Percutaneous Nephrostomy: Is Ultrasound Alone Sufficient as Imaging Guidance?

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ABSTRACT

Percutaneous nephrostomy (PN) is a frequently performed invasive procedure for the maintenance of renal function in cases of urinary obstruction. Transient hemorrhage is a common minor complication of this procedure. The aim of this study was to determine which of the selected methods was less traumatic in two groups of PN patients guided by two different radiological modalities.

A total of 64 PN procedures performed in 2018, with an equal number of two different approaches (ultrasound-guidance, ultrasound and fluoroscopy-guidance) to PN were compared to determine which method was less traumatic. Urine samples were taken from the collecting system after needle insertion and after catheter placement, and the amount of blood in the urine samples was recorded to assess hematuria. In addition, after fluoroscopy-guided procedures, the radiation exposure time, air kerma and kerma-area-product values were recorded and compared with data in the literature.

Although the average amounts of blood detected in the urine samples taken at two stages of two different methods differed, these differences were not statistically significant. There was a statistically significant positive correlation between the amount of the blood in the urine samples taken after the needle insertion and kidney parenchymal thickness (p=0.013).

To protect patients and interventional radiologists from unnecessary radiation exposure, PN with ultrasound only guidance may be a good choice for selected cases, such as those with evident pelvicalyceal dilatation, pediatric patients and pregnant women.

Key Words: percutaneous, nephrostomy, ultrasound, fluoroscopy, radiation safety

Introduction

Percutaneous nephrostomy (PN), which was first introduced by Goodwin in 1955 as a new technique, is now a routine, well-established interventional procedure with high success rates for maintaining renal function in hydronephrosis (1).

When this operation is performed with guidance from radiological imaging methods, ultrasound (US) and fluoroscopy are the standard combination. US is the most important guidance system since this modality is cheap and reliable, provides real-time imaging features, and most importantly, does not require ionizing radiation. Fluoroscopy, on the other hand, allows safe completion of the PN procedure through manipulations of a wire, dilator and catheter and the passage of a given contrast agent through the urinary tract. However, the most important disadvantage of fluoroscopy is radiation exposure (2-4). PN is most commonly applied for urinary obstructions, urinary diversion and endourological procedures (5). The success and complication rates of PN may vary depending on operator experience, operation techniques, imaging methods used for guidance, and the materials and equipment used in the procedure (6,7). The complications of PN are classified under two main headings as major and minor complications. Hemorrhage requiring transfusion or embolization is defined as a major complication (8,9). Transient hemorrhage is a condition that occurs in almost every patient (10).

In this study, this routine procedure was performed in the same interventional radiology clinic with two different methods aimed at causing minimal trauma to the kidney. In the first method, PN was performed under US only guidance, where the patient and physician are not exposed to radiation. The second method was PN under US and fluoroscopy guidance. Although there is a study in literature that has evaluated different needle sizes utilized in PNs and the associated amounts of hematuria, to the best of our knowledge, there is no such study related to radiological guidance and associated hematuria (11).

The aim of this study was to determine which of these two methods is a less traumatic intervention for the kidney, through comparisons of the amount of

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blood measured from urine samples taken during and after the intervention.

Materials and Methods

The study protocol was approved by the local Clinical Trials Ethics Committee (2019/204).

Study population: Analysis was made of the total PN procedures performed between January 2018 and January 2019 by the same interventional radiology team using two different methods for patients with various benign or malignant urinary obstruction indications. When the angiography unit was busy due to other interventions, PNs were performed under only ultrasound guidance. A total of randomly selected 64 procedures were included in the study, of which 32 were performed with US only (U-GPN), and 32 with both US and fluoroscopy (U&F-GPN).

The patients included in the study comprised 46 males and 18 females with a mean age of 60.9± 15.2 years (range, 22-86 years). Some patients had unilateral PN procedures, some had bilateral PN procedures, and some had multiple PN procedures due to catheter dislodgement. The clinics that referred patients to our unit for PN were urology, oncology and general surgery.

Patients were evaluated for the intervention through the use of platelet count, prothrombin time, partial thromboplastin time and INR values, and PN was planned for appropriate patients (9). Blood urea and creatinine values were determined. Before the procedure, the hydronephrotic kidney was evaluated by US, and the pelvic anteroposterior (AP) diameter and parenchymal thickness were measured and recorded. Prophylactic broad-spectrum antibiotics were administered before the procedure.

Informed consent was obtained from each patient.

PN procedures were performed by a team of two board certificated (EDIR) interventional radiologists with at least 5 years of experience in this field.

