North Clin Istanb 2025;12(1):62–68
doi: 10.14744/nci.2023.23356

Original Article RADIOLOGY

Efficacy and safety of diuretic infusion in saline for percutaneous nephrostomy in non-dilated renal collecting systems: A single-center experience

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ABSTRACT

OBJECTIVE: In this retrospective study, we aimed to investigate the etiology, success, and complication rate of percutaneous nephrostomy (PCN) in patients with non-dilated renal collecting system (NCT) using saline and diuretic agents.

METHODS: PCN was performed on 62 kidneys from 35 patients with NCT. Prior to the procedure, a combination of saline and furosemide infusion was administered. Several parameters were evaluated, including pre- and post-procedure levels of creatinine and blood urea nitrogen, fluoroscopy time, total air kerma (TAK), dose area product (DAP), puncture number, success rate, and complication rate.

RESULTS: Fistula was the most common etiology and was detected in 29 out of 62 kidneys. The other most common cause was ureteral injury, detected in 21 out of 62 kidneys. The success rate of our procedures was 96.7%, and the rate of minor complications was 1.7%. Transient macroscopic hematuria was one of the minor complications observed in one patient. No major complications were observed. During each procedure, the average number of needle passes was 1.44±0.5 (range: 1–3). The average duration of the complete procedure was 13.17±6.46 minutes (range: 8–31 minutes). The mean fluoroscopy time was 2.37 minutes (range: 0.8–11.6 minutes). In terms of radiation exposure, the mean DAP was 166.94±148.5 μGy·m² (range: 3.93–666.59 μGy·m²) with a median of 127.04 μGy·m², and the cumulative dose (TAK) was 72.43 mGy (range: 12–342 mGy) with a median of 42.05 mGy, respectively.

CONCLUSION: Diuretic infusion in saline is a safe and beneficial method for PCN in NCT. With its low complication rate and high success rate, PCN provides rapid treatment for various etiologies with the potential to address conditions such as fistula, ureteral injury, and urosepsis in the collecting system, which may otherwise have devastating consequences.

Keywords: Furosemide; non-dilated pelvicalyceal system; non-obstructive uropathy; percutaneous nephrostomy; urine leaks.

Cite this article as: *Dablan A, Altun O, Arslan FZ, Erdim C, Mutlu IN, Kilickesmez O. Efficacy and safety of diuretic infusion in saline for percutaneous nephrostomy in non-dilated renal collecting systems: A single-center experience. North Clin Istanb 2025;12(1):62–68.*

Percutaneous nephrostomy (PCN) is a rapid and effective treatment for urinary system obstructions in dilated collecting systems. However, when dealing with non-dilated collecting systems (NCT), PCN becomes a complex procedure that demands experience and a combination of various methods [1]. Although the success rate of PCN can reach 95% when applied to dilated renal collecting systems, it decreases to 85% for non-dilated ones [2]. To improve this success rate, various techniques, including saline infusion, administration of diuretics, use of intravenous contrast agents, and tomography guidance, are employed. Achieving sonographic visualization

Received: July 12, 2023 *Revised:* October 03, 2023 *Accepted:* December 04, 2023 *Online:* December 13, 2024

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Istanbul Provincial Directorate of Health - Available online at www.northclinist.com

of the NCT is particularly challenging and necessitates expertise. The occurrence of major complications after PCN typically falls within the range of 1–4%; such complications or failures are usually seen in patients with a non-dilated renal collecting system. This is because with NCT, the needle traverses a greater distance within the renal parenchyma compared to dilated systems, resulting in an elevated risk of bleeding. Moreover, artificially distancing the NCT increases the risk of ureteral injury and anastomotic line injury [3]. PCN is routinely performed using ultrasonography (US) and fluoroscopic examination. The entry point is determined with US, and then the guide-wire and catheter are placed under fluoroscopy [4]. Temporary dilatation of the non-dilated calyceal system is achieved with a diuretic, facilitating calyceal separation. This temporary dilatation can be monitored promptly with US at short intervals, reducing radiation exposure. However, when entering a non-dilated calyceal system, artificial dilation with furosemide must be maintained for a short period, requiring precision and sometimes necessitating multiple punctures. Therefore, PCN applied in NCT demands experience, along with a comprehensive understanding of potential complications, which can improve the success rate. In our study, we aimed to investigate the etiology, success, and complication rates of PCN in patients with NCT, utilizing saline and diuretic infusion, and performed by a team of experts in the field.

