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Safety of Upper Pole Puncture in Percutaneous Nephrolithotomy with the Guidance of Ultrasonography versus Fluoroscopy: A Comparative Study

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Keywords

Upper pole puncture · Ultrasonography-guided puncture · Fluoroscopy-guided puncture · Safety · Percutaneous nephrolithotomy

Abstract

Introduction: The aim of this study was to compare the safety of ultrasonography-guided (UG) puncture and fluoroscopy-guided (FG) upper pole access (UPA) in percutaneous nephrolithotomy (PCNL). ***Methods:*** Consecutive patients with a solitary UPA were enrolled into the study from 2012 to 2020 and analyzed in a retrospective manner. In total, 177 patients were divided into 2 groups according to the method during the puncture phase of the access: FG ($n = 105$) and UG ($n = 72$). The UG and FG groups were compared in terms of complications (i.e., pleural injury and blood transfusion rate) and surgical outcomes. ***Results:*** Gender, side, grade of hydronephrosis, type of access (i.e., supracostal vs. subcostal), Guy's stone score, age, stone diameter, skin-to-stone distance, and stone density were similar in the 2 groups ($p > 0.05$). Only in 25.9% of cases, UPA was done using a subcostal approach. The overall complication rates were similar between the groups ($p > 0.178$). For the UG and FG groups, the rate of pleural injury (8.5 vs. 4.1%) and the blood transfusion rate (8.5 vs. 2.8%) were also similar ($p > 0.05$). The fluoroscopy time and mean hemoglobin drop were significantly lower in the UG group than in the FG group (134.2 vs. 82.2 s, respectively, $p = 0.001$; 20.8 ± 9.8 vs. 16.8 ± 7.9 g/L, respectively, $p = 0.001$). Stone-free rate (SFR) was also similar in the FG and UG groups (77.1 vs. 75.0%, respectively, $p = 0.742$). ***Conclusion:*** While it is commonly expected that the complication rates are lower in UG puncture for UPA in PCNL than they are in FG puncture, the present study failed to show this difference. However, the radiation exposure time seemed to be lower in UG puncture than FG puncture and had a similar stone-free rate (SFR) for UPA in PCNL.

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Introduction

Percutaneous nephrolithotomy (PCNL) is the first-line treatment in patients with large renal stones (>2 cm) and/or a high stone burden [1]. Upper pole access (UPA) is a convenient entry point that can help increase the ease

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of access to the ureteropelvic junction and to the lower calyx [2–4]. Due to the position of the kidneys, UPA has a shorter access length than the other calyces, and no excessive force or torque is needed for the nephroscope maneuvers [4, 5]. Nevertheless, UPA is less preferred by urologists, as reported in the CROES PNCL Global Study (16.7%), due to concerns about pleural injury [6]. Primarily, fluoroscopy, ultrasound, or a combination of the two is used to localize the desired calyx in gaining renal access [7]. Concerning these radiological methods, some have suggested that ultrasonography-guided (UG) access has a lower incidence of adjacent organ injury than does fluoroscopy-guided (FG) access [8].

Until now, no study has compared the safety of gaining UPA using these 2 different radiological modalities. As such, the present study aimed to evaluate and compare the outcomes and complication rates of UG and FG UPA access in PCNL surgery.

Materials and Methods

The study protocol was approved by the local ethics committee (VTRH, July 2019). All steps of the study were planned and applied carefully, according to the Declaration of Helsinki.

Between November 2012 and March 2020, we collected data on consecutive 1,568 patients undergoing PCNL in our department prospectively and we analyzed retrospectively. UG puncture was used for renal access in the majority of patients (n = 946; 60.3%), while FG puncture was used in 622 patients (39.7%). Single upper calyx access was done in 177 (11.2%) patients who had complete data. These patients were divided into 2 groups based on the access to the coupling method of FG puncture (n = 105) and UG puncture (n = 72). All the patients were operated on by the same urological team.

