



Research article

CT-guided nephrostomy—An expedient tool for complex clinical scenarios

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ABSTRACT

Introduction & objectives: Percutaneous nephrostomy [1] has emerged as a pivotal approach in the therapeutic management of the obstructed urinary tract. A consecutive incorporation of ultrasonic and radiographic guidance, the approach experienced an almost ubiquitous distribution while most centers currently applying either one or both of these tools jointly. However, success of ultrasound-guidance is limited in obese patients and non-dilated uropathy. In turn, fluoroscopy usually requires an opacification of the urinary collecting system by intravenous or antegrade contrast media injection, which might be harmful for already impaired renal function, raise intrapelvic pressure and augment the risk of sepsis and hemorrhage. CT-guided PCN aids in overcoming these limitations. In the current study, we present the experience of a tertiary referral center with this technique. **Materials & methods:** Epidemiological and clinical data of all patients treated with a CT-guided PCN of native kidneys at the University Hospital Frankfurt between October 2003 and October 2013 were retrospectively collected from the patient charts. Procedural parameters including radiological aspects, technical and therapeutic success, complication and mortality rate have been analyzed statistically.

Results: In total, 140 PCN procedures have been performed in 77 patients with a median age of 69 (± 13). The median body mass index was 27 with 66.6% of patients being overweight or obese. Charlson comorbidity index was 7 ranging 0–16. Indications for PCNs were obstructive uropathy (62.9%), urine extravasation (22.9%), urinary tract fistulas (11.4%) and technical reasons (2.8%). In 68.8% of patients, initial diagnosis was malignancy. 56.4% of kidneys were non-dilated before puncture. In 78.4% prone position, otherwise supine oblique position (17.3%) or supine position (4.3%) was used. 71.4% of PCNs were carried out solely under local anesthesia. Technical success has been achieved in 90% with a complication rate of 3.6% (all grade minor B) and was not significantly different between dilated and non-dilated kidneys. 42.9% of fistulas and 64.3% of urinary tract leakages, healed after PCN placement. 30 days mortality rate was 5.2% without being directly associated with the PCN procedure itself.

Conclusion: CT-guided PCN is a feasible approach associated with low morbidity. It is particularly useful in complex clinical scenarios e.g. critically ill, newly operated or obese patients as well as non-dilated kidneys. Moreover, it represents a minimally-invasive option for treating leakages and fistulas of the urinary tract.

1. Introduction

Over the last decades the use of percutaneous nephrostomy [1] has emerged as a pivotal approach for urologists and interventional radiologists in the therapeutic management of different medical conditions associated with existing or impending post-renal failure, localized or

systemic infection or colic pain. In Germany, this procedure is usually performed by a urologist, whereas failure of ultrasound-guided PCN drainage requires interdisciplinary cooperation with interventional radiologists for CT-guided drainage. PCN is feasible to relieve obstruction of the upper urinary tract resulting from calculi, intrinsic or extrinsic infiltrating or compressing malignancies, strictures,

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inflammatory and functional disorders [2]. Furthermore, it is utilized for urinary diversion in patients with genitourinary fistulas, post-operative or traumatic leakages and disruptions of ureter and bladder [3,4]. Less common indications include gaining access into the pelvicalyceal system in case of a two-stage approach of percutaneous nephrolithotomy [1], particularly in a complex anatomic situation, or as a supravescical urinary diversion for recurrent bleeding of bladder cancer in a palliative setting. Despite wide acceptance of the approach, performance techniques vary significantly.

In 1955, Goodwin and associates reported on the first PCN in hydronephrosis as a blind puncture of the renal pelvis in the prone position [5]. With a successive evolution of imaging modalities such as ultrasonic and radiographic guidance [6,7], the approach experienced an almost ubiquitary distribution with most centers currently applying either one or both of these tools together. However, success of ultrasonic guidance is limited in obese patients and non-dilated uropathy [3,4]. In turn, fluoroscopy usually requires an opacification of the urinary collecting system by intravenous or antegrade contrast media injection, which might be harmful for already impaired renal function or even raise intrapelvic pressure and consequently augment the risk of sepsis and hemorrhage [8].