Highlight key points

- Diuretic infusion in saline for percutaneous nephrostomy (PCN) in NCTs showed a high success rate (96.7%) and a low complication rate (1.7%).
- Fistula (46.8%) and ureteral injury (33.9%) were the most common etiologies leading to PCN in NCTs.
- The average number of needle passes during PCN was 1.44, and the average duration of the complete procedure was 13.17 minutes. The mean fluoroscopy time was 2.37 minutes, indicating a relatively short procedure time.
- The mean dose area product (DAP) and cumulative dose (total air kerma) were 166.94 μGy·m² and 72.43 mGy, respectively, indicating relatively low radiation exposure during PCN.
- Diuretic infusion in saline offers a feasible and effective method for PCN in non-dilated pelvicalyceal systems, providing rapid treatment for various conditions such as fistula, ureteral injury, and urosepsis in the collecting system.

MATERIALS AND METHODS

Patient Cohort

The current study used data from a total of 62 US-guided PCNs that were carried out between June 2020 and June 2023 on 35 patients with NCT. The exclusion criteria encompassed cases with a history of nephrolithotomy, untreated urinary tract infection, a dilated renal collecting system, individuals younger than 18 years of age, those with a bleeding diathesis, high blood pressure, and pregnancy. Consequently, four patients were excluded from our study; of them, two had undergone prior nephrolithotomy, and the other two had a dilated collecting system. In our patient cohort, PCN was employed to treat various etiologies such as fistula, collecting system injury, hemorrhagic cystitis, and urosepsis, which obstructed urine outflow without causing dilation in the renal collecting system. PCN was inserted under the guidance of both US and fluoroscopy. To enhance visualization of the renal collecting system, 40 mg of furosemide was intravenously injected into a 250 cc saline solution 30 minutes before the procedure. All participants in this study were adults with a weight range of approximately 55–85 kg, eliminating the need for any adjustment of the furosemide dose. However, it should be noted that careful consideration of a dose ranging from 0.5 to 1 mg/kg may be necessary for obese or underweight patients. Pre- and post-procedure creatinine, blood urea nitrogen, fluoroscopy time, total air kerma arithmetic mean, puncture number, success rate, and complication rate were calculated and noted for each patient. All patients received cefazolin (1 g, intravenously) one hour before the procedure. In all patients, the blood count was within normal ranges, and none of them were taking any anticoagulant medications.

The study was approved by the Basaksehir Cam and Sakura City Hospital Clinical Research Ethics Committee and was carried out according to the tenets of the Declaration of Helsinki (date: 22.06.2023, number: 2023.06.275). An interventional radiologist with eight years of experience carried out all PCN procedures.

PCN Technique and US Examination

First, the kidneys, renal collecting system, and bladder of the patients were evaluated with a convex probe (1–5 MHz, C253 50 mm transducer ARIETTA 65, Hitachi, Tokyo, Japan). Dilatation in the calyces of the renal system was evaluated according to the grading system of hydronephrosis developed by the Society of Fetal Urology (SFU) [4]. Grade 0 and 1 dilatation according to SFU was accepted as an NCT. In these grades, no separa-

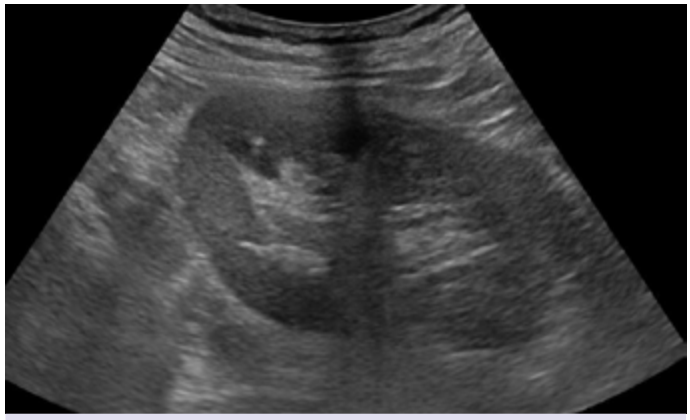

Figure 1. Baseline longitudinal US image indicated no dilation of the calyceal system in the right kidney of a patient who experienced iatrogenic rupture of the right ureter during ovarian tumor surgery.

