Upper Pole Access for Prone Percutaneous Nephrolithotomy: Advantage or Risk?

Ricardo M.O. Soares, Alec Zhu, Vidit M. Talati, and Robert B. Nadler

OBJECTIVE To analyze the outcomes of upper pole access during percutaneous nephrolithotomy (PCNL), an option pole often avoided due to the concern for pleural injury.

METHODS We retrospectively collected data on patients undergoing PCNL at our institution. Patients were divided into 3 groups according to access: supracostal upper calyx (group 1), subcostal upper calyx (group 2), and nonupper calyx (group 3). Preoperative imaging was reviewed to assess stone burden, Hounsfield units (HU), location, and Guy's Stone Score. Patients were considered stone-free if residual fragments were 3 mm or smaller on CT scan.

RESULTS We analyzed 329 PCNLs (left: 174; right: 155). Stones had a median size of 32 mm, 800 HU, and Guy's Stone Score of 2. Groups 1, 2, and 3 had 119, 108, and 102 patients, respectively. The 90-day complication rate was 20.4% (7.9% Clavien 3-4). Group 1 patients, with higher BMI and larger stones, had higher SFR than group 3 (89.9% vs 79.4%, $P = .038$), but with a significantly higher risk of complications ($P = .001$). Within group 1, left PCNL (7.0% vs 24.2%, $P = .016$) and BMI ≥30 (6.9% vs 25.0%, $P = .013$) carried a lower risk of chest tube insertion. There was no difference in complications between groups 2 and 3 (1.9% vs 2.9%).

CONCLUSION Upper pole access is safe and effective, particularly if done below the ribs. Supracostal access is an effective option to achieve higher stone-free rates in complex stones, while carrying a risk of significant hydrothorax, particularly on the right side and in nonobese patients. UROLOGY 134: 66–71, 2019. © 2019 Elsevier Inc.

Location of percutaneous nephrolithotomy (PCNL) access is based on patient anatomy and stone location. Upper pole access is often avoided due to the concern for pleural injury. We believe that access through the upper pole is a useful tool that facilitates the surgery by providing direct and stable access to the renal pelvis, ureter, and lower calyx. The goal of this study is to analyze risks and benefits of this access.

METHODS

After obtaining IRB approval, we retrospectively collected data from Northwestern Medicine Enterprise Data Warehouse on patients who underwent PCNL for kidney stones at our institution between 2005 and 2017. We only considered patients operated by a single surgeon (RBN) to reduce confounding factors. Bilateral PCNLs were separated into 2 cases. Transplant and pelvic kidney cases were excluded.

Operative reports were reviewed to check for intraoperative details. Preoperative noncontrast CT scans were reviewed to assess stone burden (sum of maximum diameter of all stones on axial and coronal images), Hounsfield units (HU), location and Guy's Stone Score (GSS).[1] Postoperative CT scans done within 24 hours of PCNL were reviewed to confirm site of access, residual stone burden and possible complications. Patients were considered stone-free if residual fragments were 3 mm or smaller on CT scan after the last procedure. Complications were further assessed through Enterprise Data Warehouse data and chart review, and reported according to Clavien-Dindo (CD) grading.[2]

Patients were in prone position for initial cystoscopy for insertion of occlusion catheter into the renal pelvis. Access was done under fluoroscopic guidance with "bull's eye" technique. If the chosen calyx for access was positioned above the ribs, deep inspiration was done to attempt subcostal puncture. If not possible, supracostal puncture was done with a normal ventilation pattern. Some patients had access done by interventional radiology (IR) due to urgent management of obstruction or difficult anatomy; the lower calyx was the preferred site of access in most of these cases.

Patients were divided into 3 groups according to the type of access: supracostal upper calyx (group 1-above 12th rib), subcostal upper calyx (group 2-below 12th rib) and nonupper calyx (group 3). Patients whose stone burden required multiple accesses were added to the lowest group number applicable; for example, a patient with both lower calyx and supracostal upper calyx accesses was added to group 1.

