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Impact of Percutaneous Renal Access Technique on Outcomes of Percutaneous Nephrolithotomy

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Abstract

Background and Purpose: Percutaneous nephrolithotomy (PCNL) is regarded as the gold standard for the treatment of patients with renal stones larger than 2 cm in diameter. Creating a percutaneous renal access is the initial and probably the most important step in performing a PCNL. Two primary methods of obtaining proper percutaneous renal access under fluoroscopic guidance are described: The "triangulation" and the "eye of the needle" techniques. In this article, we compare these two techniques in terms of success and complication rates.
Patients and Methods: From October 2010 to May 2011, 80 patients with simple renal stones were prospectively randomized into two groups according to the percutaneous renal access technique used for PCNL. Patients in group 1 (n = 40) were assigned to the eye of the needle technique, and patients in group 2 (n = 40) were assigned to the triangulation method. Patients needing multiple access points were excluded from the study. The preoperative, operative, and postoperative follow-up findings were thereafter analyzed and compared.
Results: No significant difference between the two groups was detected in terms of patient demographics (mean patient age, body mass index, stone size, or stone location). The operation time, fluoroscopic screening time (FST), and duration of hospitalization were similar in both groups ($P = 0.52$, $P = 0.32$, $P = 0.26$, respectively). Patients in group 1 had a larger drop in hematocrit postoperatively than patients in group 2 (7.6 ± 3.7 *vs* 4.8 ± 2.1, $P = 0.001$). The blood transfusion rate (7.5%) was similar in both groups, however. Although the complication rate was higher in group 1 than group 2, no significant difference was detected (20% *vs* 15%, $P = 0.76$).
Conclusions: The present study demonstrates that PCNL can be performed safely using two different percutaneous access techniques. The two techniques studied in this trial had similar FSTs, operation and hospitalization times, success rates, and complication rates.

Introduction

With technologic developments in endoscopic instruments and advancement in endourologic techniques, percutaneous nephrolithotomy (PCNL) is considered the gold standard for the treatment of patients with renal stones larger than 20 mm in diameter. The advantages of this procedure include lower operative times, lower morbidity rates, and the fact that it is minimally invasive.[1–3]

The creation of a percutaneous renal access is the initial and probably the most important step in PCNL, and the adequacy of the access directly influences the success and complication rates of this procedure. Although C-arm fluoroscopy, CT, and ultrasonography (US) can be used as guidance techniques for obtaining access to the intrarenal collecting system, C-arm fluoroscopy is the most commonly used.[4–6] Two primary methods to obtain a proper percutaneous renal access by fluoroscopy guidance are the "triangulation" and the "eye of the needle (or bull's-eye)" techniques.[7–9]

Most published studies of PCNL have focused on evaluating the effect of patient- and stone-related factors such as success rate, extent of bleeding, complication rate, fluoroscopic screening times (FSTs), and operative time on outcomes.[2,10–13] The imaging modalities used for guidance by urologists or radiologists during percutaneous renal access and renal access procedures have also recently been analyzed and compared in terms of outcomes and complications.[14–16] These studies, however, have not considered the effect of percutaneous renal access technique on outcome.

Although the triangulation and the bull's-eye techniques have been evaluated and compared using a biologic model in a published study[17], no clinical study comparing these techniques has been performed. The aim of this study is to evaluate the influence of these access techniques on operative outcomes.

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The initial results of the study were presented at the First European Association of Urology Section of Urolithiasis Meeting, London, 2011.

Patients and Methods

From October 2010 to May 2011, a total of 80 patients who had simple renal stones[18] underwent PCNL by the same surgical team. Patients were randomly assigned to one of two groups according to the percutaneous renal access technique used by the operating urologist to gain renal access (AA, AT): The eye of the needle or bull's eye technique (group 1) or the triangulation technique (group 2). Randomization was performed using computer-generated simple random tables in a 1:1 ratio. Patient and procedure-related factors, perioperative and postoperative variables such as operative time, FST, change in hematocrit, complication rates, success rates, and duration of hospitalization were compared in both groups. The indications for PCNL were large pelvic or caliceal stones that were resistant to shock-wave lithotripsy (SWL). Patients with complex renal stones and patients needing multiple accesses were excluded from the study. Before surgery, each of the 80 patients signed an informed consent form.