Some of these limitations might be overcome by utilization of cross-sectional imaging. Haaga et al. were the first to introduce a CT-guided PCN in 1977 [9]. CT provides a precise display of the renal pelvis and calyces [10], thus promoting a rapid entry of a puncture needle in pelvicalyceal group even in critically ill and obese patients as well as in non-dilated kidneys [3,11]. Moreover, the risk for injury of the surrounding tissues, particularly colon, liver and spleen, might be minimized. Of note, MRI offers similar imaging benefits, further amplified by its radiation-free principle, representing another promising option to guide PCN. However, its routine use is hampered by its high costs, necessity of MRI suitable material as well as its time-consuming fashion due to image processing [12]. Thus, CT-guided nephrostomy remains the only clinically relevant cross-sectional modality for PCN nowadays. In the current study, we present feasibility and safety of CT-guided PCN placement in a large tertiary referral center.

2. Materials and methods

2.1. Data acquisition

The study was conducted after receiving the approval of the study protocol by the institutional review board of the Goethe-University Frankfurt (no. 288/13). Epidemiological and clinical data of all patients who were treated with CT-guided PCN at department of diagnostic and interventional radiology between October 2003 and October 2013 were consecutively collected from digital patient charts. If necessary, referring hospitals and practitioners were contacted by phone or postally to obtain the appropriate follow-up information. We included all cases that had CT-guided PCNs and excluded only those who received a PCN into a kidney transplant.

In order to assess the impact of age, body mass index (BMI) and comorbidities on the results of the CT-guided nephrostomy, we evaluated BMI and Charlson Comorbidity Index (CCI) for each patient. The CCI is an established predictive parameter for mortality in respect to preexisting morbidities [13].

2.2. CT-guided intervention

CT-guided kidney puncture was carried out either in prone, supine oblique or supine position by an experienced interventional radiologist. Preceding intervention, either a low-dose CT-scan with 5 mm scan slices or contrast media were performed to evaluate the exact anatomic location of the spleen, colon and kidney as well as to determine the optimal puncture angle into the renal calix. In some cases, we used CT-guided fluoroscopy for placement of the needle, guide wire and



Fig. 1. CT-guided PCN. Transversal CT-scan of a 57-year old female patient with a recto-vesical fistula. The prone position is chosen in this case for PCN placement into both kidneys. Contrast medium is intravenously given to display the renal pelvis. In this case the renal pelvis is not dilated (A). The needle is brought into the renal pelvis (left kidney) and a nephrostoma is placed via seldinger technique (B). Finally both kidneys are drained via PCNs (C).

nephrostoma since this technique offers a real time imaging via CT despite inferior resolution as compared to the conventional non contrast enhanced CT in order to reduce exposure to radiation. In cases performed under local anesthesia we administered 1% lidocaine or an equivalent anesthetic. Other patients received general anesthesia from the attending anesthesiologist. For the puncture of the most frequently targeted posterolateral renal calix we used an 18 to 22-gauge needle. Once the needle was placed into the renal calix, contrast media was injected to confirm the correct position. If the position of the needle was incorrect, a new procedure was performed and the position of the needle was again checked for correct placement in the urinary collecting system. Once the correct position was reached, we placed a 0.035" Lunderquist guide wire into the renal calix, removed the needle and advanced either an 8 or 10 gauge nephrostomy into the renal pelvis (Fig. 1). Again, contrast media was injected via the new nephrostomy to assure the correct position and rule out accidental dislocation during the procedure.

Table 1
Degree of complications with the corresponding therapeutic consequence according to [13].

