# Pediatric Percutaneous Nephrostomy: A Multicenter Experience

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## ABSTRACT

**Purpose:** To analyze technique, outcomes, and complications of a large series of pediatric percutaneous nephrostomy (PCN) procedures performed at 4 tertiary pediatric centers.

**Materials and Methods:** Retrospective multicenter study of PCNs performed during an 11-year period. Six hundred seventy-five PCNs were performed on 441 patients (median age: 4 y, range: 1 d–18 y, median weight: 17 kg, range: 0.7–112 kg); 31% were younger than 1 year. The most frequent indications for PCN procedures included hydronephrosis (57%), calculus (14%), and infection (12%). Forty-five percent of patients had severe and 32% had moderate hydronephrosis.

**Results:** Technical success was 99% (n = 668); 7 failures occurred from lost access, during tract dilatation (n = 5) and during staghorn calculi without dilatation (n = 2). General anesthesia was used in 73% of procedures. Combined ultrasound and fluoroscopy was used in 98% of procedures. Of the 668 procedures, 561 (84%) were primary nephrostomy insertions, and 107 (16%) were a variety of exchanges (secondary catheter insertions). Twenty-four of 675 (4%) were transplanted kidneys. Access sites included lower (47%), mid (28%), and upper (12%) poles and pelvis (11%). Catheters were predominantly 7-8 French (n = 352). The mean catheter dwell time was 25 days (0–220 d). Total primary catheter days were 14,482, with an additional 2,241 days after secondary procedures. Follow-up in 653/668 (98%) procedures documented elective removal (79%) and salvage procedures (21%), which included wire exchange (8.7%), nephroureteral stent/catheter conversion (8.8%), and tube upsizing (3.5%). Periprocedural complications occurred in 30/668 (4.5%) procedures: 1 major (0.1%) self-limiting hematuria requiring transfusion and 29 (4.4%) minor complications.

**Conclusions:** PCN is safe and successful in children of all ages, with few major complications. PCN in children is associated with specific technical challenges and requires ongoing management tailored to the very young to achieve good outcomes.

## ABBREVIATION

PCN = percutaneous nephrostomy

## INTRODUCTION

Percutaneous nephrostomy (PCN) is a well-established image-guided technique of percutaneous placement of a catheter into the renal collecting system. There are many clinical indications in children: PCN provides urinary drainage in patients with supravesical urinary obstruction and temporary urinary diversion in patients with obstructive uropathies (1–6), urinary fistulas, leaks, or hemorrhagic cystitis (7–12). It may be used to evaluate residual function of a hydronephrotic kidney (1,13), may serve as a bridge to more complex interventions (percutaneous nephrolithotomy) (7), and may be used for the assessment of renal function prior to surgical procedures (1–4). First described in 1955 as a minimally invasive treatment for urinary obstruction (14), PCN placement became a widely accepted procedure in children in the 1980s, and the first series of pediatric cases were reported with a technical success rate of 98%–100% (5,6,15–17). After 30 years, PCN is still 1 of the most frequently performed interventional procedures in pediatric patients with obstructive uropathy.

Although PCN studies have been widely performed in children, published reports have been few and limited to small case series (17–19). In addition, these published reports are outdated: over the years, PCN has undergone substantial

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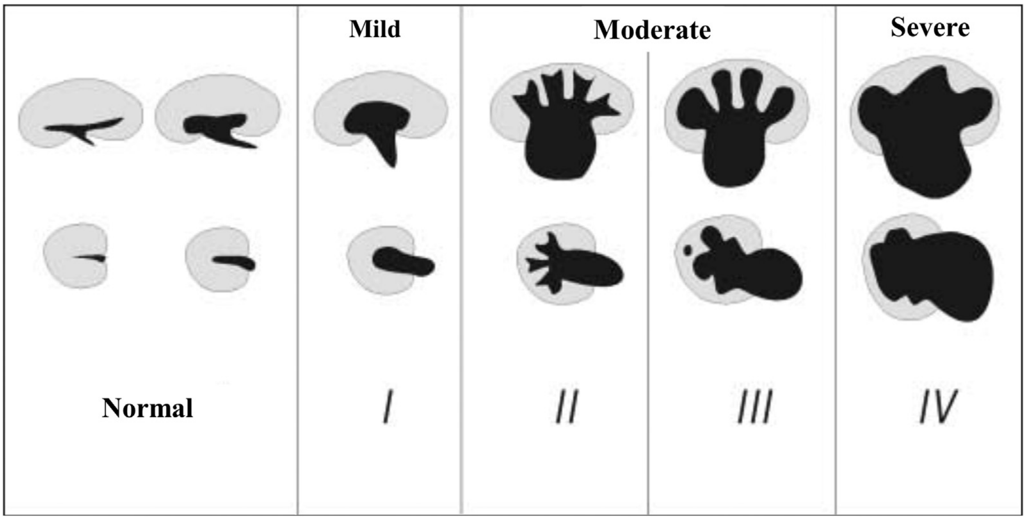