Figure 2. Longitudinal image of the same patient's right kidney, taken 15 minutes after Lasix infusion, showing a notable and significant dilatation of the pelvicalyceal system (marked with an arrow).

tion was detected in the calyces. Needle insertion was carried out under color Doppler evaluation of the main renal vascular structures in order to minimize the risk of renal vascular injury. Patients received a rapid intravenous infusion of 40 mg furosemide (Lasix) in 250 ml of normal saline solution. The infusion rate was carefully controlled to ensure that it did not exceed 4 mg/min to prevent ototoxicity. After furosemide injection, the development of dilatation in the calyces was monitored at 5-minute intervals (Fig. 1, 2). When the calyces were separated by more than 5 mm, local anesthesia with 2% lidocaine was applied to the skin, the appropriate calyx was selected and accessed with a 21-gauge Chiba needle (Cook Medical Inc., Bloomington, Indiana, USA). Urine flow was observed, and the calyx was simultaneously visualized using US. Half-diluted contrast agent was then administered, and opacification of the calyx system was confirmed under fluoroscopy. Once the puncture was successfully performed, a 0.018-inch platinum guidewire was carefully inserted through the Chiba needle. The guidewire was then exchanged with a GaltStick® introducer set (Galt Medical Corp Garland, Texas, USA) access system to provide a more stable access point. Subsequently, a 0.035-inch guidewire (Amplatz) was advanced into either the renal pelvis or the proximal ureter, ensuring precise placement. Finally, an 8 F pigtail catheter (Cook Medical Inc., Bloomington, Indiana, USA.) was inserted to complete the procedure. A new radiograph was obtained and the position of the catheter was determined. The procedure was terminated when opacification was observed in the renal collecting system in antegrade pyelography and the pigtail loop was located in the renal pelvis (Fig. 3).

Data regarding the technical success rate, associated complications, procedure time, and radiation exposure of the procedure were collected. Fluoroscopy time and TAK (cumulative dose) were measured to assess radiation exposure. In cases where bilateral PCN procedures were carried out for NCT in one patient, each PCN was considered as a separate procedure, and the duration of the procedure and radiation dose were evenly divided. Technical success and complication rates were calculated per kidney, while procedure time and radiation exposure were calculated per procedure.

A classification for complications, established by the Society of Interventional Radiology (SIR) [5], was used to determine the complication rate in the current study. Minor complications are classified as complications that do not require significant treatment, while major complications may prolong hospitalization, require extensive treatment, or even result in death.

Statistical Analysis

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS), version 23.0 (IBM Corp., Armonk, NY). Frequencies are presented as percentages, and measurements are presented as median (min–max).

RESULTS

Out of the 35 patients evaluated in our study, 18 (51.4%) were male, and 17 (48.6%) were female. The mean age of the patient group was 57.11 years (min–max: 25–

