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CLINICAL INVESTIGATION NON-VASCULAR INTERVENTIONS

Percutaneous Nephrostomy in the Neonatal Period: Indications, Complications, and Outcome—A Single Centre Experience

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Abstract
Purpose The purpose of this study was to evaluate the indications, technique for percutaneous nephrostomy (PCN) insertion, the complications related to PCN, duration of PCN, and outcome following PCN removal regarding the kidney function.
Material and methods Medical charts of 31 neonates (22 boys and 9 girls, mean age 13.9 days) treated with 43 PCN were reviewed. Collected data included indications for PCN, PCN complications, duration of PCN, and outcome of these patients by analysing the kidney function.
Results The indications for PCN insertion were obstructive urinary tract dilation in 24 neonates (four with associated infection), and non-obstructive urinary tract dilation with urosepsis or pyonephrosis in seven cases. Primary technical success of PCN placement using Seldinger technique was 97.7%. The following complications were reported: self-limited post-procedural bleeding into the pelvicalyceal system in two, chronic microscopic haematuria in five, and clinically manifested urinary tract infection in five children. Four PCN were dislocated. Cellulitis was present at the skin entry of 5 PCN, urinary leak in 5 PCN, and mechanical damage of 5 PCN. Eight PCN had to be replaced. Mean duration of PCN was 5 months. Kidney insufficiency was detected in 5/29 children with the mean follow-up of 3.9 years.
Conclusions PCN is a safe, effective transient solution in neonates with pyonephrosis or when surgery of obstructed urinary system has to be postponed. The rate of minor complications increased with PCN duration. If kidney insufficiency is present after PCN removal, it is related to the complexity of kidney anomalies.

Keywords Percutaneous nephrostomy · Pyonephrosis · Urinary tract obstruction · Complications · Outcome · Neonate

Abbreviations

CAKUT	Congenital anomalies of the kidney and urinary tract
PCN	Percutaneous nephrostomy
MAG3 renography	Mercaptoacetyltriglycine renography
US	Ultrasound
UTD	Urinary tract dilation

Introduction

Urinary tract dilation (UTD) is the most common pathology, reflecting a spectrum of congenital anomalies of the kidney and urinary tract (CAKUT) [1, 2]. The UTD classification system for the diagnosis and management of pre- and postnatal UTD has gained the consensus of various societies [3, 4]. Treatment is conservative or not necessary in more than 80% of cases, dependent on the severity of the dilation, and if the UTD is isolated or combined with

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another urinary tract pathology [5, 6]. One of the important goals of postnatal imaging is to differentiate between non-obstructive and obstructive UTD, because the prompt management of obstructed UTD has a positive effect on maintaining renal function [7]. Percutaneous nephrostomy (PCN) is indicated to relieve an obstructed or/and infected renal collecting system (pyonephrosis) which thus prevents further deterioration of kidney function or even improves it [7–10]. There are some studies dedicated to feasibility, safety, and clinical effectiveness of PCN placement in infants and children, but none of them are focused solely to neonates [11, 12]. We focused on the neonatal period because a neonate differs from the older child not only in terms of kidney morphology, but also because of many physiological changes which influence the kidney function taking place during that period [13]. Most clinically relevant CAKUT that may affect renal function are detected prenatally and in the neonates.

The purpose of this retrospective study was to evaluate the indications for PCN in the neonatal period and its primary technical success, the complications related to PCN, duration of PCN, and the outcome of neonates following PCN removal regarding the kidney function.

Material and Methods

The medical charts of 31 children hospitalized in the Department of Neonatology, 22 boys and 9 girls, aged from 3 to 35 days (mean age 13.9 days), weighting from 2380 to 4000 g, who were treated with PCN placement into the urinary collecting system between November 2010 and April 2017, were reviewed in this retrospective study, approved by the National Ethical Committee (No. 0120-339/2018/5, date of approval July 19, 2018). For this type of study, formal consent is not required.

The indications for PCN insertion were obstructive urinary tract dilation in 24 neonates (three with associated pyonephrosis and one with urosepsis) and in seven non-obstructive urinary tract dilation with urosepsis associated with progressive kidney function insufficiency (3/7) and pyonephrosis (4/7). In total, 43 PCN were inserted in 31 neonates: 12 children had bilateral and 19 unilateral PCN (6 right and 13 left kidney).