Minor	Grade	Therapeutic Consequence
	A	No therapy
	B	Basic support with hospitalization for maximum of one night
Major	Grade	
	C	Need of therapy with less than 48 h hospitalization
	D	Extended therapeutic measures longer than 48 h or intensive care
	D	Permanent consequences
	F	Death

2.3. Technical and therapeutic success rate and complications

The technical success rate and complications as well as the rate of dislocations were also evaluated. Technical success was defined as a correct placement of the CT-guided nephrostomy with an adequate size to ensure drainage or sufficient access for consecutive procedures such as PCNL or chemolitholysis. If the PCN was correctly placed but PCNL was not possible, then the CT-guided approach was considered technically unsuccessful.

Resolution of the causal medical condition i.e. urine fistulas, urinary tract leakage, sepsis, renal colic or acute renal insufficiency after placement of the nephrostomy was considered as a therapeutic success.

Complications were classified as either minor complications “grade A” and “grade B” and major complications “grade C” and “grade D” according to the society of interventional radiology (Table 1) [14]. The 30-day mortality rate was assessed.

2.4. Grade of dilatation

Kidney dilatation was classified into four categories and evaluated by ultrasound.

- Grad 0 → No dilatation
- Grade I → Only renal pelvis
- Grade II → Grade 1 + mild dilatation into the calyces
- Grade III → Grade II + significant dilatation of the calyces with loss of contour
- Grade IV → Grade III + thin parenchyma up to sacculated kidney

Grade 0 and I were defined as no relevant dilatation. This is common and reported in other studies [15,16].

2.5. Statistical analysis

Descriptive variables were presented as absolute numbers, mean ± standard deviation or percentage as appropriate. For statistical analysis we used the program BiAS for Windows (Version 11.03, Dr. rer. nat. Hans Ackermann, epsilon-Verlag, Darmstadt, Germany). We used Chi-Square- and Fishers-Exact-test to compare categorized as well as Mann-Whitney-U-Test to assess continuous variables. Correlations were calculated with Spearmans test. Significant tests were assumed when p-value was < 0.05.

3. Results

3.1. Patient demographics and indications

The study cohort consisted of 77 patients (55 (71.4%) male, 22 (28.6%) female), in whom 140 procedures were performed. Grade 0 and grade I kidney dilatation was present in 79 (56.4%) cases (Table 2).

Data on the underlying conditions and indications for PCN is demonstrated in Table 3 along with therapeutic and technical indications. Therapeutic indications are subdivided into the following categories: urinary obstruction, urine extravasation and urine fistula.

Table 2

Clinical and technical characteristics. Numbers in mean ± standard deviation (SD) or absolute numbers with percentage. CCI: Charlson-Comorbidity-Index.

	n (%)
Gender (male : female)	55 (71.4) : 22 (28.6)
Age (year)	69 ± 13
Body-Mass-Index mean (SD) (kg/m ²) (n = 69)	27 ± 5.8
• Underweight (< 18.5)	• 2 (2.9)
• Normal weight (18.5 – 24.9)	• 21 (30.4)
• Overweight (25 – 29.9)	• 27 (39.1)
• Obesity (≥ 30)	• 19 (27.5)
Side of nephrostoma (right : left)	69 (49.3) : 71 (50.7)
CCI (points)	7 ± 3.6
Dilatation (yes : no)	61 (43.5) : 79 (56.5)
Grade of dilation	• 47 (33.6)
• Grade 0	• 32 (22.9)
• Grade 1	• 45 (32.1)
• Grade 2	• 14 (10)
• Grade 3	• 2 (1.4)
• Grade 4	

Table 3

Therapeutic and technical indications for PCN. Number (n) and percent (%). PCNL: Percutaneous nephrolithotomy.

