A complete staghorn was noted in 6 (4.65%) and a partial staghorn in 9 (6.97%) children. Supine PCNL was performed in 21 (16.2%) children and the indications were single large renal pelvic calculi with/without an upper calyceal calculi and wide upper infundibulum. The remaining 102 (83.7%) children underwent PCNL in prone position.

The procedure was performed with a single tract in 118 (91.4%) children, whereas 9 (6.97%) children required multiple tracts to access the calculi. The mean drop in haemoglobin was 1.24 gm% (Table 3). None of the children required intra-operative blood transfusions. Stone clearance was achieved in 122 (94.5%) children with intra-operative fluoroscopy showing complete clearance of stone fragments. There were residual fragments in 7 (5.4%) children which could not be cleared due to non-visualization or excessive bleeding. All these residual fragments were noted in children with stones bigger than 20 mm. The residual fragments ranged between 5 and 9 mm in size. All these children underwent SWL 6 weeks later and clearance was noted. Clearance was confirmed by both ultrasonography imaging as well as plain X-ray KUB region.

Table 2 Size of stones varied between < 10 and > 31 mm

Size of stone	*n*
< 10 mm	–
< 11–20 mm	71
< 21–30 mm	40
> 31 mm	18
Total	129

Post-operatively 4 (3.1%) children needed blood transfusions due to excessive bleeding. All these children were those who require multiple tracts to access the calculi and the stone was bigger than 21 mm. Other complications that were noted was post-operative fever 12 (9.3%), stent related symptoms 4 (3.1%) and pain with vomiting 1 (0.77%). Complete clearance of stone was noted in all children by 16 weeks following PCNL. Most of the stones were calcium oxalate 108 (83.7%), calcium phosphate 3 (2.32%), uric acid 9 (6.97%) and the rest 9 (6.97%) were mixed calculi. There were no metabolic abnormalities noticed in any of these children. Post-operative serum creatinine done six weeks after this procedure showed a mean value of 0.61 mg%.

Discussion

It has been noticed that the incidence of urolithiasis is on the rise world over. Sas et al. [8] reported that urolithiasis affected around 50 cases per 100,000 children [9]. The vast majority of urinary stones in children are calcium stones, consisting of calcium oxalate and to a lesser extent calcium phosphate. However, urate, cysteine or struvite stones are less common. Just like in adults, most paediatric urinary stones can be managed effectively by minimally invasive treatment modalities such as extracorporeal shock wave lithotripsy (SWL), percutaneous nephrolithotomy (PCNL), retrograde intrarenal surgery (RIRS) [7, 10]. PCNL is currently recommended as a primary treatment option in the management of large renal stones (> 20 mm) and also in the management of lower calyceal stones > 10 mm, as per the guidelines of the European Association of Urology [11].

Improvements in endourologic devices, miniaturization of the sheaths and endoscopes, use of laser as an energy source has led to the use of PCNL as a safe and effective option in children. Earlier, adult instruments (24–30

Table 3 Operative details

Parameter	*n* (%)	
Total Patients	123	
Total Procedures	129	6 patients had bilateral renal calculi
Complete Staghorn	6 (4.65)	
Partial Staghorn	9 (6.97)	
Supine PCNL	21 (16.2)	Large pelvic calculi-16, with upper calyceal calculi-5
Single Tract	118 (91.4)	
Multiple Tracts	9 (6.97)	
Supracostal Puncture	2 (1.5)	
Auxiliary Procedures	7 (5.4)	SWL-7 (5.4)
Drop in haemoglobin (gm%)	1.24	
Operative time (min)	66 (50–90)	
Complications	19 (14.7)	Bleeding, pain, fever, stent related symptoms

SWL Shockwave lithotripsy

Table 4 Complications as per Modified clavien classification

Grade I	–	0
Grade II	Post-operative bleeding	4 (3.1%)
	Post- operative fever	12 (9.3%)
	Pain with omitting	1 (0.77%)
	Stent related symptoms	4 (3.1%)
Grade III, IV and V	–	0

Table 5 Radiation exposure during PCNL

Fluoroscopy time	45–70 s
Fluoroscopy exposure mGy	90–105 mGy

F) were used for PCNL in children, causing several complications that included drop in haemoglobin, need for blood transfusions, damage of the renal parenchyma, and increased need for postoperative analgesia. However, over the past two decades smaller calibre sheaths (11–20 F) and endoscopes are available and are in use, leading to decrease in morbidity. Recently Micro-PCNL or microperc has also been described as another minimally invasive PCNL technique that is performed using a 4.8 F all-seeing needle [12].