**Figure 1.** Classification of degree of hydronephrosis: (*i*) mild: dilatation of the renal pelvis without dilatation of the calyces, prominent reflex of the renal sinus without signs of parenchymal atrophy; (*ii*) moderate (included patients with moderate or mild to moderate hydronephrosis): dilatation of the renal pelvis and calyces, attenuated/missing sinus reflex, no/minor signs of parenchymal atrophy, missing/marginal sinus reflex; or, (*iii*) severe (included patients with severe or moderate to severe hydronephrosis): massive dilatation of the renal pelvis and calyces, missing borders between renal pelvis and calyces, significant signs of renal atrophy; and (*iv*) Normal: no hydronephrosis (20).

evolution in both its technical and imaging aspects, with modifications of puncture devices and techniques, coupled with advancing imaging modalities for guidance (1). Furthermore, data on larger pediatric series are lacking. Experience and benchmarks of PCN in adults cannot be directly extrapolated to children, because in newborns and young infants, PCN is challenging for reasons beyond the concerns pertaining to sedation and patient monitoring, including size, consistency, and mobility of the kidney, indications for nephrostomy (ie, congenital obstruction), and the need for smaller devices (1). Therefore, the primary purpose of this large multicenter retrospective study was to analyze the collective experience of PCN tube placement in children over an 11-year period at 4 tertiary pediatric centers. A secondary goal was to provide informative data, which might be useful in the development of pediatric-specific clinical guidelines. The hypothesis was that although PCN in children is similar to that in adults, it is associated with different technical and management challenges, especially in very young children.

## MATERIALS AND METHODS

This retrospective, multicenter study was approved by the institutional review boards at each site. PCN tube placement procedures performed over an 11-year period (January 2001–December 2011) at 4 pediatric centers were included. Retrospective chart review of all PCN procedures was performed to analyze indications, techniques, outcomes, and complications. The indications for PCN were broadly categorized into the following groups: hydronephrosis (including ureteropelvic junction/ureterovesical junction obstruction), renal calculus/stones, infection (sepsis/pyelonephritis/urinary tract infection [UTI]), urinary leak, and elevated creatinine.

### Definitions

Successful nephrostomy tube placement was defined according to the Society of Interventional Radiology (SIR) standards of practice committee guideline as "placement of a catheter of sufficient size to provide adequate drainage of the collecting system or allow successful tract dilation so that the planned interventional procedure can be successfully completed through the nephrostomy tract" (7). Technical failure was defined as the inability to place a nephrostomy tube. Primary catheter insertions were defined as first catheter insertions; secondary catheter insertions were defined as primary catheters that were rewired/converted to different catheters using the same access site. The degree of hydronephrosis was based on recognized criteria (**Fig 1**) (20). Infectious complications were based on laboratory-proven infections. The use of general anesthesia (GA) versus intravenous sedation for PCN patients was determined, in most cases, according to the American Society of Anesthesia classification. Procedures performed under the care of an anesthesiologist were classified as GA, irrespective of the use of airway support, inhalational agents, or intravenous medications. Procedures performed under sedation provided by the Interventional Radiology (IR) team were classified as sedation. Each PCN was counted individually (eg, bilateral were counted as 2, or PCN into an upper and lower calyx of the same kidney were counted as 2). The use of antibiotics after PCN placement was not consistent across institutions; it varied from being administered in all cases to being administered in situations where infection was a concern.

Complications were classified based on SIR standards of practice as major if the procedure resulted in minor hospitalization for therapy, unplanned increase in level of care, prolonged hospitalization, permanent adverse sequelae, or

**Table 1.** PCN Procedures in Different Patient Age Groups

| Patient age groups (years) | PCN tube placements (n = 675 patients) | |
|---|---|---|
| | n | % |
| <1 | 209 | 31 |
| 1–4 | 149 | 22 |
| 5–9 | 121 | 18 |
| 10–18 | 196 | 29 |

PCN = percutaneous nephrostomy.