	n (%)
Therapeutic	136 (97.1)
Urinary tract obstruction	88 (62.9)
Tumor related compression/infiltration	31 (22.1)
Stenosis of the ureteral implantation	21 (15)
After bladder manipulation	18 (12.9)
Ureteral stenosis	7 (5)
Ileal conduit stenosis	2 (1.4)
Upper tract obstruction (not otherwise specified)	3 (2.1)
Benign prostate hyperplasia	2 (2.1)
Ureteropelvic junction obstruction	1 (0.7)
Urolithiasis	1 (0.7)
Retropertoneal fibrosis	1 (0.7)
Benign	42 (30)
Malignant	46 (32.9)
Urine extravasation	32 (22.9)
Leakage of the ureterimplantation	18 (12.9)
Leakage of the ureter	7 (5)
Bladder leakage	4 (2.9)
Urethral-Neobladder-anastomosis insufficiency	3 (2.1)
Urine fistula	16 (11.4)
Vesiko-vaginal	4 (2.9)
Uretero-vaginal	4 (2.9)
Mainz-Pouch-1 -Ileum	3 (2.1)
Vesiko-enteral	3 (2.1)
Uretero-enteral	2 (1.4)
Technical	4 (2.9)
PCNL	3 (2.1)
Chemolitholysis	1 (0.7)

In 27 cases (19.3%), ultrasound-guided PCN was attempted but unsuccessful and consequently, a CT-guided PCN was performed. Reasons for unsuccessful ultrasound-guided puncture were missing

Table 4
Grade of dilatation and BMI as well as technical success (successful: unsuccessful) for each group. Number (n) and percent.

Dilatation Grade 0-I	n = 79
Technical success	69 (87.3%) : 10 (12.7%)
Dilatation Grade II	n = 45
Technical success	41 (91.1%) : 4 (8.9%)
Dilatation Grade III	n = 14
Technical success	14 (100%) : 0 (0%)
Dilatation Grade IV	n = 2
Technical success	2 (100%) : 0 (0%)
BMI underweight	n = 2
Technical success	2 (100%) : 0 (0%)
BMI normal weight	n = 36
Technical success	33 (91.7%) : 3 (8.3%)
BMI pre-obesity	n = 51
Technical success	45 (88.2%) : 6 (11.8%)
BMI obesity	n = 43
Technical success	38 (88.4%) : 5 (11.6%)

dilatation (66.6%), anatomic hurdles in the puncture tract (15%), poor clinical status precluding sufficient positioning (7%) and dislocation of the guide wire (4%). CT-guided PCN was performed in 100 cases (71.4%) in local anesthesia and in remaining 40 cases (28.6%) in general anesthesia or sedation.

3.2. Overall technical success rate and complications

The overall success rate was 90% in the total cohort. Therapeutic success rate was 64.3% for urinary leakages and 42.9% for urinary fistulas. In 14 cases (10%; 13 patients) the CT-guided PCN was unsuccessful of which 10 cases demonstrated no dilatation and 4 cases grade 2 dilatation. Results on grade of dilatation and BMI as well as technical success are demonstrated in [Table 4](#).

Overall, reasons for unsuccessful PCN placement were attributed to insufficient dilatation (43%) and/or in compliance (21%), anatomical obstacles (7%), failure of sufficient placement of the guide wire (7%) and injury of renal pelvis (7%). In 7 cases (50%) a correct PCN placement was possible in a second attempt. Out of the remaining, one patient received a successful retrograde stenting. Four patients were treated with observation and one patient received open pyelolithotomy after insufficient stone therapy through the initial PCN access.

Overall, 5 (3.6%) complications were recorded and classified as minor complications. Perirenal hematoma accompanied by gross hematuria was the most frequent complication in 3 cases (2.1%). In one case (0.7%), gross hematuria was encountered and in another case (0.7%), perirenal hematoma was reported. In all 5 cases, observation and rinsing measures were the treatment of choice without further operative intervention.

In the following course, dislocations occurred in 43 (34.4%) cases out of 125 successful placements of PCNs whereas in one case the data on dislocation could not be retrieved from the patient chart. Four patients (5.2%) deceased within 30 days. Death was not associated with the CT-guided PCN placement.

3.3. Procedural data

PCN was performed in 96 cases on one side and in 22 cases bilaterally. In 2 cases only CT guided fluoroscopy and in 3 cases both CT modalities were used (regular CT and CT-guided fluoroscopy).

Further procedural data is displayed in [Table 5](#). The overall time of the procedure as well as the time until successful PCN placement was measured. Overall time was recorded only for successful PCN placement from the first CT-topogram up to the last CT control.