Exclusion criteria included having a skeletal malformation, ectopic and/or malrotated kidney, collecting system anomalies, multiple access, and age younger than 18 years. Stones' complexity was classified with the Guy stone score [9]. Stone characteristics were recorded from the CT scans with the methods that we described in our previous study [10].

Initially, an open-end ureteral catheter (5–6 Fr) was inserted under fluoroscopic control. Then, the patients were transferred to the prone position. Access to the collecting system was achieved either with the aid of fluoroscopy or ultrasound imaging. None of the punctures were done above the 11th rib. If the upper pole which is desired for initial puncture was localized in a higher position, we performed a renal dislocation in some cases to avoid lung and pleural injury.

FG Puncture

Briefly, 1/3 diluted contrast agent was first injected through the ureteric catheter. To avoid pleural injury, kidney positions were determined at the maximum inspiration and expiration. Then the location of the upper posterior calyx was decided as the puncture point at the maximum inspiration. The puncture was done at the maximum expiration with an 18-gauge diamond-tipped needle and the needle was introduced into the body with bull's eye technique at the 30° fluoroscopic imaging. After getting closer to the kidney at the fluoroscopic view, maximum inspiration was done and the needle is introduced more into the upper calyx at the 0° fluoroscopic imaging.

UG Puncture

A convex abdominal ultrasound probe was put on the flank of the patient parallel to the long axis of the kidney so that the 2-dimensional view included all possible calyxes from superior to inferior poles. The calyx which had been selected for access according to preoperative non-contrast CT was identified by ultrasonography. Then an 18-gauge diamond-tipped needle was introduced through the skin to the upper posterior calyx fornix under UG with free-hand technique. Entering the target calyx was confirmed by viewing the needle path on the ultrasonography monitor. In the absence of hydronephrosis, the pelvicalyceal system was distended by the infusion of isotonic through the ureteric catheter.

If irrigation fluid flows freely through the access needle, that was accepted as successful access. We used Amplatz dilatators (Amplatz sheath, Boston Scientific, Natick, MA, USA), a rigid nephroscope (Karl Storz 26 Fr) with pneumatic lithotripter and flexible nephroscopy, as required. At the end of the operation, a re-entry nephrostomy catheter (14–16 Fr) was placed as the nephrostomy tube. An antegrade pyelography was performed to confirm the position of the nephrostomy tube, the status of the collecting system, and to understand the extravasation level. Also, we confirmed the entered calyceal (upper calyx) with antegrade pyelography.

Postoperative Care

Vital signs were monitored every 4 h on the day of operation. Complete blood count and blood biochemistry were checked immediately after the surgery and in the morning of the first postoperative day. Chest X-ray and kidney-ureter-bladder were obtained on the first operative day to evaluate hydro or pneumothorax and residual stones. Any thoracic problem was consulted to the thoracic surgery department, and chest tube placement was done to every patient according to their recommendation as none of the cases were subclinical. The nephrostomy tube was clamped for 8 h after 2 days; if the patient was afebrile, painless, and extravasation was not present, the tube was then removed. When the urine drainage persisted for >24 h, a double-J catheter placement was considered. Blood transfusion was only considered in symptomatic patients with a hemoglobin level of 90 g/L due to the liberal transfusion attitude in which patients received a blood transfusion to maintain hemoglobin level at 100 g/L or higher [11].

A non-contrast CT was done at the end of the 1st postoperative month. The stone-free status was defined as no stone detectable or the presence of fragments <4 mm on non-contrast CT imaging [12]. A stone-free rate (SFR) was reported for the single PCNL intervention. Operative/postoperative complications were classified according to the Clavien-Dindo classification system [13]. Findings and results like fluoroscopy time, operation time, mean hemoglobin drop, SFR, stay in the hospital, complications based on the Clavien-Dindo classification, and demographic findings were compared for each access modality.