Preoperative complete blood cell counts, serum creatinine levels, platelet counts, bleeding and coagulation profiles, and urine cultures were obtained from all patients. Radiologic evaluation included intravenous urography and US, with the addition of noncontrast CT in selected cases. The stone burden was determined by radiographic studies. Hydronephrosis was graded as either nil/mild or moderate/severe using US criteria.

Operative technique

Patients were initially placed in the lithotomy position under general anesthesia, and a 5F ureteral catheter was inserted. Percutaneous access was performed using C-arm fluoroscopy with patients in the prone position, with all pressure points padded. The two access techniques described previously were used for renal puncture.[7–9,19]

Bull's-eye (eye of the needle) technique

The collecting system was opacified with a contrast medium. The fluoroscopy arm was then rotated 30 degrees toward the surgeon along the axis of the posterior row of calices and the relatively avascular Brödel line. The desired posterior calix was identified, and the puncture was performed with an 18-gauge needle. The eye of the needle or bull's-eye appearance was maintained, and the needle was then advanced using a hemostat, with the fluoroscopy arm at 90 degrees in a vertical position. When the tip of the needle reached the desired calix or stone, the obturator was removed. Proper positioning was confirmed by an efflux of urine.

Triangulation technique

The optimal entry to the collecting system was selected with the C-arm in the 30-degree position after distention and opacification of the system by contrast instillation. The orientation of the puncture line was established by vertical and oblique positioning of the C-arm. The 18-gauge needle was advanced toward the calix with the C-arm in the vertical position. The cephalad-caudad movements of the needle were performed with the C-arm in an oblique position to ensure the proper depth of the puncture. Proper positioning was achieved by moving the C-arm in two axes.

The tract was dilated with Amplatz renal dilators up to 30F, and a 30F Amplatz sheath was used under fluoroscopic guidance. Nephroscopy was performed with a rigid 26F nephroscope. Stone fragmentation was accomplished using a pneumatic lithotripter (Vibrolith, Elmed, Turkey). Stone clearance and the integrity of the collecting system were confirmed intraoperatively by fluoroscopic screening, endoscopic visualization, and antegrade nephrostography. In the majority of cases, at the conclusion of the procedure, a 14F nephrostomy tube was placed inside either the renal pelvis or the involved calix. A tubeless procedure was indicated in patients with mild or moderate stone burden, no residual stones, or no perioperative complication, depending on surgeon preference.

Plain radiography of the kidneys, ureters, and bladder was obtained on postoperative day 1. On postoperative day 2, the nephrostomy tube was removed from patients who were rendered stone free and from those with clinically insignificant residual fragments (CIRF). All patients were evaluated with a spiral CT after 3 months postoperatively. Results were classified as stone free, CIRFs, and unsuccessful (residual stones). CIRFs were defined as ≤ 4 mm, nonobstructing, noninfectious, and asymptomatic residual fragments.[18] Complications were classified according to the modified Clavien grading system described by Tefekli and associates.[20]

Statistical analyses

Results are presented as the mean ± standard deviation. Data were processed using SPSS-16 for Windows (SPSS, Inc, Chicago, IL). Continuous variables were compared with the Student *t* test or the Mann-Whitney *U* test, as appropriate. Proportions of categorical variables were analyzed for statistical significance using the chi-square test or Fisher exact test. In all analyses, two-sided hypothesis testing was performed, and probability values less than 0.05 were deemed significant.

Results

During an 8-month period, a total of 80 patients with simple renal stones underwent PCNL. The bull's-eye technique was used for renal access in 40 patients (group 1), and the triangulation technique was used for renal access in another 40 patients (group 2). There were no statistically significant differences between the two groups in terms of average age, stone size, body mass index (BMI), male/female ratio, and grade of hydronephrosis (Table 1). The locations of renal stones among patients in each group are listed in Table 1. No statistically significant differences between the groups with respect to the location of stones were observed.

Percutaneous access was directed at the calix in which the stone was located. In patients with stones in the renal pelvis, the puncture was directed at the posterior lower calix, with the exception of three patients in group 1 and two patients in group 2. In these patients, the pelvis stone was fragmented via dilated midpolar accesses. Although midpolar accesses were more common in group 1 (n = 11) than in group 2 (n = 5), there was no significant difference in terms of access location between the two groups (Table 2).

