Image-Guided Access for Percutaneous Nephrolithotomy: A Single-Center Experience in 591 Patients

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Abstract

Introduction: We present our experience in image-guided percutaneous nephrolithotomy (PCNL) access in 591 patients. Materials and Methods: An IRB-approved review of all adult PCNL cases from 2009 to 2014 was performed. Patient data, information regarding stone size and location, procedural details, clinical success, complications by access site (upper pole versus middle or lower pole) and puncture location (supracostal versus infracostal) were recorded. Results: In this study, 591 patients (314 males, 278 females, mean stone size: 23 mm, range: 4–100 mm) were included. Stone clearance was achieved in 66% of patients. There were 174 total complications (29.3%). Upper pole access was less likely to require a secondary access to achieve stone clearance (p = 0.02) and was preferentially used for both larger stones (p = 0.006) and staghorn calculi (p = 0.001). If a supracostal approach to the upper pole was used, there were significantly more complications compared to an infracostal approach (p = 0.002). Conclusion: Upper pole access for PCNL provides anatomic advantages for stone clearance but significantly increases the risk for complications when a supracostal puncture is required.

Introduction

Nephrolithiasis affects nearly 10% of the US population during their lifetime with increasing prevalence over the past quarter century [1, 2]. Several treatment options are available, with percutaneous nephrolithotomy (PCNL) serving as the mainstay for staghorn and large renal stones [3–8]. PCNL can be performed through access into the upper, middle, or lower pole of the kidney. Upper pole access provides known anatomic advantages for treatment, as there is a direct course into the renal pelvis and proximal ureter [9]. However, upper pole access may require a supracostal approach to the collecting system which potentially carries greater procedural risk by crossing the pleura [10–15]. There is considerable variation in reported success and complication rates among previous PCNL studies, largely due to differences in definitions of complications and patient follow-up [9–25].
Herein, we present our experience in image-guided access for PCNL in 591 patients comparing with stone-free rate (SFR), clinical success, and complications by access site (i.e. upper versus middle or lower pole) and puncture location (i.e. supracostal versus infracostal).

**Materials and Methods**

This retrospective study was approved by an institutional review board and was Health Insurance Portability and Accountability Act compliant. Requirements for informed consent were waived. All adult patients who underwent image-guided access for PCNL during 2009–2014 were included for review. Data regarding age, sex, body mass index (BMI), and laboratory values was collected. The type of stone was recorded and categorized as a single stone, multiple stones, or staghorn calculi. Staghorn calculi were defined as single stones that involved multiple calyces. Stone size and location were also noted with location being categorized as either upper pole calyx, middle or lower pole calyx, or staghorn calci if it encompassed multiple calyces. The need for additional percutaneous access sites during a single procedure or the requirement of subsequent procedures within 6 months was analyzed. When pre-procedural imaging wasn’t available, urology notes and procedural dictations were used for data collection. SFR was defined as the percentage of patients who had no residual stones on post-procedural imaging.

Image-guided access for PCNL at our institution is performed by an interventional radiologist in the operating room prior to PCNL by the urologist in the same setting. The decision regarding the access site (i.e. upper versus middle or lower pole) was determined in conjunction by the interventional radiologist and urologist based on the patient’s stone burden and location. The puncture site (i.e. supracostal versus infracostal) was then selected based upon the patient’s anatomy and ability to achieve the needed percutaneous access. Fifteen interventional radiologists with 3–28 years of experience performed the imaged-guided accesses. To begin the procedure, the urologist obtains retrograde access to the ureter and injects a small amount of air and contrast in order to identify the renal collecting system under fluoroscopy. After identifying an appropriate calyx, an approximately 2 cm incision is made and the soft tissue is dissected. An 18G needle is then guided into the appropriate calyx under fluoroscopic guidance. Positioning within the collecting system is confirmed with a small injection of contrast. Subsequently, a wire is passed through the renal pelvis and into the ureter. The tract is then dilated to accommodate a 30F sheath. At this point, the urologist performs an initial review of the collecting system with the scope to confirm that appropriate access has been obtained or if additional access sites are needed. After appropriate access, the urologist then performs stone extraction. At the completion of the procedure, either a double J ureteral stent or nephrostomy tube or a combination thereof is left behind by the urologist. A post-procedural chest radiograph is routinely obtained to assess for pneumothorax or effusion. Follow-up imaging – either a computed tomography (CT) or abdominal radiograph (for kidneys, ureters, and bladder) – was typically performed.