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Table 1. Patients and stone characteristic

	FG (*n* = 105)	UG (*n* = 72)	*p* value
Gender, *n* (%)			
Female	34 (32.4)	26 (36.1)	0.606
Male	71 (67.5)	46 (63.9)	
Laterality, *n* (%)			
Right	57 (54.2)	34 (47.2)	0.355
Left	48 (45.7)	38 (52.8)	
Grade of hydronephrosis, *n* (%)			
≤Grade 1	43 (40.9)	22 (30.6)	0.158
≥Grade 1	62 (59.1)	50 (69.4)	
Type of access, *n* (%)			
Supracostal	81 (77.1)	50 (69.4)	0.251
Subcostal	24 (22.8)	22 (30.6)	
Guy's stone score, *n* (%)			
Grade 2	17 (16.1)	19 (26.4)	0.201
Grade 3	53 (50.4)	35 (48.6)	
Grade 4	35 (33.3)	18 (25.0)	
Age, years	48.3 (13.4)	49.2 (12.1)	0.654
Stone diameter (SD), mm	37.8 (11.6)	36.3 (12.4)	0.823
Skin to stone distance (SD), mm	112.6 (15.6)	109.0 (20.8)	0.198
Stone density on CT (SD), HU	1,048 (412)	991 (281)	0.304
Stone localization, *n* (%)			
Upper calyx	23 (21.9)	28 (38.9)	0.049
Multiple	48 (45.7)	26 (36.1)	
Staghorn	34 (32.3)	18 (25.0)	

Pearson χ^2 and Fisher's exact tests were used to compare where appropriate, and $p < 0.05$ was accepted as significant. Descriptive analyses were presented using means and standard deviation. Student's *t* test was used to compare normally distributed parameters. UG, ultrasonography-guided; FG, fluoroscopy-guided; SD, standard deviation.

Statistics

The IBM SPSS version 20.0 (IBM Co., Armonk, NY, USA) was used for statistical analysis. χ^2 test was applied to evaluate categorical data, and the 2-sided *p* value was used in inference, and $p <$ 0.05 was accepted as significant. Descriptive analyses were presented using means and standard deviation. Student's *t* test was used to compare normally distributed parameters.

Results

UPA was done in patients who had staghorn kidney stones (52 [29.3%] patients), who had multiple kidney stones (74 [41.8%] patients), and who had upper calyceal stones (51 [28.8%] patients). As such, supracostal upper calyx access (i.e., between the 11th and 12th rib) was gained in a total of 131 (74.0%) patients (Table 1).

The demographic data of the patients and the stone characteristics were similar in each group (i.e., in the UG and FG puncture groups), as shown in Table 1. Specifically, the gender, laterality, grade of hydronephrosis, type of access (i.e., supracostal vs. subcostal), Guy's stone score, age, stone diameter, skin-to-stone distance, and stone density were similar in the 2 groups ($p > 0.05$).

The mean radiation exposure time was higher in the FG group (134.2 ± 74.6 s) than that of the UG group (82.2 ± 99.1 s; $p = 0.001$). The mean hemoglobin drop was higher in the FG group (20.8 ± 9.8 g/L) than that of the UG group (16.8 ± 7.9 g/L; $p = 0.001$). The mean operation time, mean hospital stay, and SFR (77.1 vs. 75.0%) were also similar in the FG and UG groups ($p = 0.476$, $p = 0.218$, and $p = 0.742$, respectively) (Table 2).

Both groups had similar complication rates, according to the modified Clavien-Dindo classification ($p > 0.178$; Table 2). For the FG and UG groups, respectively, the rate of blood transfusion (8.5 vs. 2.8%, $p = 0.116$), urinary tract infection/fever requiring intravenous antibiotic usage (5.7 vs. 6.9%, $p = 0.739$), extravasation requiring double J insertion (3.8 vs. 2.7%, $p = 0.709$), pleural injury requiring

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Table 2. Surgical outcomes and complications