**Table 2.** Indications at Presentation in PCN Tube Placements

| Indications | n* | % |
|---|---|---|
| Hydronephrosis | 444 | 57 |
| Calculus | 111 | 14 |
| Infection | 92 | 12 |
| Elevated creatinine | 36 | 5 |
| Urine leak | 34 | 4 |
| Other (urinoma, fistula, vesicoureteral reflux) | 64 | 8 |

PCN = percutaneous nephrostomy.
*n = 781.

death. Minor complications included no therapy, no consequence, or nominal therapy, including overnight admission for observation only (7). Minor/self-limited hematuria was not considered a complication by consensus within the authorship group, since this is an expected occurrence in PCN placement. Complications were further categorized as periprocedural, mechanical, and catheter-related infectious complications. All complications were calculated based on successfully placed PCNs. Endpoints were defined in terms of the catheter (primary and secondary catheter dwell time in days, catheter removal or exchange, and catheter infection-free survival) and patient (death). Primary catheter days were the dwell time in days of the primary catheter. Secondary catheter days were the number of additional days achieved following a salvage or secondary procedure.

## Patient Population

A total of 441 patients underwent 675 PCN procedures at 4 pediatric centers over an 11-year period. Patient age ranged from 1 day to 18 years, with a median age of 4 years; but notably, 31% (209/675) of procedures were performed in children younger than 1 year (Table 1). Median patient weight was 17 kg (0.7–112 kg). The most common indication for PCN procedure was hydronephrosis of severe or moderate degree, followed by calculous disease; 106 patients had more than 1 indication (Table 2, Table 3). Most procedures (88%; n = 593) were performed on inpatients; the remaining 12% (n = 82) were outpatient procedures. PCN were performed under GA in 74% (n = 495) of procedures; the remaining 26% (n = 178) were performed with IR-administered intravenous sedation (data not available for 2 cases). PCN was performed using a combination of

**Table 3.** Degree of Hydronephrosis in PCN Procedures

| Degree of hydronephrosis | n (675) | % |
|---|---|---|
| Severe | 302 | 45 |
| Moderate | 217 | 32 |
| Mild | 77 | 11 |
| No hydronephrosis | 71 | 11 |
| Data not available | 8 | 1 |

PCN = percutaneous nephrostomy.

ultrasound and fluoroscopy in 660 (98%) procedures, fluoroscopy-only in 8 (1%), and ultrasound-only in 2 (0.3%); 1 procedure was performed with computed tomography, and 2 procedures were performed by open surgical access (data not available for 2 cases).

## Statistics

Descriptive statistics were performed using Microsoft Excel (version 2013, Microsoft Corp., Redmond, Washington). SPSS statistics software (SPSS Inc., Chicago, Illinois) was used for Kaplan-Meier survival analysis to estimate the cumulative complication-free survival for primary catheters. Mechanical complication-free and infection-free catheter survival rates for primary catheters was also estimated. Furthermore, PCNs were categorized into 2 age groups: infants (<1 year) and non-infants (≥1 year); chi-square analysis was performed using SPSS statistics software to examine the differences between these 2 groups.

# RESULTS

Of the 675 PCN procedures, 668 (99%) were technically successful. The 7 technical failures (1%) were caused by loss of access during tract dilatation (n = 5) and staghorn calculi in nondilated systems (n = 2); 1 patient underwent a successful repeat procedure 10 days later. All 7 failures occurred during primary catheter insertions. Of the 668 successful procedures, 561 (84%) were primary catheter insertions, and 107 (16%) were secondary insertions. Access was into native kidneys in 651 (96%) procedures and into transplant kidneys in 24 (4%) procedures. The right kidney was accessed in 342 (51%) procedures; the left kidney was accessed in 324 (49%) procedures, including 80 patients in whom bilateral PCNs were placed. The sites of access to the collecting systems in the 668 successful PCN procedures are reported in Table 4. A Dawson-Mueller Multipurpose Drainage Catheter (Cook Medical, Bloomington, Indiana) was most commonly used, in 580 procedures (86%). Other less commonly used catheters included: All-Purpose Drainage Catheter (n = 46) (Cook Medical; Boston Scientific, Marlborough, Massachusetts), Locking Loop Catheter (n = 9) (Uresil, Skokie, Illinois), Amplatz Anchor Catheter (n = 7) (Cook Medical), Multipurpose Drainage Catheter (n = 5) (Cook Medical), Duan Catheter (n = 3) (Cook Medical), Foley Catheter (n = 3) (Covedian, Medtronic, Mansfield, Massachusetts), Malecot Catheter (n = 2)

**Table 4.** Calyx Access Sites in Successful Placements

| TOTAL Access site | n* | % | Primary Nephrostomies | Secondary Nephrostomies |
|---|---|---|---|---|
| Lower calyx | 311 | 47 | 262 | 49 |
| Mid calyx | 184 | 28 | 154 | 30 |
| Upper calyx | 82 | 12 | 72 | 10 |
| Renal pelvis | 73 | 11 | 56 | 17 |
| Data not available | 18 | 3 | 17 | 1 |

*n = 668.