Pre-procedural Evaluation and Patient Preparation

Pre-procedural evaluation consisted of confirming the indication for PCN placement on the basis of different imaging evaluations. Ultrasound (US) of the urinary system was performed in all, and the degree of UTD is determined: three kidney units had UTD grade 2, 40 grade 3 [3]. Voiding cystouretrography was performed in 26/31 neonates (83.9%): in 11, it was normal, 12 had vesicoureteric reflux, and 3 signs of lower urinary tract obstruction. MAG3 renography was performed in 16/31 neonates and obstruction of the urinary tract was confirmed in all 16 cases. Before the procedure, evaluation of coagulation status was undertaken according to the Society of Interventional Radiology guidelines for peri-procedural management of coagulation status and hemostasis risk in percutaneous image-guided interventions, along with blood thrombocyte count, prothrombin time, partial thromboplastin time, international normalized ration (INR < 1.5), and electrolyte status evaluation [14]. However, there are no dedicated guidelines for neonates.

Percutaneous Nephrostomy

All PCN procedures were performed under general anaesthesia in a prone position, under antibiotic prophylaxis, and under fluoroscopic and US control using Seldinger technique. A 17 or 17.5 gauge needle, 0.035-inch stiff guide wire, and 6.3 Fr locking pigtail PCN have been used since August 2016.Previously, we used a 6 Fr nephrostomy set which required 0.025-inch stiff guide wire available on the market at that time. However, the technique of PCN placement was the same. After local infiltration of the puncture site and expected path from skin to the renal capsule with 1% of Xylocaine, the incision by scalpel at the puncture site was done. The dilated lower (less common middle) group calyx was punctured under US guidance. A stiff guidewire was introduced via a needle lumen into the renal pelvis, and its tip was coiled there. The needle was removed. Usually, no additional dilation of the accessible tract was performed. We used Dawson-Muller Multipurpose Drainage catheter (William Cook Europe) with rigid catheter introduction stiffening cannula of the set to enter the punctured calyx. We preferred to use the rigid cannula instead of a flexible one because of better pushibility. The guide wire and stiffening cannula were removed. The position of PCN was checked under the fluoroscopy control following the ALARA principle (Fig. 1). When the correct position of the pig tail in pyelon was achieved, the PCN was locked by pulling the protected thread. Finally, the PCN catheter was attached by firm suturing to the skin (nylon) and connected to a gravity drainage bag. 80% of the PCN placements were performed by an interventional radiologist with 25 years of experience and remaining 20% by 3 interventional radiologists with 12 to 17 years' experience.

The technical success and complications related to PCN were evaluated. Post-procedural bleeding was considered if macroscopic haematuria was present in the drainage bag for more than 48 h after procedure. Chronic haematuria was considered, if an increased number of erythrocytes

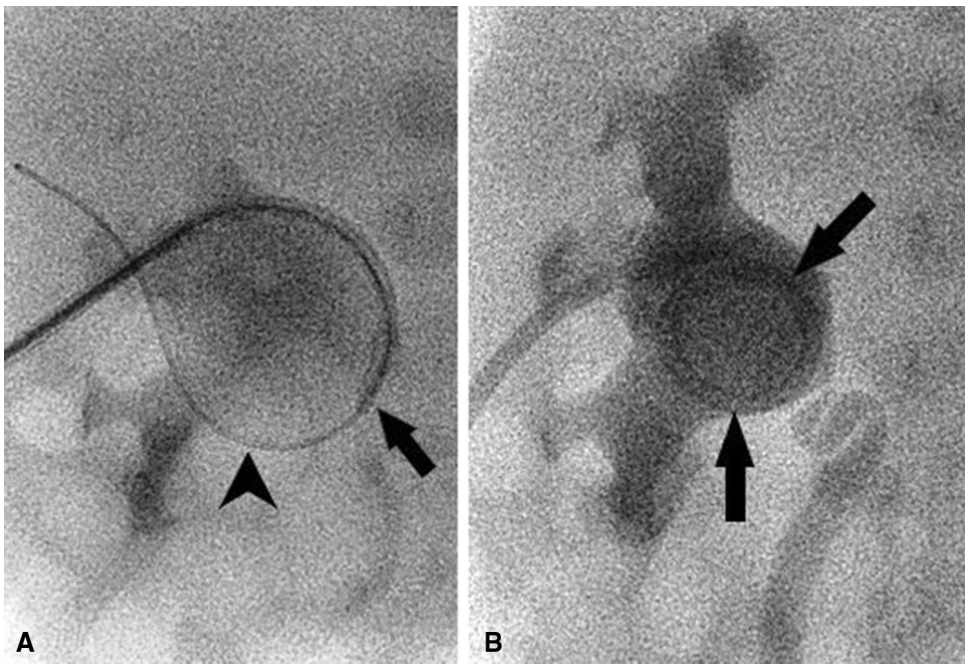

Fig.1 Percutaneous nephrostomy procedure in a 30-day-old premature girl (born at 35th gestation week) with urosepsis and pyonephrosis of the left kidney: **A** percutaneous puncture of the middle calix with a 21-gauge Chiba needle under US guidance, a guide-wire loop (0.025-inch) in the pyelon (arrowhead) and introduction of a nephrostomy catheter (6 Fr) via the guide wire (arrow), **B** optimal placement of the pigtail of the nephrostomy catheter (arrow) in the renal pyelon

(> 5) had been permanently present in urine. The complication regarding the PCN placement included dislocation (PCN was not in drainage position), mechanical damage of PCN, and leakage of urine at the site of the PCN insertion. The rate of bacteriuria and infectious complications (urinary tract infection and cellulitis) were determined. The duration of PCN catheters was recorded.

