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INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

Percutaneous nephrostomy for nondilated renal collecting system with ultrasound and fluoroscopic guidance: The results of a 10-year experience

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PURPOSE
This study aimed to evaluate the technical success rate, complications, and radiation doses of ultrasound- and fluoroscopy-guided percutaneous nephrostomy (PCN) in patients with a nondilated renal collecting system.

METHODS
Over a 10-year period, 50 patients were referred for PCN of 60 kidneys with a nondilated renal collecting system. The patients included 22 males and 28 females with a mean age of 63.2 years (range: 35-87 years). The most common reason for PCN in these patients was postoperative ureteral leaks and/or fistula (21/50 patients). PCN was performed under ultrasound and fluoroscopic guidance. During PCN, intravenous contrast media or diuretics were not used. Technical success rate, complications, procedure time, and radiation exposure of the procedure were retrospectively evaluated.

RESULTS
Ultrasound- and fluoroscopy-guided PCN for nondilated renal collecting system showed a success rate of 83.3% (50/60 kidneys) in the initial attempt. Four PCNs were repeated and were successful after the initial PCN failure. There was 1 major complication of bleeding that required transfusion in 1.9% (1/54) PCNs and there were minor complications of transient gross hematuria through the PCN catheter in 31.5% (17/54) PCNs. Mean duration of the procedure was 15.97 ± 7.81 min and median fluoroscopy time was 4.2 min (range: 1.2-15.3 min). Median dose area product and cumulative dose were 345.37 μGy·m^2 (range: 42.57-1659.76 μGy·m^2) and 46.9 mGy (range: 7.7-267.8 mGy), respectively.

CONCLUSION
Ultrasound- and fluoroscopy-guided PCN for nondilated renal collecting system was feasible with acceptable technical success rate, complication rate, procedure time, and radiation exposure.

In general, percutaneous nephrostomy (PCN) is relatively safe and easy in the dilated renal collecting system. The risk of complications related to the PCN procedure is low and includes sepsis, hemorrhage, pneumothorax, adjacent organ injury, or urine leak.[1] Considering both minor and major complications, it occurs in about 10% of patients undergoing PCN.[1] PCN in patients with a nondilated renal collecting system is challenging because the system cannot be properly delineated by ultrasonography.[2] Therefore, various percutaneous access techniques have been introduced for PCN in a nondilated renal collecting system, including intravenous contrast agent administration to opacify the renal collecting system,[2,3] diuretics administration to induce distension,[4,5] or alternative imaging guidance, such as computed tomography (CT) and magnetic resonance-guided techniques for needle entry into the collecting system.[6,7] However, such PCNs are not routine procedures. Additionally, there are some disadvantages of these PCN techniques, such as the unavailability of alternative machines or limited timeframe following a rapid washout of the administered intravenous contrast agents or diuretics.[4,8,9]

In most institutions, a combination of ultrasound and fluoroscopic guidance is the most frequently used method for PCN.[4,10] Radiologists typically utilize ultrasound guidance for the initial pelvicalyceal needle approach and continue under fluoroscopic guidance.[4,10] Previous

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studies on PCNs in nondilated renal collecting systems included only a small number of patients, while PCN studies with large sample sizes did not focus on nondilated renal collecting systems.[2-6] The aim of this study was to evaluate the feasibility and clinical outcome of PCN under ultrasound and fluoroscopic guidance without the use of intravenous contrast agents or diuretics in a large cohort of patients with a nondilated renal collecting system.

Methods

Patients

A retrospective study was conducted to evaluate the technical success rate, complications, and radiation doses of PCN for 60 kidneys (50 patients) with a nondilated renal collecting system under ultrasound-fluoroscopic guidance from July 2009 to February 2020. Two academic tertiary referral centers participated in this study. Based on the database, of the 4954 patients who received PCN during the study period, 55 patients had a nondilated renal collecting system, of which 50 were included in this study, excluding 5 patients who used intravenous contrast media or diuretics. The institutional review board of each participating hospital approved this retrospective study (No. S2020-2214-0001 and No. 2020-09-012) and waived the need to obtain written informed consent.