(Cook Medical), and Centesis Catheter (n = 1) (Cook Medical; Argon Medical Devices, Athens, Texas). Catheter sizes were as follows: 4–6 F (n = 209), 7–8 F (n = 352), and larger than 10 F (n = 103).

Follow-up was available in 653/668 (98%) PCN placements. Elective catheter removal occurred in 79% (n = 515/653) of the placed catheters, and 21% (138/653) of the catheters underwent subsequent salvage procedures: nephroureteral stent/catheter conversion (n = 58, 8.8%), exchange over a wire (n = 57, 8.7%), and tube upsizing (n = 23, 3.5%). The average dwell time of nephrostomy catheters was 25 days (median: 18 days; range: 0–220 days). The total primary catheter days was 14,482. Secondary catheters (after rewiring/conversion) prolonged their functional life by 13% (2,241 days).

Periprocedural complications occurred in 4.5% (30/668) of cases. One major complication occurred (rate: 0.1%; 1/668) in a patient (<1 year) with persistent/gross hematuria requiring transfusion but no other intervention. Minor complications (29/668; 4.4%) included: loss in initial access, site oozing, and postobstructive diuresis. Mechanical complications (ie, tube-related issues and urine leak) occurred in 17% of cases. Catheter-related infectious complications occurred after 42 (6.3%) procedures, diagnosed on day 26 (mean) after catheter placement (range: 2–112 days). These included UTI in 36 cases and infection at the tube insertion site in 6 cases. All complications from PCN tube placements are detailed in Table 5. Two non-procedure-related patient deaths occurred due to pulmonary hypoplasia secondary to prenatal anhydramnios. Both patients had severe hydronephrosis and died from pulmonary complications on day 3 and day 4 after tube placement, at 6 and 5 days of life, respectively.

Kaplan-Meier survival analysis showed a cumulative complication-free catheter survival for primary catheters of 75% at 37 days, 50% at 89 days, and 25% at 192 days (Fig 2). Cumulative infection-free catheter survival for primary catheters was 90% at 36 days, 75% at 64 days, and 56% at 131 days (Fig 3). Cumulative mechanical complication-free catheter survival for primary catheters was 75% at 42 days, 50% at 93 days, and 25% at 192 days (Fig 4).

## Infants Versus Non-infants

The categorization of the PCNs into 2 age groups (infant and non-infant) is shown in Table 6. Chi-square analysis

**Table 5.** Complications from PCN Tube Placements

| PCN tube placement complications | n | % |
|---|---|---|
| **Periprocedural complications** | **30** | **4.5** |
| *Major complications:* | | |
| Hematuria requiring transfusion | 1 | 0.1 |
| *Minor complications:* | | |
| Loss in initial access | 15 | 2.2 |
| Site oozing | 8 | 1.2 |
| Postobstructive diuresis | 6 | 1.0 |
| **Mechanical complications** | **114** | **17** |
| Tube displacement/dislodgement | 54 | 8 |
| Urine leak | 45 | 6.7 |
| Tube occlusion | 15 | 2.3 |
| **Cather-related infectious complications** | **42** | **6.3** |
| Urinary tract infection | 36 | 5.4 |
| Infection at the tube insertion site | 6 | 0.9 |

PCN = percutaneous nephrostomy.

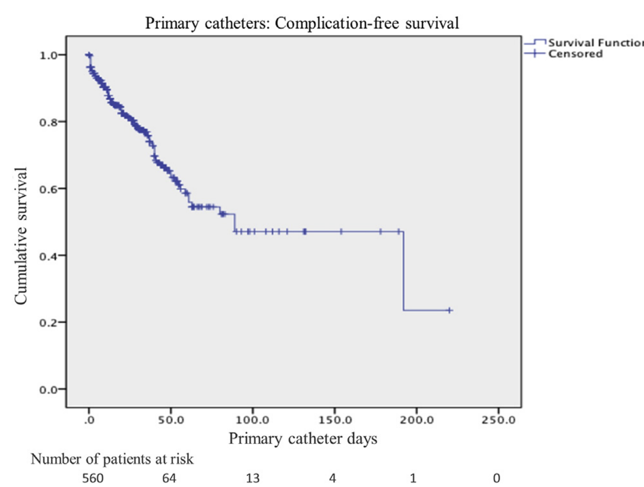


**Figure 2.** Kaplan-Meier survival analysis for cumulative complication-free catheter survival days for primary catheters.