Post-procedural Evaluation, Management and Outcome

Regular monthly follow-up included urine sample analyses for microbes (from each PCN catheter and the urinary bladder) and US of the urinary tract. Follow-up or control MAG3 renography was performed in 24 children (77.4%): 17 had signs of obstruction and 7 delay of excretion, but without signs of obstruction. Anterograde pyelography was used in four children to confirm juxtavesical obstruction.

We analysed the treatment procedures following PCN removal: children who underwent surgery and/or endoscopic interventions and children without additional interventions. The outcome of treatment was evaluated for renal function: normal, chronic renal insufficiency.

Statistical Analysis

Descriptive statistics were used to summarize the patient data. Quantitative variables were expressed as range, mean and ± SD. Qualitative variables were expressed as raw numbers, proportions, and percentages. Some data like technical success, some complications, and outcome were calculated per procedure, and some data were calculated per PCN catheter.

Results

Primary technical success was 97.7%. In an 8-day-old neonate, the first attempt at PCN insertion was unsuccessful (multiple punctures caused rapid decompression of the obstructed pyelocalyceal system), but it was successfully achieved 5 days later.

Data for radiation exposure were available for 29/31 procedures. For 18 unilateral procedures, cumulative dose area product (DAP) was 42.7 ± 58.8 (SD) (range 2 to 279) mGy cm^2), and for 11 bilateral procedure 78.3 ± 118.3 (SD) (range 6 to 435) mGy cm^2.

No major complication was reported. The rate of minor complications and their treatment are listed in Table 1. The urine sample analysis was positive for microbes: from PCN aspirate in 21 children (67.7%) and from the urinary bladder in 17 children (54.8%). Bacteriuria was not treated in most of the cases, depending on isolated microbes and clinical situation. In addition, the positive skin samples for microbes without cellulitis were found at the site of 11 PCN (25%) insertions. Microbes predominantly belonged to the patient's native skin flora and the hands of PCN caretakers.

Eight PCN catheters out of 43 (18.6%) had to be replaced during the observation time: three because of dislocation, two because of infection caused by resistant Staphylococcus aureus, two because of urinary leak (in the

Table 1 Minor complications related to percutaneous nephrostomy (PCN)

	PCN/children	(%)	Treatment
Post-procedural bleeding	2 PCN	4.6	No (transient)
Chronical haematuria	5 children	16.1	No
PCN dislocation	4 PCN	9.3	3 replacement
Urine leak	5 PCN	11.6	2 replacement
Mechanical damage of PCN catheter	4 PCN	9.3	1 replacement
Manifest urinary tract infection	5 children	16.1	IV antibiotics
Cellulitis at the puncture site	5 PCN	11.6	Local antibiotics

first due to mechanical damage of the PCN catheter, and in the second because of chronic urinary leak at the skin insertion site), and one because of catheter obstruction.

Two neonates experienced complications related to the general anaesthesia: one had severe bronchospasm on intubation, and the other had difficulty waking up from narcosis with no subsequent consequences on the health.

Post-procedural Evaluation, Management, and Outcome

The decision on PCN catheter removal and further patient management was made on clinical case by case decision and on follow-up imaging examinations. Duration of the nephrostomy tube (dwell time) varied from 0.2 to 14, mean 5 ± 3.3 (SD) months.

No interventions following PCN removal were needed in eight children (25%). Follow-up imaging showed signs of delay in urine drainage in four children, normal drainage in two (one of them had signs of obstruction on MAG3 renography as neonate), and signs of high grade vesicoureteric reflux in two. Mean duration of PCN in these children was 4.3 ± 1.5 (SD) (range 1.5–8) months.

Additional interventions were necessary in 23 children (75%): 12 children with pyeloureteric stenosis underwent Anderson-Hynes pyeloplasty (mean duration of PCN was 3.8 ± 1.3(SD) (range 1.5–7) months) and 11 children with a more complex CAKUT underwent various surgical, endoscopic, or interventional radiological procedures (mean duration of PCN was 5.9 ± 4.2 (SD) range 0.2–14) months.