The study population included 22 males and 28 females with a mean patient age of 63.2 years (range: 35-87 years). Characteristics of the study population are listed in Table 1. The indications for PCN were most commonly postoperative ureteral leaks and/or fistula (n=21) and nondilated obstructive uropathy (n=12). The postoperative ureteral leaks and/or fistula (n=21) occurred following gynecologic surgery (n=12), colorectal surgery (n=4), cystectomy (n=2), kidney transplantation (n=2), or debulking surgery for pseudomyxoma (n=1). Nondilated obstructive uropathy (n=12) was associated with underlying pelvic malignancy (n=7), kidney transplantation (n=4), or neobladder reconstruction (n=1).

A nondilated renal collecting system was defined as a kidney having no calyceal dilatation on ultrasound (grade 0-1 renal appearance on the 4-grade system was used to classify the degree of hydronephrosis).[4] None of the patients had severe coagulopathy (international normalized ratio >1.5, platelet count <50 000/mm^3). No patient was taking oral anticoagulant drugs.

Percutaneous nephrostomy placement technique

All PCN placements were performed by experienced radiologists with 7-25 years of clinical intervention experience. A percutaneous approach through the posterior calyx in the lower or mid pole was preferred in most cases to prevent vascular injury. Whenever renal calyces could not be delineated under ultrasound, percutaneous access was targeted to the posterior renal pyramid of the mid or lower pole. For PCN before antegrade endourological procedures or kidney transplant patients, the targeted level of the pyramid depended on the intended purpose of the PCN tube and/or operator's decision. During PCN placement, intravenous contrast media or diuretics were not used in any of the patients.

After local anesthesia with 2% lidocaine, under ultrasound guidance (Figures 1, 2, and 3), a 21 G Chiba needle (Cook Medical Inc.) was advanced through the center of the renal pyramid (Figures 2b and 3b). Color Doppler was used to avoid major vessel injury before needle entrance (Figure 1b). After renal pyramidal passage toward the renal pelvis or hilum and removal of the inner stylet, the Chiba needle tip was moved slightly backward while injecting a few milliliters of diluted contrast medium (with sterile saline up to 70%) to opacify the renal collecting system (Figures 1c and 2c). Once the renal calyx was visualized, an additional small amount of contrast medium was injected to ensure proper positioning of the needle tip and passage of the contrast to the renal pelvis. If the initial puncture failed, the puncture was repeated on another pyramid or the needle was further advanced to the renal pelvis or hilum to opacify the renal collecting system (Figure 3b).

When the puncture was successful, a 0.018-inch platinum guidewire was introduced through the Chiba needle (Figure 1d), and

Main points

- Ultrasound- and fluoroscopy-guided percutaneous nephrostomy (PCN) for a nondilated renal collecting system without the use of intravenous contrast agent or diuretics was feasible with an acceptable technical success rate of 83.3%, procedure time, and radiation dose.
- In terms of the technique, it is very important to target the center of the renal pyramid well under ultrasound guidance because the renal pyramid is projected into a minor calyx.
- The rate of a minor complication, transient gross hematuria through the PCN catheter, was as high as 31.5%.

Table 1. Characteristics of the study population

Characteristic	Value
Patients, n	50
Age (years), mean±SD (range)	63.2 ± 13.9 (35-87)
Sex, n	
Male	22
Female	28
Numbers of kidneys	60
Unilateral (transplanted)	40 (6)
Bilateral	10
Indications for PCN[a]	50 (60)
Postoperative urine leakage and/or fistula	21 (29)
Nondilated obstructive acute kidney injury	12 (12)
Access for endourologic procedure[b]	6 (6)
Urosepsis	6 (7)
Dislodgement of a previously placed PCN catheter	3 (3)
Hemorrhagic cystitis	1 (2)
Iatrogenic ureter injury after ureteroscopy	1 (1)

[a]Data are numbers of patients, with number of kidneys in parentheses.
[b]DJ stent removal and/or insertion after retrograde approach failure (n=3), occlusion stent insertion (n=1), metallic stent insertion (n=1), DJ stent removal before ileal ureter operation (n=1).
PCN, percutaneous nephrostomy; DJ stent, double J stent.