From the Department of Urology, Northwestern Medicine Regional Medical Group, Winfield, IL; the Department of Urology, Northwestern University - Feinberg School of Medicine, Chicago, IL; the Department of Urology, New York Presbyterian – Weill Cornell Medical Center, New York, NY; and the Northwestern University - Feinberg School of Medicine, Chicago, IL

Address correspondence to: *Ricardo MO Soares, M.D., F.E.B.U., 21 N Fremont St, Naperville, IL 60540. E-mail: soares.uro@gmail.com*

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Table 1. Demographic data (one-way ANOVA test with post-hoc analysis between groups)

	TOTAL		Group 1		Group 2		Group 3				
	n	%	*n*	%	*n*	%	*n*	%	1 vs 2	1 vs 3	2 vs 3
n	329	100	119	36.2	108	32.8	102	31.0			
	median	IQR	median	IQR	median	IQR	median	IQR	***P***	***P***	***P***
BMI	28.9	24.5-35.1	30.5	26.6-40.0	26.8	23.6-32.6	28.9	25.2-33.8	**.010**	.087	.545
Size	29	20-40	34	22-50	30	22-45	20	15-32	.549	**<.001**	**<.001**
GSS	2	2-3	3	2-4	2	2-3	2	2-3	.437	.052	.500
HU	800	600-1100	800	600-1100	800	600-1100	700	500-1000	1.000	.481	.508
	n	%	*n*	%	*n*	%	*n*	%	***P***	***P***	***P***
Gender											
Female	185	56.2	63	52.9	69	63.9	53	52.0	.217	.989	.188
Male	144	43.8	56	47.1	39	36.1	49	48.0			
Side											
Right	155	47.1	62	52.1	48	44.4	45	44.1	.484	.465	.999
Left	174	52.9	57	47.9	60	55.6	57	55.9			
Part of bilateral PCNL	66	20.1	24	20.2	18	16.7	24	23.5	.958	.536	.767
Access											
Urologist	286	86.9	112	94.1	103	95.4	71	69.6	.953	**<.001**	**<.001**
IR	43	13.1	7	5.9	5	4.6	31	30.4			
Number of accesses											
1	284	86.3	96	80.7	92	85.2	96	94.1	.856	**.004**	.067
≥2	45	13.7	23	19.3	16	14.8	6	5.9			

Bold values denotes statistical significance.

All the patients had a Councill catheter inserted as a nephrostomy at the end of the PCNL. This was removed upon review of the postoperative CT scan and decision not go for a second-look PCNL.

A one-way ANOVA test with post-hoc analysis was used to compare demographic variables and outcomes between groups. Multivariate logistic regression was performed to assess the effect of access type (groups 1, 2, and 3), BMI, primary IR access, stone size, laterality, GSS, and number of accesses on outcomes including any complication, CD grade 3-4 complications, and chest tube within 90 days, need for second look, being stone-free, and requirement for another procedure within 1 year. A forward entry model was used for all logistic regression analysis. Statistical significance was considered at 0.05. Statistical analysis was performed using SPSS Statistics for Windows version 23.0 software (IBM, Armonk, NY).

RESULTS

We analyzed 329 PCNLs, 174 on the left and 155 on the right, including 33 patients with bilateral PCNL. Stones had a median size of 32 mm, 800 HU, and a GSS of 2. Group 1 had 119 patients (36.2%), group 2 had 108 patients (32.8%), and group 3 had 102 patients (31.0%). Group 1 patients had higher BMI than group 2; group 3 patients had smaller stones (P <.001) than the other 2 groups (Table 1).

Primary access was obtained by Interventional Radiology in 13.1% of patients, with this being more frequent in group 3 (30.4%, Table 1). Among the 12 patients in Groups 1 and 2 with IR access, 5 (41.7%) required multiple accesses. There was a single complication (CD grade 1 hydrothorax) among the 7 patients in group 1 with IR access.

Multiple accesses were required in 45 patients (13.7%). Group 3 had more cases done through a single access (94.1%) (Table 1). A second look was done in 45.3% of patients, with no differences between groups (Table 2).

Global stone-free rate (SFR) was 84.8% with 9.1% of patients requiring subsequent ureteroscopy or JJ stent insertion within a year of PCNL. Comparing all groups, group 1 (89.9%) had significantly higher SFR than group 3 (79.4%) on multivariate analysis (OR 2.7, 95%CI 1.06-6.90; P = .038) (Tables 2 and 3). Given that these 2 groups had a significant

Table 2. Outcomes (one-way ANOVA test with post-hoc analysis between groups)

All Patients	Total (*n* =3 29)		Group 1 (*n* = 119)		Group 2 (*n* = 108)		Group 3 (*n* = 102)		1 vs 2	1 vs 3	2 vs 3
	n	%	*n*	%	*n*	%	*n*	%	*P*	*P*	*P*
Need for second look	149	45.3	56	47.1	49	45.4	44	43.1	.446	.56	.166
Complications Total (90 d)	67	20.4	41	34.5	16	14.8	10	9.8	**.001**	**.002**	.572
Complications Grade 3-4	26	7.9	21	17.6	2	1.9	3	2.9	**.001**	**.014**	.086
Chest tube	21	6.4	19	16.0	1	0.9	1	1.0	**.003**	**.016**	.868
Stone-free	279	84.8	107	89.9	91	84.3	81	79.4	.068	**.038**	.976
Procedures (1 y)	30	9.1	8	6.7	9	8.3	13	12.7	.78	.336	.379

Bold values denotes statistical significance.