examining the differences in degree of success showed no differences between infants and non-infants (success rate: 98.5% vs. 99%) (chi-square = 0.47; $P > .05$). Significant difference in inpatient/outpatient status were observed between infants and non-infants (chi-square = 11.64; $P = .001$): 94% of PCNs performed on infants were inpatient procedures, whereas 85% of PCNs performed on non-infants were inpatient procedures. Examination of the differences in degree of hydronephrosis between infants and non-infants showed significant differences (chi-square = 48.66; $P < .001$). Table 6 shows that the group differences were primarily caused by a greater percentage of infants having severe hydronephrosis scores (62% of infants vs. 37% of non-infants had severe scores) versus a greater percentage of non-infants having none to mild hydronephrosis (9% of infants vs. 28% of non-infants had scores of none to mild).

Chi-square analysis examining infant and non-infant differences in periprocedural, mechanical, and infectious

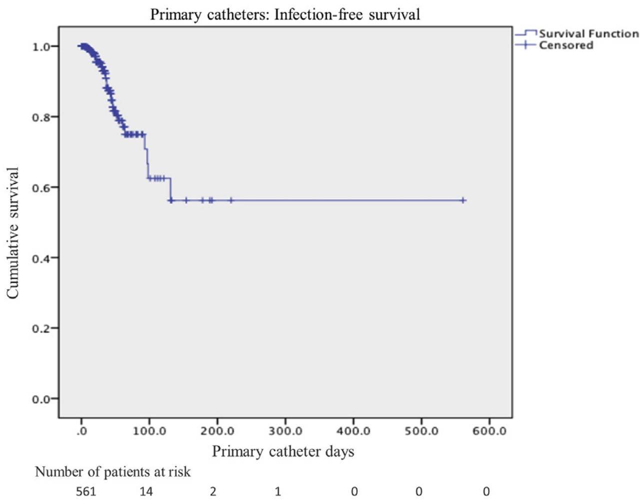


**Figure 3.** Kaplan-Meier survival analysis for cumulative infection-free catheter survival days for primary catheters.

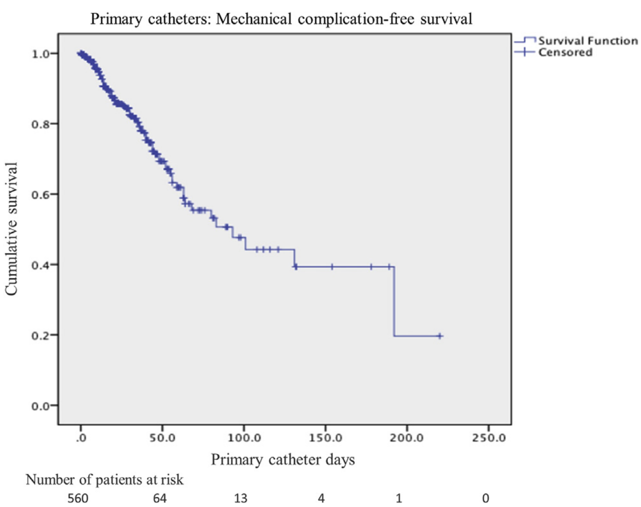


**Figure 4.** Kaplan-Meier survival analysis for cumulative mechanical complication-free catheter survival days for primary catheters.

complications showed no statistical differences *(P* > .05 for each; chi-squares of 7.04, 3.43, and 5.27, respectively), with most infants and non-infants experiencing no periprocedural (94% vs. 96%), mechanical (81% vs. 84%), or infectious (91% vs. 94%) complications.