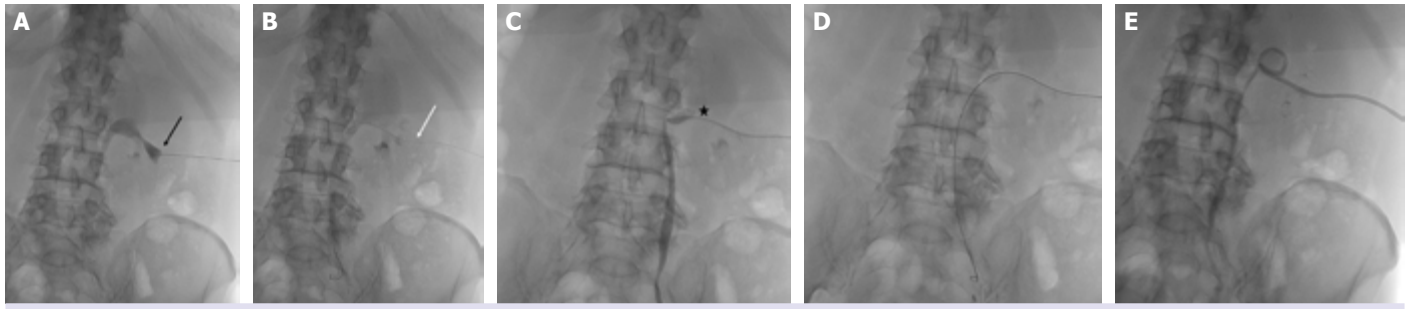

FIGURE 3. **(A)** Radiograph following the US-guided puncture of the renal pyramid using a Chiba needle. A small volume of diluted contrast medium was carefully injected through the needle (indicated with a black arrow) to visualize the renal collecting system. **(B)** A 0.018-inch guidewire (indicated with a white arrow) was introduced through the Chiba needle into the renal collecting system. **(C)** The 0.018-inch guidewire was exchanged with a GaltStick introducer system (indicated with an asterisk) to provide a more stable access point. **(D)** A 0.035-inch Amplatz guidewire was carefully advanced into the ureter, ensuring accurate positioning. **(E)** An 8 F drainage catheter was successfully inserted.

85±14.6). Among the patients, 4 required left, 4 required right, and 27 required bilateral nephrostomy. Fistula was detected in 16 patients (29 kidneys) and it was the most common cause (Table 1). Among the subtypes of fistula, rectovesical fistula was the most common, occurring in 8 patients (15 kidneys). Ureter (21 kidneys in 12 patients) and bladder injury (3 kidneys in 2 patients) were among the less common etiologies. The mean blood urea nitrogen values of the patients before the procedure were 44.34 mg/dl (min–max: 13.2–245±42.4). The weighted average of blood creatinine measured before the procedure was 1.25 mg/dl (min–max: 0.46–4.1±0.93). In the kidney-based fluoroscopy examination, the mean fluoroscopy time was 2.37 minutes (min–max: 0.8–11.6 ±0.93). For kidney-based examinations, the mean TAK was 72.43 (min–max: 12–342) and the mean number of punctures per kidney was 1.44.

The procedure was successfully completed in 34 out of 35 patients (60 out of 62 kidneys), achieving a success rate of 96.7%. However, the procedure was not successful in one patient with a bilateral non-dilated percutaneous collecting system, primarily due to the deep placement of the kidneys, which posed challenges for optimal US visualization. In response to this, the urology team carried out a retrograde DJ stent placement procedure to address the patient's condition. Notably, during one procedure, a minor complication occurred in a single patient, characterized by minor bleeding. The hemorrhage spontaneously resolved within 24 hours, requiring no further interventions. The rate of minor complications was calculated at 1.7%. Importantly, no major complications were observed throughout the procedures.

TABLE 1. Etiological factors for non-dilated obstructive renal collecting systems

Diagnosis	Number of patients (kidneys)
Fistula	16 (29)
Rectovesical	8 (15)
Vesicovaginal	5 (9)
Enterovesical	1 (2)
Ureterovaginal	1 (1)
Vesicoscrotal	1 (2)
Ureter injury	12 (21)
Bladder injury	2 (3)
Urethra injury	2 (4)
Hemorrhagic cystitis	1 (2)
Urosepsis	1 (2)
Calix rupture	1 (1)

DISCUSSION

PCN has been the preferred procedure in recent years over an open surgical approach for the temporary drainage of the renal collecting system. PCN involves the opening of a narrow needle tract in the calyces, which immediately reveals the intervening structures with imaging methods, making it a cost-effective and feasible technique with less morbidity [6]. In patients with a non-dilated or minimally dilated collecting system, many modalities such as US, magnetic resonance imaging (MRI), computed tomography (CT), and fluoroscopy have been used to visualize the calyceal system and increase the success of PCN [2, 3, 7, 8].

