ORIGINAL RESEARCH

Analysis of Risk Factors for Pulmonary Complications in Patients Undergoing Upper Pole Prone Percutaneous Nephrolithotomy (uPPCNL): A Single Center Experience

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Introduction: To determine the risk factors contributing to pulmonary complications among patients who undergo upper pole prone percutaneous nephrolithotomy (uPPCNL). This will serve as a guide to urologists who utilize uPPCNL among their patients, so that they may monitor them more closely for these events.

Methods: A retrospective chart review was done on all patients who underwent uPPCNL from January 2015 to December 2017. Patient characteristics (age, gender, BMI, co-morbidity) and stone demographics (Stone size, Guy's Stone score, laterality, stone location) were summarized as well as intraoperative parameters inclusive of operative time, number of tracts, estimated blood loss, and length of hospital stay. Point biserial correlation and Pearson Chi-square for independent tests were used to identify the independent predictors of pulmonary complications.

Results: Nine hundred ninety-two patients underwent uPPCNL during the study period. Fifty-two (5.2%) had pulmonary complications. Sixty-seven pulmonary complications were tallied because some had two complications at one time. The most common was pleural effusion 35(48%), followed by atelectasis in 16(30%), hospital-acquired pneumonia 14(27%) and acute respiratory distress syndrome 2(4%). Forty-one (78.8%) and 11(21.2%) required medical and surgical interventions, respectively. Higher Guy's stone scores, larger stone size, and longer hospital stay were significant predictors for developing pleural effusion. Patients with higher preoperative serum creatinine and longer hospital stay were significantly associated with surgical management ($p < 0.05$).

Conclusion: The incidence of pulmonary complications after uPPCNL is low and only a minority need surgical management. When risk factors are present, these patients need to be monitored closely so that a timely intervention may be done to avoid life-threatening consequences.

Key words: Upper pole access percutaneous nephrolithotomy (PCNL), pulmonary complications, pleural effusion, staghorn, stone burden

Introduction

Percutaneous nephrolithotomy (PCNL) is considered the gold standard for the treatment of renal stones > 2cm and staghorn calculus. It provides less post-operative pain, shorter recover time, earlier hospital discharge compared to the traditional open stone surgery. The success rates of the procedure in managing complex renal stones is influenced by the chosen renal access, with the upper pole access providing higher stone clearance rates.[1] Upper pole access prone PCNL can be performed with either a supracostal or infracostal approaches. The supracostal puncture,

which is most often utilized on the left given the higher position of the kidney, is associated with a higher pulmonary complication rate compared to an infracostal approach.[2,3] In spite of this, the uPPCNL continues to be preferred by urologists when dealing with stones in the superior calyx, proximal ureter, stones, in morbidly obese patients, and in selected large-burden, staghorn or complex calculi.

The National Kidney and Transplant Insititute performs a high volume of cases of PCNLs every year and majority of these cases are uPPCNL. This approach of uPPCNL was introduced in the country at our institute and has since then, been the authors' preferred approach for almost all their cases of renal stones. By analyzing the risk factors leading to pulmonary complications, they will gain significant knowledge that can help predict which patients are likely to suffer a potential complication. This is valuable in helping the surgeon maintain a more vigilant approach when choosing uPPCNL in high-risk patients while being able to monitor them postoperatively so that a timely intervention may be given immediately. The objective was to determine risk factors for developing pulmonary complications among patients who had uPPCNL.

Methods

This retrospective chart review was approved by the Research and Ethics Committee. Absolute confidentiality was maintained throughout the data gathering. Data collection was limited to those patients who developed pulmonary complications.

Patient and stone characteristics, intraoperative and postoperative events were summarized. The patient demographics such as age, sex, body mass index, co-morbidities- history of smoking, chronic obstructive pulmonary disease, hypertension, diabetes, chronic kidney disease, and laterality of uPPCNL (right, left, or bilateral.) The stone features include stone size, location, Guy's stone score (GSS), and laterality. The outcome parameters include intraoperative factors such as estimated blood loss (EBL), need for a second or multiple access/tract, operative time, intraoperative transfusion requirements, length of hospital stay (LOS) and the specific pulmonary complications (atelectasis, pulmonary edema, pneumonia, pleural effusion, hydrothorax, hemothorax, pneumothorax, acute respiratory distress syndrome) following PCNL.

Analysis of the results was done into two sections, namely: 1) Descriptive and 2) Inferential. Descriptive analysis presented the summary statistics of all variables included in the study. Continuous variables were summarized using mean and standard deviation, while categorical parameters were described in frequency and percentage cross tabulations. In determining the risk factors associated to the management done (i.e, medical or surgical) and the specific pulmonary complications, point biserial correlation and Pearson Chi-square for Independent tests were used. Statistics with corresponding p-values not exceeding 0.05 were deemed significant risk factors.