Exclusion Criterias: Renal transplant patients, pediatric patients, patients with an international normalized ratio (INR) >1.3 and patients with pyonephrosis were excluded from the study. In addition, if hemorrhage was observed in the renal collecting system and a blood clot filling the pelvicalyceal structures, then the PN procedure was not included in the study since a homogeneous urine sample could not be obtained.

Techniques: With the patient in the lateral decubitus position, the most appropriate and safe retroperitoneal incision location, preferably Brödel's avascular line, was selected under US guidance. The

local site was then cleaned, and sterile draping was applied. Preoperatively, 10 mL of 2% lidocaine was injected into the subcutaneous soft tissue of the selected PN tract.

I. First Step: The first step of the PN procedure was performed in both groups under real-time imaging with a US device (Aplio 300; Toshiba, Minato, Japan) and a 3.5 MHz convex probe. In the first group, the first access site was to the lower pole posterior calyx group of the kidneys and was made with a subcostal approach using an 18 G needle, and approximately 10 cc urine was collected. The initial urine samples were separated and marked for analysis in a tube to measure the amount of hematuria.

To provide optimal pelvicalyceal dilatation and to ensure the same conditions for both techniques, 10 mL saline was injected through the needle in US-guided interventions. Approximately 10 mL water-soluble iodine contrast agent was injected into the collecting system during fluoroscopy after the needle insertion to the collecting system in the US and fluoroscopy-guided interventions.

The guidewire was then advanced to the dilated kidney collecting system, and the tract was extended through dilators (6-8F).

II. Second Step: The second step of the procedure was catheterization; 8 French (F) nephrostomy kits (Flexima™, Boston Scientific) were used in all patients. In the first PN group, catheterization was completed under US guidance. To ensure that the catheter was in the pelvicalyceal system, approximately 10 cc saline was administered under US guidance, and fluid movement in the collecting system was confirmed with color Doppler imaging.

In the second PN group, catheterization was completed under uniplanar flat- panel fluoroscopy (Artis zee; Siemens, Forchheim, Germany) guidance. To check the position of the catheter and to detect the location of the obstruction, an additional 10 mL water-soluble iodine contrast agent was injected into the collecting system through the catheter.

In both groups, the second urine samples were taken after the catheterization was checked. The samples were separated for analysis in the tube and marked.

The catheter was locked and fixed to the skin with 0 silk sutures. The distal end of the catheter was connected to a urine bag.

The fluoroscopy time, dose area product (DAP) and cumulative radiation doses were recorded. The first and second urine samples, which were collected from the needles and catheters, were sent to the laboratory at 30-minute intervals to prevent mixing up the samples.

The procedure summarized in Table 1.

Statistical Analysis: Data obtained in the study were analysed statistically using SPSS vn 20.0 software (SPSS, Inc., Chicago, IL, USA). Comparisons were made using the Student's t-test and the Chi-square test. Correlations between the groups were examined using Pearson's test. A value of $p < 0.05$ was considered statistically significant.

Results

No statistically significant differences were observed between two groups (U-GPN and U&F-GPN) in terms of the parameters as: age, gender, kidney pelvis diameter, malign or benign causes. The average measurement values of kidney pelvis AP diameters were 34.6±22.2 in the first group and 23.3±10 in the second group. The average kidney parenchymal thicknesses were 10.4±6.2 in the first group and 13.8±3.1 in the second group. Only the differences about kidney parenchymal thickness values in two groups were statistically significant (Table 2).

The average amount of the blood measured in the first urine samples of the first and second groups were 67.9±111 and 43.1±81, respectively. After catheterization, which was the second step of the procedure, the average amount of the blood in the urine samples was higher in the first group (882.3±1585.4) than in the second group (741.9±1175.2). No statistically significant difference was observed between the two groups in terms of hematuria both in the first (p=0.31) and second steps (p=0.68) of the procedures (Table 3).

In both steps of the 64 PN procedures, there was negative correlation between the amount of the blood in the urine samples and kidney pelvis AP diameter, but this correlation was not statistically significant (p>0.05). In the first step of the 64 PN procedures, there was a statistically significant positive correlation between the amount of the blood in the urine samples and kidney parenchymal thickness (p=0.013). In the second step of all the procedures, there was a positive correlation between the amount of the blood in the urine samples and kidney renal parenchymal thickness, but this correlation was not statistically significant (p>0.05) (Table 4).

The most important causes of hydronephrosis in patients undergoing PN were malignancy and urolithiasis. Of the 64 PN procedures, 24 were performed because of benign diseases and 40 were performed because of malignant diseases (Table 5). The average amount of hematuria in the urine samples of patients with hydronephrosis caused by benign and malignant diseases were 47.21±81.66 and 60.53±106.45, respectively in the first step; and 542.50±1143.22 and 973.93±1503.83 respectively in the second step. These differences were not statistically significant (p>0.05) (Table 6).