The operative time and FST were similar in both groups (67.4 ± 22.9 *vs* 64.8 ± 29.7 minutes, $P = 0.52$, 3.9 ± 1.3 *vs* 3.7 ± 1.3 minutes, $p = 0.32$, respectively) (Table 2). Patients in group 1

Table 1. Demographic Values of Patients and Stone-Related Parameters and Statistical Differences of Groups

	Group 1 (eye of needle)	*Group 2 (triangulation)*	P
N	40	40	
Mean age (y)	46.9 ± 13.2	44.1 ± 16.1	0.640
M/F	27/13	31/9	0.452
Mean BMI (kg/m^2)	27.4 ± 5.2	25.4 ± 6.1	0.115
Stone size (mm^2)	571.5 ± 419.1	454 ± 271.8	0.340
Stone location			
Pelvis	16	17	0.820
Upper pole	1	3	0.615
Midpolar	8	3	0.194
Lower pole	15	17	0.819
Degree of hydronephrosis			0.823
Nil or mild	22	21	
Moderate or severe	18	19	

BMI = body mass index.

had a significantly greater postoperative drop in hematocrit than patients in group 2 (7.6 ± 3.7 *vs* 4.8 ± 2.1, $P = 0.001$); however, the blood transfusion rate (7.5%) was similar in both groups. The overall success rates of 90% and 92.5% (including CIRFs in 10% and 10%) were achieved in group 1 and group 2, respectively ($P = 0.69$). The patients with residual stones (four patients in group 1 and three patients in group 2) underwent SWL as an additional treatment modality. While five (12.5%) patients underwent tubeless and stentless PCNL in group 1, from group 2, only three (7.5%) patients underwent tubeless PCNL ($P = 0.709$).

A severe (Clavien grade IV) complication of urosepsis was observed in one group 1 patient with a solitary kidney. Clavien Grade III complications (hemothorax necessitating chest tube and urine leakage needing Double-J placement) were observed in two patients in group 2; however, only one patient from group 1 underwent Double-J placement for urine leakage. The complications observed are listed in detail in Table 2. Although the complication rate was higher in group 1, this difference was not statistically significant. Finally, no significant difference was observed in terms of hospitalization time of the groups ($P = 0.26$). The perioperative and postoperative findings are listed in Table 2.

Discussion

Percutaneous renal access for the drainage of a hydronephrotic kidney was first performed and described in 1955 by Goodwin and associates.[21] PCNL was introduced in 1976; subsequent technologic developments and refinement in endourologic techniques have allowed PCNL to become the management option of choice for large renal stones and/or stones that are resistant to SWL or ureteroscopy.[1,22]

PCNL is an endoluminal procedure that is performed through a gate—the parenchymal access—therefore, obtaining proper access to the renal collecting system plays a key role in the success of the PCNL. The formation of a renal access includes the selection of the proper calix, the initial puncture, tract dilation, and insertion of the access sheath. Failure or inefficiency in one of these steps may lead to unfavorable results or failure of the entire procedure.

The ideal puncture should be in a straight line traversing the shortest distance from the skin to the infundibulum. Transparenchymal posterior puncture of the calix is the preferred route of percutaneous entry into the renal collecting system, because this approach commonly avoids major vascular injuries, allows the greatest maneuverability of the endoscope, and facilitates reaching the calices.[23] Identifying the posterior calix, however, may be difficult in two-dimensional radiographic evaluation. Eisner and colleagues[24] hypothesized that the calix just lateral to the medial calix (the second calix) is statistically the most likely to face posteriorly and to be the most posteriorly positioned calix. This group therefore recommended targeting the second calix for percutaneous lower-pole renal puncture to ensure optimal access to the collecting system. In another study, the authors used air retrograde pyelography during percutaneous renal access to identify the posterior calix.[25] These authors emphasized that using air pyelography allows more rapid identification of the appropriate access site, does not obscure views of the stone, and decreases radiation exposure.