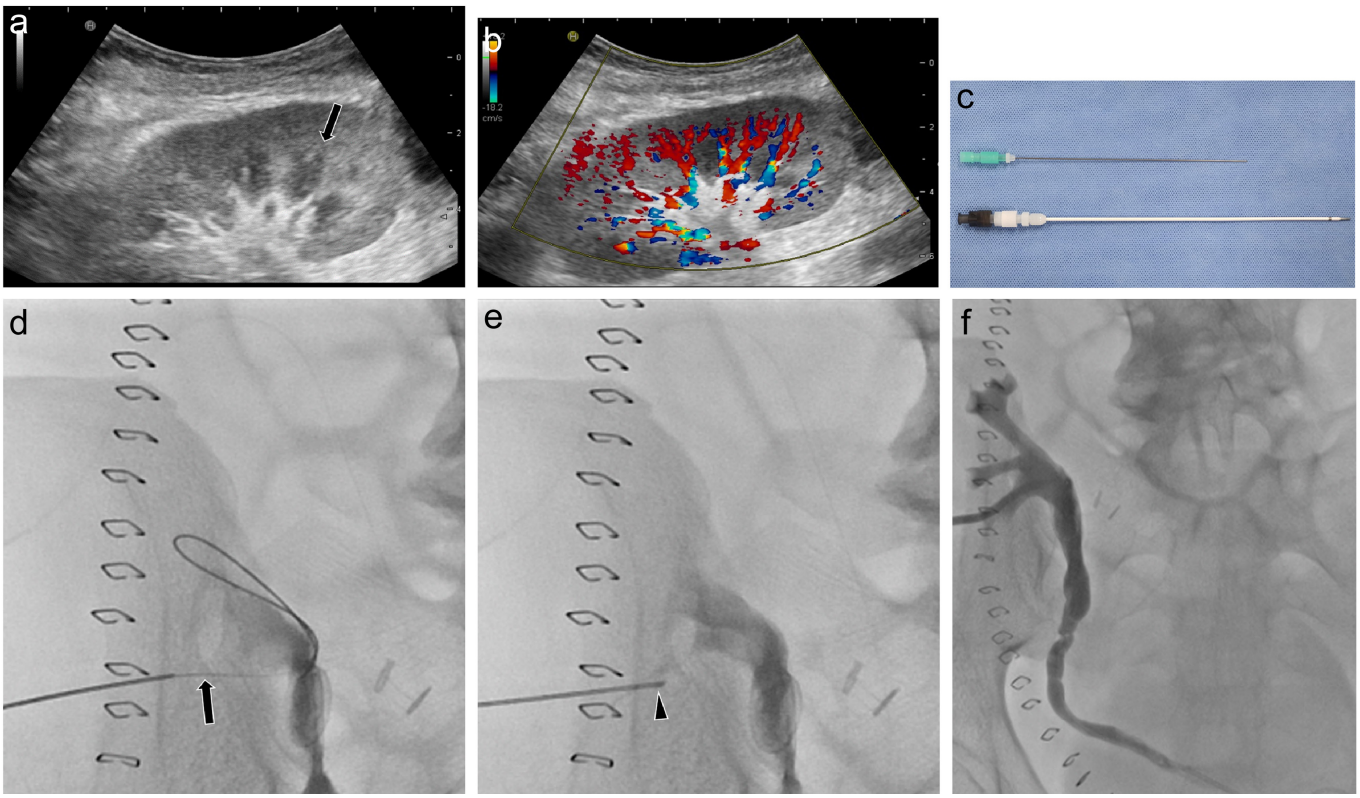

Figure 1. a-f. A 35-year-old woman with a double J stent for ureteral stricture following kidney transplantation presented with elevated serum creatinine level. Grayscale **(a)** and Color Doppler **(b)** ultrasonography images show nondilated renal collecting system. Color Doppler image helps identify renal vasculature. The renal pyramid (**a**, *arrow*) at the lower pole was punctured. Panel **(c)** shows a 21 G Chiba needle and a 6 F Neff catheter that were used for puncture. **(d)** Radiograph after ultrasound-guided puncture of the renal pyramid with a Chiba needle. A small amount of diluted contrast medium was gently injected via the needle (*arrowhead*) to opacify the renal collecting system. **(e)** A 0.018-inch guidewire (*arrow*) was inserted through the Chiba needle into the renal collecting system. **(f)** Finally, an 8.5 F drainage catheter was successfully inserted.

the needle was exchanged with a Neff® set access system (Cook Medical Inc.), followed by the introduction of a hydrophilic 0.035-inch guidewire (Terumo Corporation) into the renal pelvis or the proximal ureter. Finally, an 8.5 F pigtail catheter (Cook Medical Inc.) was placed (Figure 1e). All procedures were completed with the confirmation of the tip of the PCN catheter shaped as a pigtail and the catheter position on the last radiograph.