In the second step of the second group, the mean duration of fluoroscopy use was 1.26±0.2 minutes, and KAP and cumulative dose amounts of 305.48±73.71 μGym^2 and 16.7±5.06 mGy were measured, respectively.

During the PD procedures, no major complications were identified.

Discussion

Currently, with the development of modern endourological techniques and materials, the PN procedure is indicated for many patients and remains important in many diseases of the urinary system (5). PN is a relatively effective and safe procedure that does not require general anesthesia and has low risk and low morbidity rates. This procedure is routinely performed to preserve renal function and most urinary obstructions of benign or malignant etiology are not an absolute contraindication, although bleeding diathesis is defined as a relative contraindication (9).

The success rate of the PN procedure has been reported as 84-99%, depending on the clinical scenario. In cases of insufficient dilatation of the collecting system to establish access or in complicated cases of kidney stone disease, this rate decreases to 80% (8).

Different methods have been applied and suggested in terms of materials or input techniques for the PN process (2,11-16). In the current study, the Seldinger method was used in all the procedures and comparisons were made of the urine samples obtained after establishing needle and catheter access to the collecting system.

The overall minor and major complication rates of PN have been reported to be approximately 10%. Major complications are classified as hemorrhage requiring transfusion, which has an incidence of 1-4%, and vascular injuries requiring embolization or nephrectomy have been reported with an incidence of 0.1-1% (8,9,17). In a retrospective study of 569 PN procedures, 3 (0.5%) patients developed bleeding complications that required treatment (6). In the current study, no bleeding complications that required treatment occurred. However, if a clot due to transient hemorrhage filled the pelvicalyceal system after catheterization, homogeneous urine samples could not be collected, and these cases were excluded

Table 1. Summary of the procedures

Percutaneous Nephrostomies (n=64)			
U-GPN (n=32)		U&F-GPN (n=32)	
Ultrasound Only Guidance	**First step** 18 G needle insertion ↓ 10 ml urine sampling ↓ 10 ml saline injecton ↓ Catheterization ↓	18 G needle insertion ↓ 10 ml urine sampling ↓ 10 ml WSCA injection ↓ Catheterization ↓	Ultrasound Guidance
	Second step 10 ml saline injection ↓ 10 ml urine sampling	10 ml WSCA injection ↓ 10 ml urine sampling	Fluoroscopy Guidance

U-GPN: Ultrasound guided percutaneous nephrostomy, U&F-GPN: Ultrasound and fluoroscopy guided percutaneous nephrostomy
WSCA: Water soluble contrast agent

Table 2. The differences between two groups (U-GPN and U&F-GPN) in terms of some parameters

Parameters	U-GPN	U&F-GPN	p values
Age, years	58.38±16.54	63.47±13.58	ns [a]
Gender, male/female	25/7	21/11	ns [b]
APD (mm)	34.6±22.2	23.3±10	ns [a]
PT (mm)	10.4±6.2	13.8±3.1	0.008 [a]
Causes, malign/ benign	17/15	23/9	ns [b]

U-GPN: Ultrasound guided percutaneous nephrostomy, U&F-GPN: Ultrasound and fluoroscopy guided percutaneous nephrostomy, APD: Kidney pelvis anteroposterior diameter, PT: Parenchymal thickness, ns: Non-significant
Values ara expresses as mean ± SD (range) where applicable.
[a]Student-t test
[b]Chi-square test

Table 3. The differences between first and the second steps of both U-GPN and U&F-GPN in terms of hematuria

Parameter		U-GPN	U&F-GPN	p values
The average amount of the blood	First Step	67.9±111	43.1±81	p=0.31
	Second Step	882.3±1585.4	741.9±1175.2	p=0.68

U-GPN: Ultrasound guided percutaneous nephrostomy, U&F-GPN: Ultrasound and fluoroscopy guided percutaneous nephrostomy
Values ara expresses as mean ± SD (Standart Deviation) where applicable.
Student-t test

Table 4. Correlation between the average amount of the blood measured both in the first and second urine samples with APD and PT values

Parameters		r values	p values
The average amount of the blood measured in the first urine samples	APD (mm)	-0.115	0.367
	PT (mm)	0.310	0.013
The average amount of the blood measured in the second urine samples	APD (mm)	-0.167	0.187
	PT (mm)	0.166	0.190

Correlations between the groups were examined using Pearson's test. APD: Kidney pelvis anteroposterior diameter, PT: Parenchymal thickness