		FG (n = 105)	UG (n = 72)	p value
Fluoroscopy time (SD), s		134.2 (74.6)	82.2 (99.1)	0.001
Mean hemoglobin drop (SD), g/L		20.8 (9.8)	16.8 (7.9)	0.001
Operation time (SD), min		87.7 (23.3)	83.1 (25.8)	0.476
Stay in hospital, days		3.9 (2.2)	3.6 (1.2)	0.218
SFR, n (%)		81 (77.1)	54 (75.0)	0.742
Clavien-Dindo classification of complications, n (%)				
1	Urine leakage without intervention	3 (2.8)	2 (2.7)	0.975
2	Bleeding requiring a blood transfusion	9 (8.5)	2 (2.8)	0.116
	Fever required i.v. antibiotic usage	6 (5.7)	5 (6.9)	0.739
3a	Double J stent placement	4 (3.8)	2 (2.7)	0.709
	Chest tube insertion	9 (8.5)	3 (4.1)	0.252
3b	Endoscopic treatment for ureteral stone	2 (1.9)	2 (2.7)	0.701
	Total complication	33 (31.4)	16 (22.2)	0.178

SFR, stone-free rate; UG, ultrasonography-guided; FG, fluoroscopy-guided; SD, standard deviation.

chest tube insertion (8.5 vs. 4.1%, p = 0.252), and endoscopic treatment for steinstrasse (1.9 vs. 2.7%, p = 701) were likewise similar between the 2 groups.

Discussion

UPA has been shown to be an effective and safe access method, with high SFRs and acceptable complication rates for removing complex kidney stones [14]. Despite this, most urologists do not prefer UPA because of the pleural complications that can occur [6, 15, 16]. In a prospective study, CROES investigated the use of UG and FG percutaneous access and found that most surgeons prefer FG puncture (86.3%) [6]. The same study also reported UPA to be significantly less utilized (8.9%) compared to the other access methods [17]; however, several studies have identified the UPA to be the best access method, with 80–90% SFRs [4, 5]. In the CROES study, subcostal access was obtained in only 31.8% of patients, and Patel et al. [18, 19] reported a subcostal access rate of 29.9%. In the current study, UPA was performed in 177 patients (11.2%) with upper calyceal stones, staghorn stones, and multiple kidney stones; in 26.0% of cases, UPA was done using a subcostal approach. While subcostal access is preferable, most often, the kidney lies in a higher position, and in such patients, access only can be provided through a supracostal puncture. The supracostal approach, however, bears some risk of pleural complications.

The major advantage of UG puncture that it is easier to identify the adjacent organs (i.e., the lung, bowel, and pleura). Therefore, it has been thought that UG puncture may reduce the rate of pleural injury when compared to FG puncture; however, no comparative study has yet been conducted in the literature of this field. For FG access, the reported overall pleural injury rates have been up to 10% [5, 20, 21]. Soares et al. [14] reported that 16% of patients required chest tube insertion after supracostal access by FG puncture. In a large retrospective study, Li et al. [22] stated that 15 (3.1%) patients had pleural injury after PCNL, although UPA was only gained through UG puncture in 482 (6%) of the patients.

In the current study, the chest tube placement rate was higher in the FG group (8.5%) than it was in the UG group (4.1%). However, this difference was not statistically significant. In our clinical practice, at the beginning of surgery, we evaluate the kidney using ultrasound to identify the calyceal anatomy, stone localization, and adjacent organs. If we identify the pleura or suspect pleural injury could occur, we prefer to gain lower or middle-pole access to avoid pleural injury. In this way, UG may decrease the rate of pleural injury simply by decreasing the use of UPA. As a result, UPA was used more commonly in the FG group than it was in the UG group in the present study.

Another important point is that the position of the pleura is reflected in the level of the 10th costa at the mid-axillary line and the level of the mid-scapular line, as it is partially inserted into the 12th costal margin [23]. When

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gaining access, we attempted to enter as laterally as possible because the pleura is located more inferiorly at the mid-scapular line. In a recent study, PCNL was performed using an individual 3-dimensionally printed surgical guide that can decrease the initial access time and decrease the complication rate [24]. After a deep inhalation, we determined the location of the desired calyx. After a deep exhalation, the needle was inserted until Gerato's fascia, and during the next deep inhalation, the kidney was located, and the first-determined area was used as the point of access. Finally, we entered the upper calyx. We believe that this method reduces the rate of pleural injury.