**Table 6.** Infant versus Noninfant Comparison

| | Infants (<1 year) | Noninfants (≥ 1 year) | Statistics |
|---|---|---|---|
| No. of PCNs | 209 | 466 | |
| Inpatient | 197 | 396 | *P* = .001, chi-square = 11.64 |
| Outpatient | 12 | 70 | |
| Success | 206 | 462 | *P* > .05, chi-square = 0.47 |
| Failure | 3 | 4 | |
| **Degree of hydronephrosis** | | | *P* < .001, chi-square = 48.66 |
| Severe | 130 | 172 | |
| Moderate | 58 | 159 | |
| Mild | 13 | 64 | |
| No hydronephrosis | 5 | 66 | |
| Not available | 3 | 5 | |
| **Indications** | | | |
| Hydronephrosis | 171 | 273 | |
| Calculus | 5 | 106 | |
| Infection | 30 | 62 | |
| Elevated creatinine | 18 | 18 | |
| Urine leak | 7 | 27 | |
| Other (urinoma, fistula, vesicoureteral reflux) | 16 | 48 | |
| **Periprocedural complications** | | | *P* > .05, chi-square = 7.04 |
| Hematuria requiring transfusion | 1 | 0 | |
| Site oozing | 3 | 5 | |
| Loss in initial access | 5 | 10 | |
| Postobstructive diuresis | 4 | 2 | |
| **Mechanical complications** | | | *P* > .05, chi-square = 3.43 |
| Tube displacement/dislodgement | 22 | 32 | |
| Urine leak | 13 | 32 | |
| Tube occlusion | 4 | 11 | |
| **Catheter-related infectious complications** | | | *P* > .05, chi-square = 5.27 |
| Urinary tract infection | 17 | 19 | |
| Infection at tube insertion site | 1 | 5 | |

PCN = percutaneous nephrostomy.

## DISCUSSION

In repeated studies, the percutaneous route to establish drainage has been shown to be safer, quicker, easier, and less expensive than surgery (5,21). This report is of a large collaborative study that describes the collective pediatric experience with PCN procedures performed at 4 tertiary pediatric centers. It provides robust outcome data, which may inform future pediatric nephrostomy guidelines. These results from a large pediatric population show that a high technical success rate (668/675, 99%) can be achieved with PCN tube placements, even in an infant patient population (206/209, 98.5%). Smaller studies have also reported good technical success rates, ranging from 56% to 100%, with PCN tube placements in children (1,5,17,22).

There are conflicting opinions regarding the safety of performing PCN in children on an outpatient basis (4,21,23). Cochran et al suggested that PCN could be more safely performed as an inpatient procedure; they proposed guidelines to reduce the risk of sepsis (a major complication of PCN) if PCN needed to be performed on outpatient basis (23). In a study of 39 outpatient PCN encounters, Hogan et al reported that outpatient PCN can be safely performed in a select group of children and adolescents (ie, in patients without signs of active infection, with responsible parents who are educated about tube care, who have access to appropriate medical care near home, who have no coexistent medical illness requiring hospitalization, and who have adequate renal function prior to the procedure). Furthermore, outpatient PCNs are not performed on patients with stones (4). Gray et al showed in 48 adult patients that outpatient PCN is cost-effective and safe when patients are carefully selected based on clinical stability and suitability (patients with UTIs, coagulopathy, and staghorn calculi excluded) (21). The choice of GA versus sedation for PCN is based on 2 main factors: (*i*) institutional availability of anesthesia resources and practice norms and (*ii*) the clinical status of the patient if/when both GA and sedation are options. At our 4 pediatric centers, overnight admission of a patient was decided on a case-by-case basis depending on age, comorbidity, presence of renal stones, and technical difficulties. Usually, outpatient PCN was performed on patients without signs of active infection and who, in general, met the criteria outlined by Hogan et al above. In our study, 12% of the PCN procedures (82/675) were performed successfully as outpatient procedures, of which 50/82 were performed successfully under IR sedation, 31/82 were performed successfully under anesthesia, and 1/82 failed (under GA). These results suggest that outpatient PCN can be safely performed in children. In our experience, the rates of inpatient PCN placement overall are high (88%; 593/675), especially in infants (94%; 197/209).

In this series, most patients had severe or moderate hydronephrosis, as expected. The targeted calyx for PCN placement depends on the intended purpose. Lower-pole calyces have the lowest risk of complications, but interpolar calyces may provide greater mechanical advantage for future placement of a ureteral stent (9). For treatment of focal small-volume stone disease, nephrostomy placement in the stone-containing calyx is desirable. However, in a kidney with large-volume stone disease, placement of the nephrostomy tube into an upper- or lower-pole calyx may allow easier access to the entire collecting system during percutaneous lithotomy (9). In our experience, we observed that the lower-pole calyx was accessed in most of the cases (47%); the mid-pole calyx was accessed in 28% of the cases; and the upper-pole calyx and renal pelvis were accessed the least, in 12% and 11% of the cases, respectively, with similar distribution between primary and secondary procedures. In terms of indications, lower (n = 197) and mid (n = 134) calyces were accessed the most in patients presenting with hydronephrosis (n = 444). The lower calyx was also commonly used for PCN in patients with calculus (58/111) and infection (38/92). In this series, the distribution for access for 38 patients undergoing lithotripsy was similar to the whole population (52% lower pole, 26% mid pole) but was different in those 28 patients who underwent stent placement (48% lower pole, 48% mid pole). Of the 73 patients in whom access was through the pelvis (11%), severe hydronephrosis was present in 84% (n = 61), calculus in 14% (n = 10), and bladder atrophy in 1% (n = 1) (data not available in 1 case). The findings from infant versus non-infant patient comparison showed that infants are more likely to have severe hydronephrosis (130/209; 62%) and low incidence of renal stone disease (5%; of 111 patients with renal calculus, only 5 were infants).