Table 3. Outcome analysis (multivariate logistic regression)

	Stone-Free Rate			Complications Total (90 d)			Grade ≥3 Complications (90 d)			Chest Tube (90 d)			Procedures (1 y)		
	P	OR	95% CI	*P*	OR	95% CI	*P*	OR	95% CI	*P*	OR	95% CI	*P*	OR	95% CI
BMI	.394	0.987	0.957-1.018	**.03**	**0.963**	**0.930-0.996**	**.01**	**0.912**	**0.849-0.978**	.119	**0.953**	**0.897-1.012**	.105	0.957	0.907-1.009
Stone size	.199	0.986	0.966-1.007	.423	0.991	0.969-1.0113	.973	1.001	0.966-1.036	.789	1.005	0.967-1.045	.24	0.98	0.948-1.013
Number of access	.702	1.153	0.557-2.385	.42	1.289	0.696-2.387	.729	1.202	0.424-3.410	.583	1.35	0.462-3.943	.534	0.634	0.151-2.666
Right vs left	.819	0.924	0.473-1.808	.119	1.616	0.883-2.959	**.03**	**3.315**	**1.119-8.772**	**.017**	**4.31**	**1.302-14.286**	.806	0.904	0.405-2.020
GSS	.313	0.553	0.175-1.745	.2	2.123	0.671-6.723	.574	1.724	0.258-11.519	.652	1.676	0.178-15.741	.754	0.754	0.175-3.252
4 vs 1															
Group 1 vs 2	.068	2.257	0.943-5.405	**.001**	**3.311**	**1.610-6.803**	**.001**	**15.625**	**3.311-71.429**	**.003**	**22.727**	**2.874-200**	.78	0.86	0.298-2.481
Group 1 vs 3	**.038**	**2.703**	**1.055-6.897**	**.002**	**3.636**	**1.595-8.333**	**.014**	**5.291**	**1.406-20.0**	**.016**	**12.821**	**1.595-100**	.336	0.597	0.208-1.709
Group 2 vs 3	.976	3.497	0.417-2.463	.572	1.319	0.505-3.448	.086	0.072	0.004-1.453	.868	0.754	0.027-21.277	.379	0.638	0.234-1.739

Bold values denotes statistical significance.

difference in cases requiring multiple accesses, we separately analyzed the outcomes in the subgroup of 284 patients with a single access; again, the SFR was significantly higher in group 1 than group 3 (90.6% vs 79.2%, $P = .013$) (see Supplementary Table 1).

The 90-day complication rate was 20.4%, with 7.9% being CD grade 3-4 (primarily chest tube insertion) (Table 2). No deaths were recorded. Group 1 had a significantly higher risk of any complications (34.5%, $P = .001$) and grade 3-4 complications (17.6%, $P = .001$), which were mostly chest tube insertion (16.0%; $P = .003$) (Tables 2 and 3). Within group 1, right PCNL carried a 4.2 times higher risk of chest tube insertion than on the left side (24.2% vs 7.0%, $P = .016$).

In our cohort, 221 patients had stones in the lower calyx, 194 in the renal pelvis, 94 in the upper calyx, 91 in the middle calyx, and 30 in the ureter. We analyzed more in detail the 120 cases with just lower calyx stones, with or without renal pelvis stone (see Supplementary Table 2). About 60% of these patients had an upper calyx access (32.5% supracostal, 26.7% subcostal). Group 1 had significantly higher SFR than group 3 (97.4% vs 77.6%, $P = .02$) and less need for a second look than group 2 (20.5% vs 31.3%, $P = .013$). As expected, complications were also higher, but with the rate of chest tube insertion being lower than in the whole cohort (10.3% vs 16.0%).

In the whole cohort, increasing BMI was associated with lower risk for having any complications (OR 0.96, $P = .03$, 95% CI 0.930-0.996) and CD grade 3-4 complications (OR 0.912, $P = .01$, 95% CI 0.849-0.978). Within group 1, patients with a BMI ≥30 had a 4.5 times lower risk of requiring a chest tube (6.9% vs 25.0%, $P = .013$) (Table 4).