Another common complication in PCNL is hemorrhage. Blood transfusion rates have been reported to vary between 0.8 and 24%, according to the technique used, the stone burden, the collecting system anatomy, the access tract, the access number, and the surgeon's experience [1]. Concerning the transfusion rate, UPA is safe as lower pole access [16]. The safest way to gain access is through the parenchyma, into the fornix of the desired calyx; gaining access at any other site can increase the risk of injuries to the interlobar and segmental branches, resulting in hemorrhage [25]. Accordingly, using UG puncture, rather than FG puncture, may help decrease the vascular injury and transfusion rates [17]. However, there are conflicting results in the literature. The CROES study reported hemorrhage (13.8 vs. 6%) and blood transfusions (11.1 vs. 3.8%) to be significantly higher in the FG group than in the UG group. However, separate analyses of the CROES study database reported an increase in bleeding and transfusion rates to be associated with a larger sheath size, longer operating times, and balloon dilation (compared with telescopic/serial dilation) [17]. Our results also showed an insignificant difference between the groups.

The overall complication rate has been seen to vary between 18.5 and 21.7% for PCNL, and it is more common in UPA [18]. According to the modified Clavien-Dindo classification, our overall and major complication rates were comparable with those reported in the current literature. Furthermore, according to the CROES study, the overall and major complication rates for UG access were 18.5 and 3.3%, respectively, and for FG access were 21.7 and 5.1%, respectively [18]. Our rates were relatively higher than this, which can be explained by the higher rates of UPA and higher stone complexity observed in our study.

Various steps, such as dilatation, checking the stone-free status, and introducing nephrostomy, require fluoroscopy imaging. It was expected that the UG group would have a lower radiation exposure time; in accordance with our findings, in other studies, the radiation exposure time has been reported to be quite limited in UG access, which is a major advantage for both healthcare providers and patients [17, 26]. Gaining UPA with UG can be challenging in patients with minimal hydronephrosis, but saline injection from the ureteral catheter can resolve this problem [27].

To our knowledge, this is the first study comparing the impact of imaging modalities during UPA. This is an interesting study, despite the 2 imaging modalities seeming to have similar surgical outcomes. We found that UG UPA provides an opportunity to decide whether UPA is safe or not; then, if UPA seems to be safe, the results are comparable for FG and UG UPA. Although the complication rates of the 2 modalities were statistically similar, UG access seemed to be slightly better than FG in this regard.

The present study did have certain limitations, such as reporting the retrospective data of a relatively small patient group. For example, the minor complication rate observed in the present study was lower than that given in previous studies, which is likely due to the study's retrospective design. Second, we could not provide information about the kidney dislocation that we performed in some cases for upper calyceal access. In addition, the stone burden was described in terms of a single dimension (i.e., stone diameter in millimeters); it would have been more informative to indicate more than one stone dimension for complex stones (e.g., the stone volume), but volume calculations require specific software that we did not have.

Conclusion

The present study revealed similar efficacy and safety profiles for FG and UG puncture in solitary UPA in prone PCNL. However, UG puncture seemed to be more promising than FG puncture because of resulting in less radiation exposure. Future prospective randomized studies may provide a better understanding of the true impact of UG puncture in PCNL.

Statement of Ethics

The study protocol was approved by the local ethics committee (VTRH, July 2019). All steps of the study were planned and applied carefully, according to the Declaration of Helsinki. All pro-

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cedures performed in the study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Conflict of Interest Statement

The authors declare that they do not have any conflicts of interest to disclose.

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The authors did not receive any financial support.

Author Contributions

A.S.: project development, data collection, data analysis, and manuscript writing; A.C.: data analysis and editing; O.O.: data analysis and editing; K.E.: data analysis; C.C.: data collection; B.E.: data collection and editing; T.T.: data analysis and editing; and Y.T.: manuscript writing and editing and supervision.

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