Transient minor bleeding/hematuria after PCN tube placement is frequently seen and is considered a normal sequelae rather than a complication, occurring in up to 95% of cases in some reports (9). This is often due to small vessel or venous bleeding. Persistent gross hematuria more than 3–5 days after PCN placement may indicate severe arterial injury requiring treatment (9). Severe bleeding after PCN placement necessitating transfusion or other intervention is a major complication and is reported to occur in 1%–4% of adult patients (7). In this pediatric series, 1 patient (<1 year of age) had persistent/gross hematuria after PCN placement and required transfusion but no other intervention (major complication rate 0.1%; 1/668). Self-limited hematuria was recorded in 19.8% of procedures (132/668). Other studies have also reported hematuria (21%), blood clots in the urine (7%), and bleeding diathesis immediately after PCN placement (4%) (2,5).

Dislodgement of the catheter may occur as a result of placement of a short segment of catheter within the collecting system, inadequate fixation, or expansion of the nephrostomy tract after tube placement (after a few weeks) (24). In a predominantly adult study (50 patients: 46 adult and 4 children), catheter dislodgement occurred in 2 cases (3.5%), their ages unspecified (24). Younger children and infants are unable to care for the tube; therefore, catheter damage or dislodgement is a concern in these patients (2,4). Multiple studies reported tube dislodgments in pediatric populations, with dislodgement rates ranging from 5% to 14% (2,4,5,18). In our study, we observed that 8% (n = 54) of mechanical complications were due to tube-related issues, such as tube displacement or dislodgement. Furthermore, 10% (n = 22) of the infant population in our series experienced tube displacement/dislodgement compared to 6% of the non-infant population (n = 32). Hence, careful fixation of the catheter once inserted must be emphasized (18).

Another finding from our study was that catheter-related infectious complications occurred in 6.3% (42/668) of procedures, presenting as UTI in 36 cases and tube insertion site infection in 6 cases, with infection noted on the 26th day (mean) (range: 2–112 days) after catheter placement. In the infant population, catheter-related infectious complications occurred in 8.7% (18/206) of cases, compared to 5% (24/462) in the remainder of the population. UTI was the most common infectious complication in both infant and non-infant groups (8.2% [n = 17] and 4% [n = 19], respectively). Other studies reported the rate of procedure-related sepsis in pediatric patients to be 0%–5% (4–6,17). In PCN specifically, the risk of procedure-related infectious complications is common and is a major concern, as reported by Cochran et al (23). A higher incidence (21%) of procedure-related sepsis was reported in an adult cohort study of 55 patients by Cochran et al, in which fever and shaking chills were considered signs of sepsis. Other studies may not have considered these signs as definitive of infection, and several guidelines were proposed to reduce the risk of developing infection in outpatient PCN (23). In our study, fever/shaking chills (n = 14) were not considered to be specific for infection, since sepsis was defined based on laboratory-proven infections. A significant risk factor for sepsis in PCN patients is the presence of stones/calculi, especially in patients without any signs of preexisting infection (23). In our pediatric cohort, 5 (12%) of 42 patients who developed sepsis/infection had renal stones/calculi, 2 with staghorn calculi, and 12% (5/42) of patients with infection had sepsis.

The limitations of this study are those inherent to a retrospective study. Data from some clinical charts and notes were limited and thus could not be included in the analysis. To avoid inconsistency in the data collected between institutions, standard data elements were requested from each site. Email communication between sites occurred if there was uncertainty about data elements, during both the data collection and data analysis phases, to obtain consensus. However, there could still be some minor residual differences in the interpretation and clinical documentation between institutions. Many different providers from the 4 institutions performed these procedures, with varying levels of experience and possibly different technical nuances, thus providing some inherent heterogeneity to the data collection.

In conclusion, PCN is safe and successful in children of all ages, with few major complications. Results in infants younger than 1 year are similar to results in older children except in terms of severity of hydronephrosis and inpatient management. PCN in children is associated with specific technical challenges and requires ongoing management tailored to the very young to achieve good outcomes. This large study from 4 tertiary pediatric centers provides informative data, which may ultimately be valuable for the development of guidelines for PCN procedures in children.