Number of accesses, stone size, and GSS, although correlating with increased need for a second look, were not associated with any difference in SFR or complications (Table 2).

Among patients with only subcostal access, there were no significant differences in the risk of any complications (16.8% for group 2 vs 9.9% for group 3; $P = .572$) (Table 3).

DISCUSSION

It is the authors' belief that upper pole access is a useful tool that facilitates PCNL by providing direct and stable access to the renal pelvis, ureter, and lower calyx. This is based on the fact that the kidneys are tilted posterolaterally, resulting in the upper pole lying closer to the lumbar skin than the lower pole. Therefore, upper calyx access provides a straight tract parallel to the long axis of the kidney, causing less torque of the rigid nephroscope and reducing the chance of injuring the infundibular venous plexus.[3] When possible, the upper calyx was punctured from below the rib, but in many patients it lied higher and was only accessible with a supracostal puncture.

Preminger et al had reported that upper calyx access required supracostal puncture in over 80% of patients,[4] while the CROES group[5] and Patel et al[6] reported 69.2% and 70.1%, respectively. Our series shows that 47.5% of upper calyx punctures were feasible below the ribs (group 2). It has been demonstrated that supracostal access carries an increased risk of thoracic injuries[7] due to the anatomy of the parietal pleura,[8] which is reflected to the level of the 10th rib at the midaxillary line, but partially inserts

Table 4. Correlation of BMI and side in group 1 (univariate logistic regression)

	Left		Right				
	n	%	*n*	%	*P*	OR	95% CI
Complications Total (90 d)	12	21.1	29	46.8	**.004**	**3.295**	1.468-7.400
Complications grade 3-4	5	8.8	16	25.8	**.02**	**3.617**	1.229-10.649
Chest tube	4	7.0	15	24.2	**.016**	**4.229**	1.311-13.635
Stone-free	51	89.5	56	90.3	.878	1.098	0.333-3.622
Procedures at 1 y	3	5.3	5	8.1	.545	1.579	0.360-6.929
	BMI <30		BMI ≥30				
	n	%	*n*	%	*P*	OR	95% CI
Complications Total	24	42.9	14	24.1	**.036**	**0.424**	0.190-0.945
Complications grade 3-4	16	28.6	4	6.9	**.005**	**0.185**	0.058-0.596
Chest tube	14	25.0	4	6.9	**.013**	**0.222**	0.068-0.725
Stone-free	50	89.3	53	91.4	.706	1.272	0.365-4.431
Procedures at 1 year	5	8.9	2	3.4	.24	0.364	0.068-1.961

Bold values denotes statistical significance.

onto the 12th rib medially to the midscapular line[9]. Given that the pleura courses superiorly as you move laterally, there is less risk of parietal pleural injury if punctures are done more laterally in the intercostal space, as in most supine PCNLs. Also, the intercostal neurovascular bundle runs on the lower border of the ribs and, therefore, access in the lower half of the intercostal space decreases damage to the bundle.[10]

In regard to upper calyx access, CROES data showed association with higher complication rates, including blood transfusion and hydrothorax, and length of stay in hospital.[5] A single-center retrospective study that included 305 patients with upper pole access found an OR of 2.13 for major complications with upper calyx access ($P = .025$).[11] However both of these studies did not differentiate between supracostal and subcostal upper calyx access. In our study, we stratified upper pole access into supracostal vs subcostal and clearly demonstrated that upper calyx access done below the ribs does not increase the risk of complications (total, grade ≥3 or intrathoracic) compared to mid/lower calyx access (Table 2).

Previous data on SFR is very heterogeneous. We considered 3 mm as a threshold for clinical SFR given previous data showing that complications and reintervention are significantly more likely for residual fragments larger than 4 mm.[12] Supracostal access has been shown to be useful in patients with staghorn stones, upper ureteric stones, upper pole calyceal stones, and high-lying kidneys.[9] Additionally, supracostal access is particularly helpful in obese patients with large upper pole stones.[13] Some studies suggest better SFR with upper pole access[14,15] whereas others have found that supracostal access does not increase SFR compared to subcostal upper pole access.[7] The CROES data even showed lower SFR with supracostal access.[5] However, the patients with upper pole access in this retrospective multicenter study had higher stone complexity and burden. Moreover, in the CROES study only 9.0% of patients had upper calyx access, while in our series that number reaches 69.3%, suggesting more familiarity with the approach.