Table 5

Procedural data with dose-length product (mGy cm), effective dose (mSV), number of needle passages (n) and time of the procedures in minutes (min). SD: Standard deviation.

	Mean (± SD)
Dose-length product (mGy cm)	
CT PCNs (n = 137)	186.6 ± 249.7
CT fluoroscopy (n = 5)	317 ± 107.4
Effective dose (mSV)	
CT PCNs (n = 137)	3.2 ± 4.2
CT fluoroscopy (n = 5)	5.4 ± 1.8
Number of needle passages (n)	
All (n = 141)	2.5 ± 2.8
Only successful (n = 125)	2.2 ± 2.5
Time of successful PCN placement (min)	
CT (n = 122)	20.1 ± 10.5
CT fluoroscopy (n = 3)	12.7 ± 12.4
Overall time of the procedure (min)	
Unilateral	36.3 ± 16.6
Bilateral	51.5 ± 16.

3.4. Statistical results

Statistical analysis revealed no significant influence on the technical success rate of the CT-guided PCN by BMI, CCI or position of the patient. Furthermore, there were no significant associations with the number of punctures per intervention of the grade of dilatation, BMI, CCI or position of the patient.

4. Discussion

Since its first reported use in 1977 by Haaga et al., CT-guided PCN has developed to a unique alternative compared to ultrasound-guided PCN especially in clinically challenging scenarios. Despite the fact that ultrasound-guided PCN is considered the gold standard for percutaneous access to the renal urinary collecting system [17], it has considerable limitations in patients with anatomical obstacles such as retrorenal colon, obesity or in non-dilated kidneys. Earlier studies have shown that CT-guided PCN can be considered as a quick and safe technique into the urinary collecting system that might potentially overcome the limits of ultrasound-guided PCN [8–11,18]. In our study, 27 (19.3%) patients received the CT-guided PCN as a second-line treatment after failure of ultrasound-guided PCN. In 66.6% (n = 18/27) the most common reason for unsuccessful ultrasound-guided puncture was insufficient dilatation of the urinary collecting system. In line with the study by Sommer et al., similar limitations of ultrasound-guided PCN have been reported: a non-dilated urinary tract (30.4%), anatomical obstacles (30.4%) or extensive surgery (21.7%) which necessitated CT-guided PCN [3].

Minor and major complications for ultrasound-guided PCN are reported to be as high as 11.1% and 7.7%, respectively [19]. Fever, flank pain or macroscopic hematuria lasting less than 72 h are commonly defined as minor complications, whereas occlusion of the nephrostoma, macroscopic hematuria or retroperitoneal hematoma requiring blood transfusion, sepsis and urinoma are considered major complications. Of note, complication rate of ultrasound-guided and fluoroscopy-guided PCN is reported to be similar lying in the range of 3.9% for major and 9.1% for minor complications, respectively [20]. In line with this finding, CT-guided PCN is associated with 2% and 13.3% for major and minor complications, respectively [3,8,21]. At first glance, there seems to be no considerable disparity between different PCN techniques in terms of the complication risk. However, flaw of prospective randomized trials followed by substantial imbalances in patients' characteristics as well as indications for the procedure in previous reports makes the final judgement on this issue at least vague.

Although the overall success rate of CT-guided PCN in our study was 90%, there were 6/14 cases (43%) in which it failed due to insufficient dilatation of the urinary tract. The overall success rate in our study appears to be lower compared to studies from Thanos et al. and Egilmez et al. who reported 100% success rates with the CT-guided assistance [2,4]. However, our cohort consisted of 54.4% of patients with no dilatation compared to 31% and 3.8%, respectively, in the aforementioned studies [2,4]. Of note, anatomical obstacles that prohibited a safe ultrasound-guided access were present in 14.8% in our patient cohort. Hopper et al. reported that 4.7% of their patients in prone position presenting with retrorenal colon which made an ultrasound-guided PCN impossible [22]. In our analysis other anatomical obstacles were responsible for unsuccessful ultrasound-guided PCN such as limited space between the costal arc and iliac crest as well as cranially located kidneys. Especially in cases where anatomical obstacles prohibit ultrasound-guided PCN, CT-guided assistance is a considerable benefit due to its superior imaging quality [10]. Furthermore, in our study two patients (7.4%) could not be put into the prone position due to recent extensive abdominal surgery and were placed in an elevated supine position. The prone position is the most commonly used position for PCN but prone oblique or elevated supine position are also considered a safe access if feasible for the patient [8,11,23]. Only in one case of our investigation, anatomical hurdles prohibited CT-guided PCN.