### Table 1. Demographics and clinical information

| Gender       | Overall (n = 591) | Supracostal (n = 375) | Infracostal (n = 216) | p  |
|--------------|-------------------|-----------------------|-----------------------|----|
| Male         | 313               | 199                   | 114                   | 1.0000 |
| Female       | 278               | 176                   | 102                   |   |
| Age, year    | 53 (14–92)        | 53 (14–92)            | 54 (15–90)            | 0.48 |
| Stone size, mm | 23.0 (4–100)     | 23.6 (4–90)           | 22.1 (5–100)          | 0.2  |
| Mean BMI     | 32.3              | 33.7                  | 30.0                  | 0.03* |
| Creatinine   |                   |                       |                       | 0.69 |
| ≤ 1.2        | 435               | 278                   | 157                   |   |
| > 1.2        | 156               | 97                    | 59                    |   |
| Platelet count |                 |                       |                       | 0.42 |
| ≤ 150 × 10^3 | 525               | 330                   | 195                   |   |
| > 150 × 10^3 | 66                | 45                    | 21                    |   |
| INR          |                   |                       |                       | 0.06 |
| ≤ 1.5        | 343               | 229                   | 114                   |   |
| > 1.5        | 248               | 146                   | 102                   |   |

INR = International normalized ratio. Statistically significant values are labelled *.

### Table 2. Distribution of cases by access and puncture site

|                      | Total (n = 591) | Supracostal (n = 375) | Infracostal (n = 216) |
|----------------------|----------------|-----------------------|-----------------------|
| Upper pole           | 424 (71.7%)    | 317 (53.6%)           | 107 (18.1%)           |
| Middle/lower pole    | 167 (28.2%)    | 58 (9.8%)             | 109 (18.4%)           |

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obtained to assess for residual stones on post-procedural day 1. If the patient had a nephrostomy tube placed at the time of PCNL, a nephrostogram was usually performed on post-procedure day 1 to assess for obstruction or ureteral injury.

Complications were recorded according to the Clavien score classification system. Clavien scores of 1 or 2 were categorized as minor, whereas Clavien scores 3, 4, and 5 were classified as major complications. Complication rates between supracostal and infracostal groups for coagulopathic patients based on international normalized ratio and platelet count were compared. Statistical analysis was performed using Fisher’s exact test and Student’s t tests for categorical and continuous data, respectively, with p < 0.05 considered significant.

Results

Total 591 PCNL cases were included for analysis. Patient demographic information, clinical information, and stone size arranged with respect to puncture site may be found in table 1. Patients who received supracostal puncture had a higher mean BMI (p = 0.034). Otherwise, there were no significant differences between supra- and infracostal groups. Treated stones included staghorn calculi (29.6%), multiple stones (41.7%), and single stones (27.1%). Mean stone size was 23.0 mm (range 4.0–100 mm). The distribution of PCNL access and puncture sites are in table 2. Supracostal approach was more likely to be utilized for cases requiring upper pole access (p = 0.0001). Overall, the SFR was 66% (n = 390) after either a single session of PCNL or a planned staged PCNL procedure. There were 63.1% of patients who were not stone-free required re-intervention within 6 months of their initial PCNL, while only 4.9% of stone-free patients required re-intervention within the same time span (p < 0.001).

There were 174 total complications (29.4%), including 49 major complications (8.3%) and 125 minor complications (21.1%). Pleural effusions requiring treatment (5.4%), post-procedural venous thromboembolism (2.7%), and renal pseudoaneurysm requiring treatment (1.6%) were the most common major complications. A pleural effusion not requiring treatment (16.7%) was the most common minor complication. Follow-up imaging was performed with CT (73.4%), abdominal radiograph (for kidneys, ureters, and bladder) (12.5%), nephrostogram (5.9%), or ultrasound (1%). Only 7.1% of patients had no imaging follow-up documented.