Successful PCN was defined as satisfactory placement of a PCN catheter in the renal collecting system with successful opacification of the ureter or renal pelvis on antegrade pyelography.

Data collection

Data on technical success rate, associated complications, procedure time, and radiation exposure of the procedure (the fluoroscopy time, dose area product (DAP), and cumulative dose) were obtained. Bilateral PCNs for nondilated renal collecting system in one patient were considered as two unique PCNs, and the procedure time and radiation dose were equally divided between the two. Technical success and complications were calculated per kidney. Procedure time and radiation exposure were calculated per procedure.

Complications were defined according to the Society of Interventional Radiology (SIR) as follows[1]: minor complications included those resulting in (1) no therapy with no consequences or (2) nominal therapy with no consequences including overnight admission for observation only; major complications required, (3) therapy and minor hospitalization (<48 h), (4) major therapy, unplanned increase in the level of care, prolonged hospitalization (>48 h), (5) permanent adverse sequelae, or (6) death.

Results

The success rate of PCN under ultrasound and fluoroscopic guidance for a nondilated renal collecting system was 83.3% (50/60 kidneys). Four PCNs were repeated and successful after the initial PCN failure.

During the follow-up period (mean 9.3 days; range: 1-60 days), out of 54 PCNs (45 patients) including 4 successful repeated PCNs, 31 patients (36 PCN catheters) underwent elective removal of the PCN catheters; after double J stent insertion (20 PCNs in 19 patients), ureter embolization (5 PCNs in 3 patients), surgical ureteroplasty (3 PCNs in 2 patients), ureter stone removal (2 PCNs in 1 patient), or after spontaneous resolution on follow-up antegrade pyelography (6 PCNs in 6 patients). Ten patients (13 PCNs) were transferred after PCN catheter insertion and 3 patients (3 PCNs) were discharged while maintaining a PCN catheter without drainage complications. One patient (2 PCNs) died 5 days after PCN because of the progression of recurred cervical cancer.

The rate of a major complication (bleeding) was 1.9% (1/54). After the procedure, the hemoglobin level decreased from 9.8 g/dL to 7.6 g/dL but the patient stabilized after a transfusion of 3 units of red blood cells and the hemoglobin level recovered to 11.5 g/dL. There was no septic shock or adjacent organ injury related to the PCN procedure. There was no mortality associated with the PCN technique itself in this study. The rate of a minor complication (transient gross hematuria through the PCN catheter) was 31.5% (17/54). However, the complication resolved within 3 days in all patients (Table 2).