The goals of surgical intervention for renal stones remain the same as in for adults: to achieve stone clearance with the minimal number of procedures, risk conferred, and complications [13]. The choice of intervention is determined primarily by the size and location of the stone, patient anatomy, and patient (and provider) preference [13]. Secondary factors include patient comorbidities, composition of stone, and equipment availability. Currently, the choice of the type of surgical intervention is heavily influenced by the institution where the child obtains care [14]. As of today there exists no consensus regarding the maximum size of residual fragments that are considered clinically significant for children, and as a result there is no clear definition as to what constitutes "stone-free" status (Table 4) [13].

Children with renal stones are exposed to radiation during diagnostic evaluation, operative treatment, and for surveillance after surgery (Table 5) [15, 16]. PCNL typically uses fluoroscopy, which delivers ionizing radiation and this is a matter of concern. Ristau et al. [17] reported the median fluoroscopy times for unilateral URS, bilateral URS, and PCNL were 1.6, 2.5, and 11.7 min, respectively. This was equivalent to 16.8 mSv for PCNL. For a patient undergoing a CT scan, PCNL, and three radiographs in a 1-year period, the average cumulative radiation exposure would be 32 mSv, and the current guidelines recommend a maximum dose of 50 mSv in a 12-month period, and an average of < 20 mSv/year over a 5-year period [18]. This definitely approaches the limits of recommended ionizing radiation exposure for a child requiring PCNL for a single large stone. It is a particularly important to look at the cumulative radiation exposure in children, considering that they are more likely than adults to require future diagnostic imaging and surgical interventions that use ionizing radiation [19].

In spite of the AUA recommendations for the use of both SWL and PCNL as options in the management of renal stones greater than 20 mm in children, several experts recommend PCNL because SWL has been found to be less effective than PCNL for large renal stones [13, 20]. Accumulated evidence has also shown that PCNL has been considered as a first-line therapy in the treatment of renal stones greater than 20 mm in children, with stone clearances of approximately 90% [21]. Several of the contemporary series have shown good outcomes with PCNL in children (Table 6).

The stone-free rates reported in literature have range widely from 58 to 99% when PCNL was used as primary, monotherapy [28]. The reported complication rates range from 15 to 39% [13]. Most of these complications are of minor in nature, however complications greater than or equal

Table 6 Contemporary outcomes of PCNL in children

Author	*n*	Age (mean)	Tract size	Lithotrite	Stone clearance (%)
Dede et al. 2015 [22]	39	5.8	12 F	PNE/HOL	82
Daw et al. 2015 [23]	26	3.7	14 F	HOL	77
Citamak et al. 2016 [24]	346	8.5	14–30 F	PNE/HOL	73
Yadav et al. 2017 [25]	639	12.2	≤ 2–4 F	PNE/HOL	94
Pelit et al. 2017 [26]	74	1.8	17 F	PNE	84
Sharma et al. 2019 [27]	20	8.4	18–22 F	–	95
Nerli et al. 2018 [7]	10	11.5	18 F	PNE/HOL	90
Present Series	123	11.0	12/16 F	PNE/HOL	94.5

PNE pneumatic lithotripsy; *HOL* Holmium laser lithotripsy to Clavien 3 occur in 1–16% (Table 4). Operative bleeding leading to need for blood transfusions in < 10% of cases [13]. Other complications reported include, postoperative fever (30%) and transfusions (24%). When efficacy rates were stratified using tract size (14, 20, 24 F), they were similar in all groups, however there were no complications noted in the group using 14 F tract size [29]. Onal et al. [30] reported on a large multi-centric study that demonstrated that the most significant determinants affecting complication rates were operative time, sheath size, mid-calyceal puncture, and partial staghorn formation. Moreover, PCNL has not been responsible for loss of renal function or scarring [31].

Conclusion

PCNL in children is a safe and effective means of managing renal calculi. Refinements in percutaneous access techniques, miniaturization of instruments, and technologic advances in energy sources for lithotripsy have led to improvement of outcomes and have lowered the morbidity rates in children following PCNL.

Declarations

Conflict of interest The authors declare conflict of interest as none.

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