The technical success rate of using these modalities has been reported to be in the range of 82.7–100% in several studies [2, 9–11]. In our study, the success rate was 96.7% in non-dilated PCNs performed with furosemide under the guidance of US and fluoroscopy. The SIR has published guidelines for PCN for the self-assessment of quality-oriented operators. According to the guidelines, the acceptable success rate for high-quality PCN is 95% for an obstructive renal collecting system, and 80% for a non-dilated collecting system [5]. PCN procedures guided by CT or MRI have shown success rates of up to 100%. However, it is very important to recognize the disadvantages of these techniques. CT-guided PCN procedures are associated with longer duration, higher complication rates, and a greater number of punctures [12]. MRI-guided interventions are promising, but it is still considered to be experimental and require specialized MRI-compatible equipment. Therefore, the widespread use of MRI-guided PCN is limited [8].

US and fluoroscopy are the most cost-effective and fundamental modalities that are used routinely [1, 2]. US is widely recognized as a reliable guidance system for PCN with several advantages, including the absence of ionizing radiation, affordability, and the ability to provide real-time, high-quality, cross-sectional anatomical details [2]. Won et al. [1] recently conducted a large cohort study to evaluate the feasibility and outcomes of PCN performed under US and fluoroscopic guidance, without the administration of intravenous contrast agents or diuretics. These authors reported a mean procedure time of 15.97 minutes and a median fluoroscopy time of 4.2 minutes [1]. However, we observed a shorter mean procedure time of 13.17±6.46 minutes and a median fluoroscopy time of 2.37 minutes in the current study. While our study employed similar techniques as Won et al. [1], we attribute the shorter procedure and fluoroscopy times primarily to the utilization of calyceal dilatation facilitated by the infusion of procedural saline and furosemide. Previous reports have suggested that calyceal dilatation can contribute to a reduction in procedure time. For instance, Egilmez et al. [12] reported longer median procedural duration in patients with lower hydronephrosis grades.

Liu et al. [2] reported that the use of contrast-enhanced US-assisted PCN could increase the success rate in patients with NCT to 100%, emphasizing its high technical success rate. The authors attributed the high success rate to the excellent suitability of the US contrast agent for intracavitary use, which helps to overcome poor visualization in the prone position and improves imaging of the targeted calyx, even in the presence of increased abdominal gas [2]. In our study in which PCN was carried out on 62 kidneys, no major complications were observed, keeping the major complication rate much lower than the 4% acceptable threshold established by the SIR. Similarly, Yagci et al. [11] also reported no major complications in their study involving 22 nephrostomies with saline and diuretic infusion. Although the literature reports major complication rates of up to 8–9% for procedures such as renal hemorrhage, sepsis, solid organ injury, bowel perforation, vascular injury, hemothorax, and pneumothorax requiring transfusion, the nephrostomy procedure for NCT, performed after diuretic and saline infusion, has demonstrated itself to be a safe method with a low incidence of major complications [3].

We observed transient macroscopic hematuria in 1.7% of the percutaneous nephrostomy procedures in the current study, which was resolved within 24 hours. The minor complication rate in the current study was therefore well below the upper limit of 15% recommended by the Royal College of Radiologists for minor complications [1]. The reported rates of minor complications in percutaneous nephrostomy procedures in the literature range from 5.3% to 31.5% [1, 2]. In particular, nephrostomy carried out without a diuretic for non-dilated renal system resulted in a minor complication rate of 31.5% [1]. Liu et al. [2] reported a minor complication rate of 20.4% upon treatment with contrast US. Both of these rates exceed the upper limit specified by the Royal College of Radiologists. Other studies using different techniques [1–3, 10, 12] have reported minor complications that exceed the recommended limit.

The number of punctures required during PCN can vary depending on the technique and severity of hydronephrosis. Targeting a non-distended calyx poses challenges due to limited visibility, making it difficult to navigate a guidewire securely. Multiple needle punctures, manipulation of catheters in a non-distended collecting system, and prolongation of the procedure increase the risk of complications, particularly hemorrhage and infection [3]. Sommer et al. [13] reported that a mean number of 3.6 passes±2.6 were required when a combination of CT and fluoroscopy was used to guide PCN in patients with nonobstructive uropathy, specifically in cases of failed US-guided procedures resulting in urine leakage. Liu et al. [2], reported that the mean number of needle passes per kidney was 1.4±0.5 (range, 1–3). We were able to complete the procedure with a relatively low mean number of renal punctures (1.3±0.4), further supporting the low rate of complications observed.