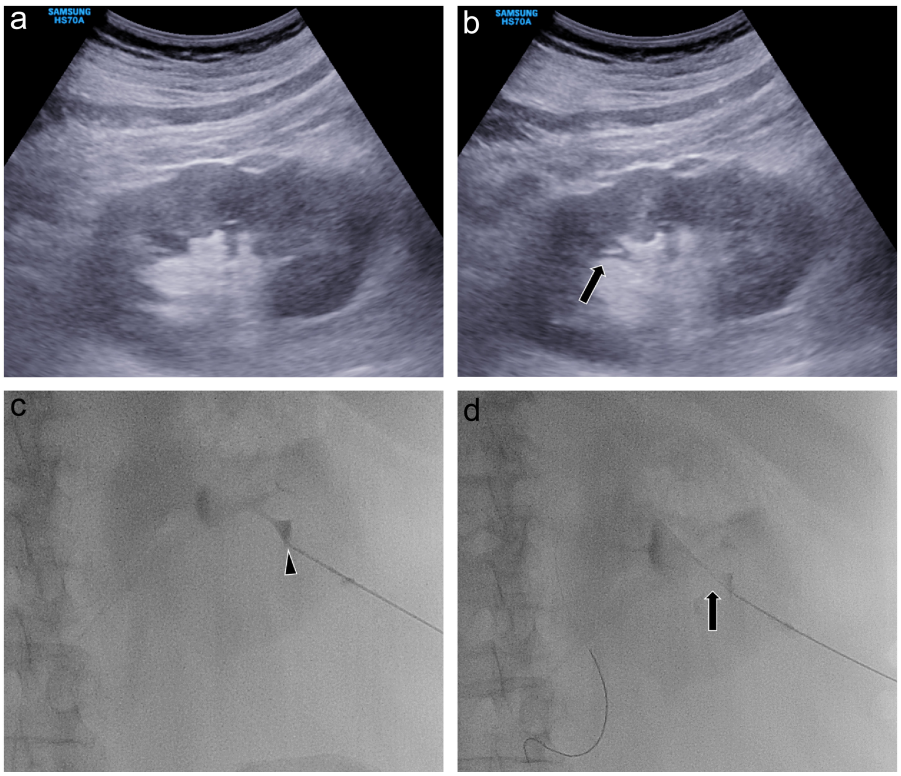

Figure 2. a-d. A 64-year-old man with catheter dislodgement 4 days after PCN catheter insertion. Ultrasonography image (**a**) shows nondilated renal collecting system without calyceal dilatation. Panel **(b)** shows a 21 G Chiba needle introduced through the center of inferior renal pyramid (*arrow*). On radiograph **(c)**, a small amount of diluted contrast was gently injected via the needle (*arrowhead*) to opacify the renal collecting system. Panel **(d)** shows a 0.018-inch guidewire (*arrow*) inserted through the Chiba needle into the renal collecting system. Finally, an 8.5 F drainage catheter was successfully inserted (not shown).

Procedure time was analyzed in a total of 45 PCNs out of 54 PCNs including 4 successful repeated PCNs. Nine PCNs were excluded either because the PCN was combined with double J stent insertion/removal (n = 7) or because one of the bilateral PCNs failed (n = 2). The mean duration of the procedure time was 15.97 ± 7.81 min (n = 45; range: 7-40 min).

Data for radiation exposure were available for 38 PCNs. The median DAP was 345.37 μGy·m^2 (range: 42.57-1659.76 μGy·m^2) and the median cumulative dose was 46.9 mGy (range: 7.7-267.8 mGy). The median fluoroscopy time was 4.2 min (range: 1.2-15.3 min).

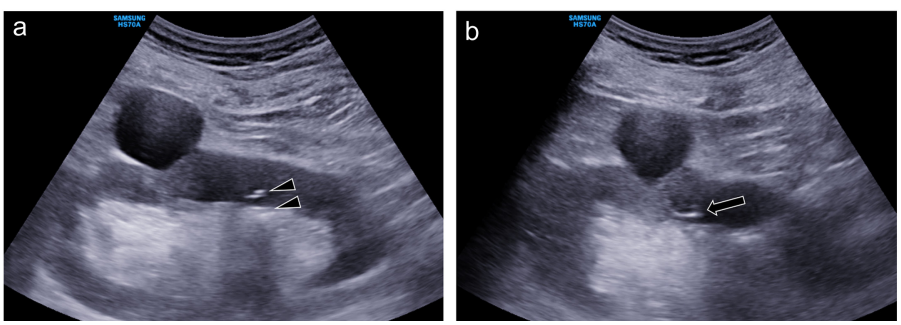

Figure 3. a, b. A 68-year-old man with urosepsis due to ureter stone, presented with elevated serum creatinine level and low blood pressure. **(a)** After initial puncture through the inferior renal pyramid failed, the ultrasonic view degraded due to residual contrast agent (*arrowheads*). Panel **(b)** shows the second attempt in which the Chiba needle was advanced through the mid pole renal pyramid (*arrow*). Thereafter, renal collecting system was accessed with the use of a 0.018-inch guidewire and finally, an 8.5 F drainage catheter was successfully inserted (not shown).

Discussion

In this study using ultrasound and fluoroscopic guidance without requiring intravenous contrast agents, diuretics, or alternative guidance modality in a nondilated renal collecting system, the success rate was 83.3%. This rate is within the range of 82.7%-96.2% reported in several studies based on 22-26 kidneys.[2-4,6] They used 1) double-contrast pyelography technique by using carbon dioxide or air to visualize distended non-dependent calyces after intravenous contrast administration,[2] 2) diuretics and normal saline infusion to dilate the pelvicalyceal system,[3,4] or 3) combined CT and fluoroscopy-guided PCN.[6] However, the major complications in these studies were as high as 8%-9%, and there are disadvantages that require intravenous contrast or diuretics administration or CT equipment.[2,4,6] In patients with renal failure, the use of contrast media is limited, and the pelvicalyceal opacification by intravenous urography is sometimes unsatisfactory, but the technique in this study has the advantage that it can be used even in patients with renal failure because no contrast media is used.