Obesity is generally associated with a number of complications that might potentially impair a successful PCN placement [1]. Obese patients do not necessarily tolerate the prone position well due to a rising intraabdominal pressure and consequently reduced respiratory volume [23,24]. In this case a supine oblique or supine position might be beneficial but simultaneously hinders the sufficient renal access. We were able to perform 21.6% of the procedures in the supine oblique or supine position. No influence on the technical success rate has been observed in regards to BMI or patient position. This supports the assumption that obese patients do not necessarily require CT-guided PCN in the prone position and might consequently be safely placed in a supine or elevated supine position [8,11].

Importantly, resolution of urinary leakage and fistulas by performing PCN drainage was observed in 64.3% and 42.9%, respectively. Malignancy was the main cause for leakage in 57.1% and in 62.5% in fistulas. There are only a few studies that have investigated the efficacy of successful resolution of urinary leakage and fistulas via PCN drainage and/or ureteral stenting. Dowling et al. included 27 patients in their study and were able to achieve a success rate of 73% through PCN as a primary therapy with or without ureteral stenting [25]. In cases with urinary leakage and concomitant urinoma, ureteral stenting might represent another therapeutic option compared to PCN. Studies have reported that failure of successful retrograde stenting in patients with urinary leakage is as high as 50–95% when diagnosed late [26] and thus PCN represents the treatment of choice particularly for morbid or newly operated patients, in which retrograde manipulations might be contraindicated due to perioperative risks as well as issues associated with fresh anastomotic procedures. Urinary fistulas on the other hand might be better managed by retrograde stenting which is reported in a study from Selzman et al. who successfully treated patients with ureterovaginal fistulas and retrograde ureteral stenting with up to 100% success rate [27]. Nonetheless, in the aforementioned candidates, PCN might constitute a useful conservative treatment option as well.

To assess whether comorbidity plays a crucial role for CT-guided nephrostoma we also evaluated the impact of Charlson Comorbidity Index (CCI) for each patient. The median was 7 points (0–16) which is rather high and implicates a relevant morbidity: for instance malignancy (6 points), high age (one point for each decade beginning from 50 years of age, median age 66, 2 points) or cardiovascular disease such as myocardial infarction (1 point), heart insufficiency (1 point) and diabetes (1 point) already sum up to > 6–8 points and are common in

elderly people [13]. Our data did not show any influence of CCI on the technical success of the procedure emphasizing the fact that CT-guided PCN can also be safely performed in multi-morbid patients. The complication rate was low (3.6%) and only minor complications have been observed. No reported death was associated with CT-guided PCN drainage in our study. In line with our study, most commonly reported complications are hematuria or perirenal hematoma with an incidence of approximately 10% that typically resolved with conservative management [3,28].

This study has several limitations. Data was collected in a retrospective, non-randomized fashion at one center, resulting in a limited sample size potentially restricting the validity of the findings. We do not have a control cohort managed by e.g. retrograde filling and dilation of the pelvis and subsequent ultrasound-guided PCN-placement. Nonetheless, we believe to yield a real-life data on the procedure that supports the interdisciplinary cooperation between urologists and radiologists particularly in complex clinical situations.

5. Conclusions

This study indicates that CT-guided PCN is a procedure with a low complication rate even in obese and morbid patients. Importantly, it represents a reasonable option of a minimally invasive treatment attempt for urinary leakages and fistulas.

Conflicts of interest

None.

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