In this study, we used lower, midpolar, and upper pole access in 60, 16, and 4 patients, respectively. There was no statistically significant difference in terms of calices that were targeted between the two groups in this study. In addition to patients with midpolar renal stones, midpolar access was preferred for renal pelvis stones in five patients (three patients in group 1 and two patients in group 2). In these patients, the middle calix was the preferred target because of mild medial rotation of the kidney, proper dilatation of the middle calix, and narrow lower-pole infundibulum We normally prefer to gain access, however, through puncture of the lower posterior calix in patients with pelvic stones.

Although stones in the lower pole of the kidney are more technically challenging because of their greater variations in the three-dimensional anatomy, the incidence of thoracic complications in upper-pole access is higher.[26–28] The triangulation technique is commonly preferred for approaching upper-pole stones because of the medial and superficial localization of the upper pole compared with the lower pole.[29] In this study, upper-pole access was used for three patients in group 2. Among these patients, hemothorax was observed in only one patient. Upper-calix accesses were performed through the intercostal space in group 2, but upper-calix access was performed through the subcostal space in one patient in group 1.

The operator (urologist *vs* radiologist), imaging modality used for guidance (fluoroscopy *vs* US *vs* others), and access type are other important aspects of the initial percutaneous renal access. Compared with fluoroscopy, US appears to be superior in terms of avoiding major intrarenal vascular injury.[30] Recently published studies emphasize that the use of color Doppler US for guidance during PCNL significantly decreases blood loss and rates of transfusion.[31,32]

In Eastern and European countries, urologists establish their own percutaneous renal access, but in the United States, access is often performed by interventional radiologists.[14–16,33] In studies that compared accesses obtained by urologists *vs* those obtained by radiologists, the authors observed a significantly higher stone-free rate among patients whose access was obtained by urologists.[15,33] This difference may be attributed to a lack of familiarity with the steps of the PCNL procedure among radiologists. Although Watterson[33] and coworkers reported

Table 2. Perioperative and Postoperative Results

	Group 1 (eye of needle)	Group 2 (triangulation)	P
Duration of operation (min)	67.4 ± 22.9	64.8 ± 29.7	0.52
FST (min)	3.9 ± 1.1	3.7 ± 1.3	0.32
Targeted calix			
Upper pole	1	3	0.61
Midpolar	11	5	0.16
Lower pole	28	32	0.43
Stone-free status (%)			0.92
• Stone free	32 (80%)	33 (82.5%)	
• CIRF	4 (10%)	4 (10%)	
• Rest	4 (10%)	3 (7.5%)	
Hematocrit drop (%)	7.6 ± 3.7	4.8 ± 2.1	0.001
Nephrostomy tube			0.709
• Tubuless	5 (12.5%)	3 (7.5%)	
• Presence	35 (87.5%)	37 (92.5%)	
Complications (n)	8	6	0.76
Grade I			
• Fever	2	1	
Grade II			
• Blood transfusion	2	2	
• Urine leakage	1	1	
• Urinary tract infection	1		
Grade III			
• Pneumothorax		1	
• Double-J placement for urine leakage	1	1	
Grade IV			
• Urosepsis	1		
Duration of hospitalization (d)	3.5 ± 3.1 (1–20)	2.9 ± 1.8 (1–8)	0.26

FST = fluoroscopic screening time; CIRF = clinically insignificant residual fragments.

increased complication rates in the radiologist-performed access group, Tomaszewski and associates[15] did not detect any significant difference in access-related complications between groups. These studies, however, provided no information about the access technique used.

Multiplanar fluoroscopic imaging is essential to gain a proper renal puncture. In both techniques, mediolateral and cephalad-caudad movements of the needle and depth of the puncture should be adjusted based on different fluoroscopy projections (including the oblique, vertical, and 30-degree positions).[9,19] Maintaining the needle's orientation in different orientations may be very difficult and time consuming. Furthermore, gaining access sometimes necessitates multiple attempts. In our study, no significant difference was detected in terms of FST and operative time ($P = 0.278$ and $P = 0.334$, respectively) in either group. A recent study evaluated and compared two access techniques in an animal model. The authors of this article showed that both techniques had similar learning curves, with higher FST with the triangulation technique.[17] Mues and colleagues[29] described a modification without rotation of the C-arm, thereby diminishing radiation exposure.