Results according to clinical indicators of coagulopathy are shown in table 3. There were no significant differences in major, minor, or total complications based on international normalized ratio or platelet count. There were significantly more minor complications (p = 0.0007) and total complications (p = 0.0001) in non-obese patients when compared with obese patients.

Results according to access site

SFR and complication rate by access site are shown in table 4. Stone type, size, additional access and procedure rates by access site are shown in table 4, in which 71.7%
of cases required upper pole access. The SFR was 65.6% in patients where the upper pole was accessed, which was not significantly different from that of the middle/lower pole group (66.4%) \((p = 0.89)\). There were significantly more staghorn calculi in the upper pole access group compared to middle or lower pole access group (29.2 vs. 16.2%; \(p = 0.001\)). Furthermore, mean stone size (24.1 mm) was significantly larger in the upper pole access group (\(p = 0.006\)). When the upper pole was originally accessed, however, fewer patients required an additional access site (13.7%) in order to achieve stone clearance (\(p = 0.02\)). Yet, major complications were higher (10.1%) for upper pole access (\(p = 0.008\)). No difference in minor complications was observed between the groups (\(p = 0.43\)).

### Results According to Puncture Site

The 11th intercostal space was utilized in 90.7% of supracostal cases and the 10th intercostal space was used in the remainder. Total 29.5% of supracostal cases were performed for staghorn calculi, compared to 18.5% in the infracostal group (\(p = 0.003\)). No differences in the number of access sites required to achieve stone clearance (\(p = 0.75\)) or in the need for repeat interventions (\(p = 0.30\)) was observed between the 2 groups. SFR and complication rates arranged by puncture site are shown in Table 5. There was no difference in SFR between the groups (\(p = 0.59\)). There were significantly more major complications in the supracostal group (supracostal 10.9%, infracostal 3.7%, \(p = 0.002\)). Supracostal punctures also resulted in more total complications (\(p = 0.005\)). There was no significant difference in minor complications between groups (\(p = 0.27\)). For supracostal punctures, the most common complication was hemothorax or hydrothorax requiring chest tube placement (2.9%). The most common minor complication for a supracostal puncture was pleural effusion not requiring treatment (16.8%). In the infracostal puncture group, the most common major complication was renal pseudoaneurysm requiring embolization (1.9%) and the most common minor complication was pleural effusion not requiring treatment (12.5%).

A sub-analysis was performed for the cases where upper pole access was obtained. In this analysis, no significant difference in SFR between a supracostal (67.6%) and an infracostal approach (64.2%) to the upper pole was seen (\(p = 0.52\)). A supracostal approach to the upper pole was associated with a higher rate of both overall (supracostal 34.1%; infracostal 18.7%; \(p = 0.002\)) and major complications (supracostal 12%, infracostal 4.7%, \(p = 0.04\)). No significant difference in the requirement for additional access (supracostal 7.3%, infracostal 10.3%, \(p = 0.31\)) or need for additional treatments (supracostal 24.3%, infracostal 20.6%, \(p = 0.51\)) to achieve stone clearance was observed.

### Results for Patients with and without CT Follow-Up

Total 434 patients (73.4%) had CT imaging as follow-up after PCNL to assess for any residual stones. Of this group, 264 (60.8%) were stone-free on follow-up CT. This was significantly less than the SFR observed for patients without CT follow-up (80.3%, \(p < 0.001\)). When comparing patients with CT follow-up only, no differences were observed in SFR by either access site (\(p = 0.91\)) or puncture location (\(p = 0.08\)). When comparing patients without CT follow-up, no differences were observed in SFR by either access site (\(p = 0.34\)) or puncture location (\(p = 0.25\)).