In our study, even after multivariate analysis adjusting for possible confounders (side, stone size, GSS, patient BMI, and number of accesses), supracostal upper calyx access was associated with higher SFR when compared to just mid/lower calyx access (OR = 2.703, 95% CI 1.055-6.897, $P = .038$). The difference in SFR was even more pronounced in patients with no stones in the upper and mid calyces (see Supplementary Table 2). This is due to the fact that the access is made away from the stones, giving perfect exposure to the renal pelvis and the lower calyx. One of the strengths of our SFR data is that every patient was evaluated with a CT scan within 24 hours of surgery, a significantly more sensitive method to assess SFR than X-Ray or ultrasound as used in other studies.[6,16]

A retrospective study of 240 PCNL patients, of which a third had supracostal access, showed a significant increase in total complications with access above the 12th rib (16.3% vs 4.5%) with 87.5% of intrathoracic complications happening in the supracostal group.[17] Kekre et al reported a 9.8% risk of requiring chest tube after supracostal access in a 102-patient cohort; however, a third of these punctures were done into the mid or lower calyces, inserting a significant confounder into the results as these are clearly safer than supracostal access into the upper calyx.[18] In our series, we had 16 patients with a supracostal access into mid or lower calyces that were included into group 3. Only one of these patients had hydrothorax, which was managed conservatively (CD grade 1), with no grade ≥3 complications.

Within supracostal access patients, going above the 11th rib carries a 3.5-fold increased risk of complications[17] and 5.6-fold risk of hydrothorax[5] compared to punctures between the 11th and 12th ribs. However, Kara et al reported no significant differences in complications between the 10th and 11th intercostal space access.[19] In our series, only 2 patients required puncture at that level with one of them having a small pleural effusion managed conservatively (CD grade 1). On the other hand, the risk of intrathoracic complications with subcostal upper calyx access is almost negligible; in our series, it was 23 times lower than in supracostal access (0.9% vs 16.0%, $P = .003$).

It is our practice to leave a nephrostomy tube after the first look PCNL in order to facilitate a possible second look during the same hospital admission. Several centers advocate tubeless PCNL to minimize patient bother and reduce length of stay. A recent retrospective study of tubeless PCNL included 52 patients with supracostal access of the upper calyx and reported very low rate of thoracic complications.[20] However, our group 1 patients had a median stone size of 34 mm (compared to 21 mm in the above study), making it more likely to need a second look and therefore justifying the insertion of nephrostomy.

About 19% of patients in group 1 required more than 1 access. Number of accesses alone was not associated with increased complications or higher SFR on multivariate analysis. Our rate of multiple accesses when upper calyx was punctured compares favorably with other series where that rate was as high as 38%.[21]

To our knowledge, ours is the first study showing that a supracostal puncture of the right upper calyx carries a higher risk of requiring a chest tube than on the left side (OR = 4.229, $P = .016$). This could be explained by a very interesting study looking at the relative position of the 11th and 12th ribs and upper renal calyx on CT in both full inspiration and full expiration. Hopper and Yakes found that the angle between lung edge and upper calyx in prone position was significantly less favorable on the right.[22] This study also showed that the phase of respiration had little effect on the position of the upper calyx or the pleura in relation to the ribs. However, for a supracostal access in prone position, full expiration reduced the chance of lung injury from 86% to 29% on the right and from 79% to 14% on the left. The CROES data did not show a difference of complications between left and right kidney (OR 0.96; 0.59-1.56), but, again, those patients were not stratified by subcostal vs supracostal.[5]

Interestingly, our data showed that patients with higher BMI had lower risk of any complication, grade 3-4 or requiring a chest tube (Table 4). There is no parallel to this finding in the literature, with some studies finding no correlation of BMI with complications.[11] It is our belief that this could be related with the amount of perirenal fat pushing the kidney away from the pleura and possibly causing a tamponade effect, but we now plan to further assess this finding prospectively.

This study is obviously limited by being a retrospective analysis and by the nonrandomization between groups, thus increasing the risk of confounding variables and selection bias that may have not been controlled for, even with multivariate analysis. Moreover, being single surgeon and single institution data, the results might not be generalizable to other centers.

CONCLUSION

Our study is a retrospective analysis of PCNLs done by a single surgeon with special interest in upper calyx access. Our data clearly shows that upper pole access, when done below the ribs, is safe with a similar complication rate to mid/lower calyx access. Supracostal access is also an effective option to achieve higher SFRs in lower calyx stones and in complex stones, but carries an increased risk of significant hydrothorax, particularly on the right side and in nonobese patients.

Additional prospective studies are needed to better characterize the outcomes of PCNL following different access sites.

SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.1016/j.urology.2019.08.031.

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