Blood loss necessitating transfusion is classified as a grade II complication according to the Clavien system and is a common complication of PCNL.[20] The incidence of bleeding has been reported to vary between 0.8% and 45%.[34–36] Bleeding often occurs as a result of percutaneous renal access, but it may also occur from parenchymal injury in different steps of the procedure, such as tract dilation, stone fragmentation, and stone removal or from lesions of the vascular system arising from arteriovenous fistulae or pseudoaneurysms.[37] Excessive torque on the rigid nephroscope may also lead to renal trauma and bleeding.[9]

In this study, to eliminate the effects of stone type and access number on perioperative and postoperative parameters, patients with complex renal stones and patients needing multiple accesses were excluded from the study. In addition, tract size, nephroscope size, dilation type, and lithotripters used were similar in both groups. Patient-related factors such as diabetes mellitus and hypertension have been found to be independent predictive factors of the bleeding risk. Patients with these conditions, however, were not investigated and excluded from the study.

Stone size was similar in both groups.[10,38,39] The drop in hematocrit was significantly greater in group 1 than group 2 (7.6 ± 3.7 versus 4.8 ± 2.1, $P = 0.001$). This difference may be related to the fact that the triangulation technique creates an access that is in alignment with the infundibulum. Using this technique, the efficient use of rigid instruments is promoted, and excessive torque that may lead to parenchymal trauma and bleeding is decreased.[40] Transfusion rates, however, were not significantly different in the two groups (5% , 5%). The overall success and complication rates were also similar in the two groups.

The success of the renal access, complication rate and duration of operation and hospitalization are parts of a cascade. Gaining access successfully plays a key role in this cascade. Operative time is a perioperative parameter that is influenced by patient-, stone- and procedure-related factors and is an important determinant of perioperative and postoperative complications.[12] The presence of hydronephrosis, stone size, stone type, and operator experience have been found to be the main factors affecting operative times. To make a renal access to the hydronephrotic kidney could be easier. Maintaining the renal access, however, may be more difficult in severe hydronephrotic kidneys. The exploration of scattered stone fragments could prolong the duration of operation.[11] In the present study, no significant difference was found in terms of grade of hydronephrosis between the two groups.

BMI is another patient-related factor affecting the parameters of the procedure. The PCNL procedure in obese patients (BMI >30) is more challenging than in nonobese patients because of the difficult renal access, poor fluoroscopic visualization, and obscure anatomic landmarks.[41–43] In obese patients, access to the desired calix may be limited by the excess subcutaneous as well as peri/pararenal fatty tissue that makes three-dimensional configuration difficult.[11] No obese patients were present in the present study, and the BMIs were similar in both groups.

In this study, patients had similar stone sizes and stone types, and no significant difference was found between the two access type groups in terms of operative time.

Hospitalization time has been found to be affected by the presence of diabetes, large stone burden, intercostal access, multiple accesses, impaired renal function, and nephrostomy tube placement.[44] Although most of these factors were eliminated, the presence of diabetes was not investigated in the present study. The duration of hospitalization was slightly longer in group 1, but this difference was not statistically significant (3.5 ± 3.1 [1–20] *vs* 2.9 ± 1.8 [1–8] days, $P = 0.26$). This difference may originate from one patient in group 1 in whom urosepsis developed and who was hospitalized for medical treatment for 20 days after PCNL. The longest hospital stay was for a group 2 patient with postoperative hemothorax.

Limitations of this study include the fact that the procedures were performed by two experienced surgeons. Moreover, to compare the access techniques, the duration of gaining an access, access attempts, and FST should be recorded separately.

Conclusions

The present study demonstrates that PCNL can be safely performed using two access techniques: The eye of the needle technique and the triangulation technique. Both access techniques were associated with similar operative times, hospitalization times, and success and complication rates. The triangulation technique was associated with less blood loss because of better alignment of the access tract with the infundibulum, thereby decreasing the necessity for exerting excessive torque. While the triangulation technique is performed with multiplanar C-arm imaging, two-planar C-arm imaging is sufficient for the eye of the needle technique. The triangulation technique seems to be the safest technique for approaching upper-pole stones because of the anatomic position of the kidney.

Disclosure Statement

No competing financial interests exist.

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Abbreviations Used

BMI = body mass index
CIRF = clinically insignificant residual fragment
CT = computed tomography
FST = fluoroscopic screening time
PCNL = percutaneous nephrolithotomy
SWL = shockwave lithotripsy
US = ultrasonography