Radiation exposure during PCN is an important issue. However, in a recent study, reassuring results have been reported [1], which established 4000 μGy·m^2 as a reference level for dose area product (DAP) and fluoroscopy time of 15 minutes for PCN. The average DAP during PCN in the current study was 166.94±148.5 μGy·m^2, with a wide range from 3.93 to 666.59 μGy·m^2. The median DAP was determined to be 127.04 μGy·m^2. The observed radiation doses (DAP) were well below the established reference level and well within the acceptable limits. Won et al. [1] identified two crucial factors that can help attain low radiation doses. Firstly, the use of US-guided puncture significantly reduced the need for fluoroscopy, thus minimizing radiation exposure. US guidance allows for precise needle placement, reducing reliance on continuous fluoroscopy throughout the procedure. Secondly, the absence of intravenous contrast media further contributed to the reduction in radiation exposure, as it eliminated the need for fluoroscopic contrast imaging.

Nephrostomy procedure for non-dilated collecting systems that involve saline infusion along with diuretics is a widely adopted technique that is associated with a high success rate and relatively low risk of complications. However, it is important to consider some potential disadvantages associated with this procedure. For example, the use of a diuretic to dilate the pelvicalyceal system can help improve calyceal visualization during PCN, especially in patients with NCT. Of note, the achieved dilation is temporary, typically lasting around 15 minutes, and gradually returning to baseline within 30 minutes [11]. While furosemide is effective in promoting diuresis, it should be used with caution. It is contraindicated in patients with anuria, severe metabolic disturbances, or hypersensitivity to the drug. Rapid infusion carries a rare risk of ototoxic side effects. To minimize ototoxicity, careful administration, limited dosage, and avoidance of high infusion rates are necessary. Caution is also advised when combining furosemide with contrast agents due to an increased risk of radiocontrast nephropathy. Importantly, ototoxic side effects associated with furosemide administration were not reported by Yagci et al. [11] and were also not observed in the current study.

There are some limitations in our study. First of all, only US and fluoroscopy-guided PCN was carried and the success and complication rates of other imaging modalities (such as MRI or CT) were not evaluated. A relatively limited number of patients were included in the study. Temporary dilatation was achieved with a diuretic and the effects of other agents such as US contrast medium, air, or CO_2 were not evaluated. The classical approach was re-applied in patients in whom the procedure was unsuccessful rather than enabling access with different techniques.

Conclusion

PCN with saline and diuretic infusion is a reliable and practical treatment option for patients with NCT and can be considered as an alternative to an open surgical approach. With its low complication and high success rates, PCN provides rapid treatment of various conditions with potentially devastating outcomes such as fistula, ureteral injury and urosepsis in the collecting system.

Ethics Committee Approval: The Basaksehir Cam and Sakura City Hospital Clinical Research Ethics Committee granted approval for this study (date: 22.06.2023, number: 2023.06.275).

Authorship Contributions: Concept – AD, OA, FZA, CE, INM, OK; Design – D, OA, FZA, CE, INM, OK; Supervision – AD, OA, FZA, CE, INM, OK; Fundings – AD, OA, FZA, CE, INM, OK; Materials – AD, OA, FZA, CE, INM, OK; Data collection and/or processing – AD, OA, INM, CE, OK; Analysis and/or interpretation – AD, OA, INM; Literature review – AD, OA, INM; Writing – AD, OA, FZA; Critical review – AD, OA, FZA.

Conflict of Interest: No conflict of interest was declared by the authors.

Use of AI for Writing Assistance: The authors declared that this study did not utilized any AI-assisted technologies, including Large Language Models (LLMs), chatbots, or image creators, in the production of this manuscript.

Financial Disclosure: The authors declared that this study has received no financial support.

Peer-review: Externally peer-reviewed.

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