### Discussion

PCNL was able to achieve stone clearance in 66% of patients but SFR was not influenced by either puncture or access site. Major, minor, and overall complication rates were 8.3, 21.1, and 29.3%, respectively. Supracostal puncture was associated with a higher major and total complication rate. Larger, more complex stones were more likely to be approached with a supracostal puncture and with upper pole access. Although upper pole access cases were associated with a higher rate of major complications, the subset of upper pole access cases performed via an infracostal puncture had significantly fewer major and total complications when compared to those utilizing supracostal puncture. Therefore, the high major complication rate associated with upper pole access is a result of higher utilization of a supracostal puncture when at-

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Table 5. Stone-free rate, complication rate, percentage of staghorn calculi, mean stone size, need for additional access during the procedure, and need for an additional procedure within 6 months according to PCNL access site

| Puncture site | Supracostal | Infracostal | \(p\)-value |
|---------------|-------------|-------------|-------------|
| SFR           | 65.3%       | 66.3%       | 0.59        |
| Minor complications | 22.3%       | 18.5%       | 0.27        |
| Major complications | 10.9%       | 3.7%        | 0.002       |
| Total complications | 33.2%       | 22.2%       | 0.005       |

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tempting to access the upper pole. Supracostal puncture was associated with pleural effusions or hemothoraces requiring treatment.

This study represents one of the largest-scale comparisons of clinical success and complication rates by puncture site and access site, with a high rate of CT follow-up (73.4%). Our results are generally consistent with those of prior studies, which have reported success rates ranging from 74.4–98.3% and complication rates of 1.5–50.3%, with higher complication rates in cases utilizing supracostal puncture [9–25]. The high rate of CT follow-up in this cohort in combination with the modality’s sensitivity for the detection of any residual stones is likely to be the reason for the observed 66% SFR, which is slightly lower than that seen in prior work. Since these prior studies have relied primarily on less-sensitive radiographs for the detection of residual stones and complications, the results presented here are likely a more accurate representation of both stone-free and complication rates. This study also adds important information regarding renal calyx access site to the existing literature. For instance, the data revealed that upper pole access cases required fewer additional access attempts and repeat interventions, particularly for staghorn calculi, which is consistent with the American Urological Association recommendation that staghorn calculi be approached via upper pole access to minimize the need for additional puncture or subsequent procedures [4]. The high incidence of repeat treatments in patients with residual stones suggests that post-PCNL cross-sectional imaging may be useful to guide patient and clinician decision making in assessing the need for further intervention. Furthermore, our findings suggest that when upper pole access is required, clinicians should pursue an infracostal approach to minimize complications. In this cohort, non-obese patients experienced a higher rate of complications than obese patients even though the latter group had a higher incidence of both staghorn calculi and supracostal punctures. The clinical significance of this finding is unclear.

There are limitations to this study. First, selection bias is introduced by inclusion of multiple interventionalists and urologists in the study, with some likely preferring certain approaches. Second, the number of cases performed in certain subgroups was small, and consequently, some results did not reach statistical significance. Third, all procedures were performed at a single institution. Fourth, our institution did not routinely perform CT urography or dual-energy CT during the time period from which the data was collected. This limited our ability to assess metrics like stone volume, stone composition, and modern scoring systems, which is a drawback in the interpretation of the data. Fifth, the study was retrospective in nature which meant that important data points regarding stone size and post-procedural imaging follow-up were not available for all patients. In these instances, we relied on dictations and notes in the medical record but objective data for all patients would strengthen this report. Finally, all the procedures at our institution were performed via a 30F sheath; thus, the results may not be entirely applicable to practices that use a smaller sheath size and miniaturized instruments.

In conclusion, this study contributes important findings to the PCNL literature. For example, supracostal puncture and upper pole access are both used more frequently in complicated stone disease in PCNL cases, but have a similar SFR when compared to infracostal or middle/lower pole access. There is, however, a significant increase in major complications in both supracostal and upper pole access PCNL cases, except in the subset of upper pole access via infracostal puncture. This suggests that infracostal puncture should be sought when possible, even with upper pole access, to minimize major complications. This study adds additional patients to the existing literature regarding PCNL, but a prospective, randomly-controlled trial is still needed.
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