Table 2. Complications of 54 percutaneous nephrostomy placement in 45 patients

Complications	n (%)
Major complications	
Bleeding requiring transfusion	1 (1.9)
Minor complications	
Transient gross hematuria	17 (31.5)
Resolved ≤ 1 day	7
Resolved ≤ 2 days	6
Resolved ≤ 3 days	4

In terms of technique, it is very important to target the center of the renal pyramid well under ultrasound guidance because the renal pyramid is projected into a minor calyx. Thus, the puncture path through the center line of the renal pyramid passes through the axis of the corresponding minor calyx.[12] If the needle has passed through the renal pyramid to some extent, whether the renal calyx is opacified is confirmed by gently injecting the contrast medium under fluoroscopy. In cases of initial puncture failure and degraded ultrasonic view, it is advised to retry in another pyramid or further advance the needle into the pelvis or hilum to opacify the renal collecting system.

The PCN procedure time varies depending on various factors, such as the degree of hydronephrosis, whether CT is used, and the skill level of the operator.[13,14] Egilmez et al. reported that the mean procedure time of CT-guided PCN was prolonged from 14 min to 20 min if the hydronephrosis grade decreased from grade 3 to grades 0-1.[13] In this study, the

mean procedure time of 15.97 min was longer than the mean procedure time of 9.1 minutes in the study where PCN was performed with ultrasound guidance in patients with dilated renal collecting system,[14] but was shorter than the mean procedure time of 20 min for CT-guided PCN with the same grade of hydronephrosis.[13]

The procedure time of the present study is acceptable considering the nondilated renal collecting system. Furthermore, the technique in this study obviates the waiting time for achieving pelvicalyceal opacification by contrast media.

Radiation exposure during PCN procedures is another important concern. Considering the reference level of 4000 uGy·m^2 for DAP and 15 min for fluoroscopy time in PCN, derived from the Radiation Doses in Interventional Radiology Procedures study,[15] 345.37 uGy·m^2 (range: 42.57-1659.76 μGy·m^2, for median DAP) and 4.2 min (range: 1.2-5.3 min, for median fluoroscopy time) obtained in this study seem acceptable. It is hypothesized that ultrasound-guided puncture and the absence of intravenous contrast media contributed to the low radiation dose.

Several studies of the nondilated renal collecting system have reported 8%-9% of major complications above the 4% threshold recommended by the SIR in 22-26 kidneys.[1,3,5] There was 1 major complication of bleeding that required transfusion in 1.9% (1/54) PCNs in this study. There was no septic shock complication or adjacent tissue damage related to the PCN procedure. Disadvantages of the fluoroscopy-guided PCN include inadequate visualization of the perinephric anatomy with the risk of adjacent organ injury during the puncture process. In the present study, ultrasound was used as the primary guidance. It can help prevent visceral and adjacent organ injury, such as inadvertent colon penetration.[3,16] In addition, intravenous contrast media or diuretics were not used during the procedure. This can reduce the chances of sepsis, which can result from elevated intrapelvic pressure.[6]

In this study, hematuria showed a temporary improvement within 3 days in most cases and was clinically a minor complication. The rate of hematuria improved by conservative treatment, as a minor complication, was 31.5%, which was higher than the range of 5.3%-28% of minor complication rates during general PCN procedures[17-21] and higher than the 15% upper margin for minor complications, as recommended by the Royal College of Radiologists.[11] However, complications are highly dependent on patient selection.[1] Only a few studies have reported minor complication rates in nondilated renal collecting systems. Degirmenci et al. demonstrated that the patients with a nondilated renal collecting system had a 6-time increase in overall complication rates, highlighting the importance of the clinical status of the patients.[3]

There were several limitations of the study. First, this study retrospectively reviewed the clinical and imaging findings. For example, the number of needle perforations thought to have a significant impact on complications was not analyzed due to the lack of reliable data. Second, complications according to the number of punctures were not analyzed because reliable data were not obtained. Third, the PCN procedure was not uniform across all patients as it was performed by multiple interventional radiologists with varying clinical experience. Fourth, data on radiation exposure were not available for the entire procedure.

In conclusion, ultrasound- and fluoroscopy-guided PCN in the nondilated renal collecting system was feasible with acceptable technical success rate, complication rate, procedure time, and radiation exposure.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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