## REFERENCES

1. Koral K, Saker MC, Morello FP, Rigsby CK, Donaldson JS. Conventional versus modified technique for percutaneous nephrostomy in newborns and young infants. J Vasc Interv Radiol 2003; 14:113–116.
2. Yavascan O, Aksu N, Erdogan H, et al. Percutaneous nephrostomy in children: diagnostic and therapeutic importance. Pediatr Nephrol 2005; 20:768–772.
3. Linscott L. Pediatric urologic interventional radiology. Semin Intervent Radiol 2011; 28:407–414.
4. Hogan MJ, Coley BD, Jayanthi VR, Shiels WE, Koff SA. Percutaneous nephrostomy in children and adolescents: outpatient management. Radiology 2001; 218:207–210.
5. Stanley P, Bear JW, Reid BS. Percutaneous nephrostomy in infants and children. AJR Am J Roentgenol 1983; 141:473–477.
6. Irving HC, Arthur RJ, Thomas DF. Percutaneous nephrostomy in paediatrics. Clin Radiol 1987; 38:245–248.
7. Ramchandani P, Cardella JF, Grassi CJ, et al. Quality improvement guidelines for percutaneous nephrostomy. J Vasc Interv Radiol 2003; 14: S277–S281.
8. Barbaric ZL, Hall T, Cochran ST, et al. Percutaneous nephrostomy: placement under CT and fluoroscopy guidance. AJR Am J Roentgenol 1997; 169:151–155.
9. Dagli M, Ramchandani P. Percutaneous nephrostomy: technical aspects and indications. Semin Intervent Radiol 2011; 28:424–437.
10. Stables DP, Ginsberg NJ, Johnson ML. Percutaneous nephrostomy: a series and review of the literature. AJR Am J Roentgenol 1978; 130: 75–82.
11. Farrell TA, Hicks ME. A review of radiologically guided percutaneous nephrostomies in 303 patients. J Vasc Interv Radiol 1997; 8:769–774.
12. Zagoria RJ, Hodge RG, Dyer RB, Routh WD. Percutaneous nephrostomy for treatment of intractable hemorrhagic cystitis. J Urol 1993; 149: 1449–1451.
13. Lee WJ, Patel U, Patel S, Pillari GP. Emergency percutaneous nephrostomy: results and complications. J Vasc Interv Radiol 1994; 5:135–139.
14. Goodwin WE, Casey WC, Woolf W. Percutaneous trocar (needle) nephrostomy in hydronephrosis. J Am Med Assoc 1955; 157:891–894.
15. Elyaderani MK, Kalinowski D, Gabriele OF. Percutaneous nephrostomy by pigtail catheter in children. South Med J 1981; 74:421–423.
16. Winfield AC, Kirchner SG, Brun ME, Mazer MJ, Braren HV, Kirchner FK Jr. Percutaneous nephrostomy in neonates, infants, and children. Radiology 1984; 151:617–619.
17. Ball WS Jr, Towbin R, Strife JL, Spencer R. Interventional genitourinary radiology in children: a review of 61 procedures. AJR Am J Roentgenol 1986; 147:791–796.
18. Riedy MJ, Lebowitz RL. Percutaneous studies of the upper urinary tract in children, with special emphasis on infants. Radiology 1986; 160:231–235.
19. Laurin S, Sandstrom S, Ivarsson H. Percutaneous nephrostomy in infants and children. Acad Radiol 2000; 7:526–529.
20. Beetz R, Bokenkamp A, Brandis M, et al. Diagnosis of congenital dilatation of the urinary tract. Consensus Group of the Pediatric Nephrology Working Society in cooperation with the Pediatric Urology Working Group of the German Society of Urology and with the Pediatric Urology Working Society in the Germany Society of Pediatric Surgery. Urologe A 2001; 40: 495–507; quiz 508–509.
21. Gray RR, So CB, McLoughlin RF, Pugash RA, Saliken JC, Macklin NI. Outpatient percutaneous nephrostomy. Radiology 1996; 198:85–88.
22. O'Brien WM, Matsumoto AH, Grant EG, Gibbons MD. Percutaneous nephrostomy in infants. Urology 1990; 36:269–272.
23. Cochran ST, Barbaric ZL, Lee JJ, Kashfian P. Percutaneous nephrostomy tube placement: an outpatient procedure? Radiology 1991; 179:843–847.
24. Shermi F. Percutaneous nephrostomy: a well established and efficacious procedure. Med J Islam Repub Iran 1988; 2:105–111.