Table 5. Causes of hydronephrosis in U-GPN vs U&F-GPN

Primary Diseases	U-GPN	U&F-GPN	Total
Urolithiasis	13	3	16
Malignity			
Bladder Cancer	9	10	19
Prostat Cancer	4	2	6
Over Cancer	1	0	1
Cervix Cancer	2	8	10
Endometrium Cancer	0	1	1
Lymphoma	0	1	1
Rectum Cancer	0	1	1
Pelvic retroperitoneal mass	1	0	1
Others			
Benign prostat hyperplasia	1	2	3
Retroperitoneal fibrosis	0	1	1
Ureteropelvic junction obstruction	1	2	3
Ureter Injury	0	1	1
Total	32	32	64

U-GPN: Ultrasound guided percutaneous nephrostomy, U&F-GPN: Ultrasound and fluoroscopy guided percutaneous nephrostomy

Table 6. Comparison of benign and malign causes in terms of hematuria detected in U-GPN and U&F-GPN procedures

	Benign causes	Malign causes	p
First Step	47.21±81.66	60.53±106.45	0.6
Second Step	542.50±1143.22	973.93±1503.83	0.23

from the study, even if the PN procedure was successful.

In the first group, both steps of the PN procedure were performed under US guidance alone, and the average amount of blood was slightly higher in the first urine samples. In the second group, the average amount of blood was higher in the second urine samples taken after catheterization performed under both US and fluoroscopy guidance. This result may be related to the smaller average kidney pelvis AP diameters and higher average renal parenchymal thickness values in the second group. However, no statistically significant difference was determined between the two groups in respect of the transient hematuria values.

In overweight patients, poor sonographic visibility and real-time needle, wire and catheter manipulations are difficult due to the large distance between the skin surface and the renal lower pole calyx group (18). In US-only-guided procedures, it is difficult to determine how far the guidewire has advanced in the kidney collecting system or to what depth the dilator has moved over the wire and to observe the final location of the distal end of the catheter. Especially for obese patients or for patients with non-dilated collecting systems, a combination of US and fluoroscopy may be required for imaging (19). In such cases, some studies in literature have recommended that the procedure should be completed with fluoroscopy and/or computed tomography to avoid complications (4).

However, the use of fluoroscopy leads to radiation exposure for the patient and the interventional radiologist and also requires iodinated contrast agents (20). The internationally accepted principle of "as low as reasonably achievable" must not be forgotten for radiation safety in medical imaging. Guidelines provide some suggestions related to radiation safety and protection during PN procedures (8,9). The reference air kerma (cumulative dose) and kerma-area product (KAP) are used to estimate skin dose and to predict X-ray stochastic effects (21). In the current study, the mean duration of fluoroscopy use was 1.26±0.2 minutes, and KAP and cumulative dose amounts of 305.48±73.71 μGym^2 and 16.7±5.06 mGy were measured in 32 PN procedures, respectively. These time and radiation dose values do not exceed the proposed reference values previously described in literature for adults undergoing PN procedures (21). Although fluoroscopy-guided PN is defined as a low-dose procedure, a US-guided PN procedure may be preferred by experienced interventional radiologists in the appropriate cases (22,23). In a recent study, low-dose radiation was shown to increase the proliferation of cells carrying the p53 mutant genes (24). US-only-guided interventions may be considered in cases where the dilatation is significant, the distance between the skin surface and the dilated collecting system is short, and the sonographic visibility is sufficient for safe entry and wire-catheter manipulations. An advantage of this method is that patients are protected against ionizing radiation, which is of particular importance for pregnant and pediatric patients (3,25).

The Limitations of This Study Are As Follows: First, the sample size was relatively small. Second, the US-guided PN interventions were not timed, which eliminated the possibility of comparing PN procedure times between two groups. Third, the body-mass indexes of the patients were different and the distance between the skin surface and the hydronephrotic renal lower pole calyx group was not measured. Therefore, the possible effects of soft tissue thickness on the duration of the procedure and also the probable association of soft tissue thickness with amount of the hematuria could not be evaluated. Last, the concomitant comorbit factors such as diabetes mellitus or hypertension were not known. Nevertheless, the results of this study can be considered meaningful, although further comprehensive studies are required to confirm the findings.

In conclusion, PN is a safe and effective intervention in the management of hydronephrosis that provides drainage of urine out of the body to maintain renal function. There are many different methods in terms of materials used or input techniques for the PN process. US-only-guided PN can be used by experienced interventional radiologists as a safe treatment method for selected cases with hydronephrosis, such as pregnant or pediatric patients where radiation exposure should be avoided.

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