Kidney function data were available for 29/31 (90%) children after PCN removal. The children were followed-up from 7 months to 7.6 years, mean 3.9 years ± 2.1 (SD). Progressive development of kidney insufficiency was reported in four children with complex anomalies (one already had kidney transplantation at the age of 5). Chronic kidney insufficiency grade 1 developed in one child who did not require interventions after PCN removal, but this was associated with renal dysplasia.

Discussion

This study systematically reviews the indications and complications related to PCN insertion solely in neonatal period and the outcome of these children regarding the kidney function following PCN removal. Obstructive uropathy associated with CAKUT and urosepsa/pyonephrosis are the main indications in neonates for PCN. There are many objective situations in neonates where surgery has to be postponed, like the presence of infection and severe comorbidities like neurological impairments, cardiovascular congenital anomalies, and metabolic dysfunctions. In addition, a neonate needs time to gain optimal body weight and size for surgical procedures. In these situations, PCN serves as a bridging procedure until definitive corrective surgery in order to prevent further deterioration of renal function [15].

The neonatal kidney is small, usually less than 5 cm and it lies much closer to the skin surface with less subcutaneous and perirenal fat which makes it more mobile compared to the older child. Various needle and guide wire combinations have been described in the literature for access to dilated systems in children [8–10, 16–20]. The choice of technique and deployment material/device is operator dependent. Experience of having performed many PCNs, along with familiarity and comfort with the needed equipment, are essential when working with neonates. Our group has been most comfortable using the Seldinger technique. There are some reports about the use of a trocar technique in neonates and small children [19, 20]. The main advantage of a trocar technique is a reduction in procedural steps. However, it may result in major renal injury and bleeding and is feasible only in patients with pronounced dilation of collecting system [20].

The kidney mobility can be a major challenge. Neonatal kidney tends to push away from the needle, resisting puncture regardless of the type of the technique. Kidney mobility can be reduced to some point by placing a pad under the neonate's abdomen (neonate is in prone position) in order to push the kidney slightly back and upwards. This manoeuvre prevents the kidney from moving forward and downward during the kidney puncture. It is important to

puncture the collecting system on the first or second attempt because multiple punctures may result in rapid decompression of the obstructed pelvicalyceal system into the perinephritic space, especially in a very small baby. Also the incision at the puncture site by a scalpel allows easier and more precise insertion of the puncture needle and prevents that the firm and elastic neonatal skin "catches" the needle and consequently the needle does not travel along the guiding line.

Recommendations on how to reduce the dose during paediatric interventional procedures are well known and must be followed [21, 22]. The radiation dose for PCN insertion in children is lower than in adults [12, 23]. The values of DAP are within a wide range. In bilateral procedures, the dose was twice bigger than for unilateral procedure. Higher doses were associated with difficulties during the PCN placement due to extensive kidney mobility, firm kidney parenchyma or hardly visible peripheral calyces.

Different minor complications associated with inserted PCN are well described [9, 12, 24]. The incidence rate depends on the type of complication and also on duration of PCN. The duration of PCN inserted in the neonatal period is longer than in older children [11, 12, 15, 17, 19]. The longer the baby has the PCN inserted, the more likely complications like PCN dislocation or infection occur [17, 18, 25]. Dagli et al. reported that PCN dislocation in the early post-placement period occurs in less than 1% of the patients, but it increases to 11–30% in the subsequent months despite the "locking system" which fixes the nephrostomy tube into the collecting system [18]. The rate of these complications can be reduced by training the medical staff and the parents in handling the PCN properly.

Basically, normal renal function was preserved in the majority of our neonates following the PCN removal. Early insertion of PCN allowed rapid reduction in pressure on the renal parenchyma in obstructive uropathies or prevented the development of septic shock by evacuating pyonephrosis. In addition, 25% of our neonates did not need any interventions after PCN removal which is in line with the data form the literature, where even severe urinary tract obstruction in neonates can be transient and diminished with the baby's growth [26–30]. This reflects the facts that neonates need time for tissues to mature and develop, which is not the case in older children. In the relatively small number of patients who had a combination of lower urinary tract obstruction and congenital kidney parenchyma anomalies, PCN together with other therapeutic measures contributed to a slower progression of renal function deterioration.

The main limitation is the retrospective nature of the study.

Conclusions

In conclusion, the PCN is a feasible and effective treatment in neonates with a high primary technical success, with predominantly minor complications. The duration of PCN is longer in comparison with older children due to the immaturity of the babies and severe CAKUT presented at birth. The reported kidney insufficiency is primarily related to the complexity of kidney anomalies.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical Approval A study was approved by the National Ethical Committee (No. 0120–339/2018/5, date of approval July 19, 2018). All procedures performed were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study formal consent is not required.

Consent for publication For this type of study formal consent for publication is not required.

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