Standard Surgical Technique of uPPCNL

The surgical procedure is done initially with the patient on lithotomy position wherein a ureteral catheter is inserted by cystoscopy under fluoroscopic guidance followed by a retrograde pyelography to determine renal anatomy. The patient is then repositioned to the prone position and draped in a sterile manner. Under, fluoroscopic guidance, an appropriate site is chosen for the percutaneous access needle which is typically advanced either through a supracostal or subcostal approach via the Bull's eye (hub-over-tip) technique. Once the depth of the needle has been confirmed to be in the desired calyx using oblique views, the egress of either urine or injected saline through the access needle is seen, and a guidewire is advanced down the ureter and into urinary bladder under fluoscopic guidance. Progressive serial dilation is then done using serial Amplatz dilators up to 30Fr, followed by insertion of the Amplatz sheath. Nephroscopy is done using a 26Fr. rigid nephroscope and the stones are fragmented with either an ultrasonic or pneumatic lithotripsy. Fragmented stones are either aspirated with the vacuum function of the ultrasonic lithotripter or extracted with a renal stone grasper. Stone-free status is confirmed by fluoroscopy and direct visualization by nephroscopy. Dependent on the clinical indications, urinary drainage is achieved with either a 6Fr x 24cm indwelling

ureteral stent or a 16-20Fr Foley catheter which is used as a nephrostomy tube, or both.

After the procedure, the patient is turned back to supine position and extubated. The patient is then transferred to the post-anesthesia care unit until they are clinical stable to transfer to the room.

Post-operative chest radiographs were taken on patients who complained of dyspnea or chest pain. When the chest radiograph suggests the presence of a pleural effusion as evidenced by the obliteration of the costophrenic angle or the opacification of the chest cavity, an ultrasound is done to determine the total fluid volume, followed by ultrasound-guided thoracentesis or pigtail insertion if the total volume is >300cc. It is also performed on patients who show evidence of desaturation on room air and are dyspneic, requiring oxygen supplementation. Patients with minimal effusion on chest X-ray and no desaturation were managed conservatively.

Results

A total of 992 adult patients underwent elective uPPCNL under general anesthesia during the period of January 2015 until December 2017. Out of the 992 patients, 52 (5.2%) patients who had pulmonary complications were analyzed and included in this study. Table 1 shows the patient demographics with pulmonary complications who underwent upper pole access PCNL. The mean age was 50 years old with a male to female ratio of 1:1 and BMI (body mass index) of 26.63 ± 5.19 kg/m^2. The co-morbid conditions included hypertenstion in 25 (48%); diabetic mellitus in 9 (17%) and chronic kidney disease in 7 (13%). Out of the 52 patients, only 5 (10%) had a smoking history and 9 (17%) underwent ipsilateral renal surgery/procedure. The average pre-operative serum creatinine was 2.03 ± 2.67 mg/dl.

Table 2 shows the intra-operative factors of patients with pulmonary complications who underwent upper pole access PCNL. There was no preference for right or left laterality, which occurred 42% or 46% incidence, respectively. Only 12% of the total sample or 6 cases had bilateral synchronous procedures. Majority had higher grades of Guy Stone III or IV, 40% and 44%, respectively. Only 1 (2%) and 7 (13%) had Guy Stone scores I and II, respectively. The mean stone diameter was 4.6±1.96. Forty-eight (92%) patients required only a single upper pole access and only 4 (10%) required

Table 1. Summary of patient clinical demographics with pulmonary complications who underwent upper pole access PCNL.

Patient's Profile (Total Sample, N = 52)	Summary Statistics	
Sex		
Male n (%)	29	56%
Female n (%)	23	44%
Age (years), Mean ± SD	49.74 ± 3.97	
BMI (kg/m^2) Mean ± SD	26.63 ± 5.19	
Co-morbiditiy, n (%)		
Diabetes mellitus	9	17%
Hypertension	25	48%
COPD (chronic obstructive pulmonary disease)	0	0%
Asthma	0	0%
Chronic kidney disease	7	13%
Smoker n (%)	5	10%
Previous ipsilateral renal surgeries n (%)	9	17%
Pre-operative serum creatinine (mg/dl) mean ± SD	2.03 ± 2.67	

Table 2. Summary of intraoperative factors of patients with pulmonary complications who underwent upper pole access PCNL.

PIntra-operative Factors	Summary Statistics	
Laterality n (%)		
Left	24	46%
Right	22	42%
Bilateral	6	12%
Guys stone classification n (%)		
I	1	2%
II	7	13%
III	21	40%
IV	23	44%
Stone diameter size (cm) mean ± SD	4.6 ± 1.96	
No. of tracts		
Single	48	92%
Two	4	10%
Operative time (minutes) mean ± SD	153 ± 67	
Estimated blood loss (ml) mean +-SD	344.98 ± 299.8	
Patients received blood transfusion, n (%)	7	47%

an additional access (multi-tract PCNL.) The mean operative time was 153±67 minutes, mean estimated blood loss was 344.98±299.8 ml. Only 7 (47%) required blood transfusions.

Table 3 shows the preoperative and intraoperative factors of patients with pulmonary complications treated with conservative and surgical treatment. Out of the 52 patients, 41 were managed medically (78.8%) and 11 were managed surgically (21.2%). Patients who required surgical management had significantly longer hospital stay than the former, 12 vs. 6 days ($p < 0.05$) and higher pre-operative serum creatinine 4.5 vs 1.73 mg/dl ($p < 0.05$). These findings indicated that higher creatinine and longer hospital stay were significantly associated with surgical management.

Table 3. Summary of preoperative and intraoperative factors of patients with pulmonary complications treated with conservative and surgical treatment.

Pre-operative and intra-operative factors	Surgical		Conservative		p-value
Sex					0.927
Male n (%)	6	55%	23	56%	
Female n (%)	5	45%	18	44%	
Age (years), Mean +- SD	49.27 ± 13.79		49.48 ± 14.19		0.964
BMI (kg/m^2) Mean +-SD	28.55 ± 7.27		25.93 ± 4.43		0.139
Co-morbiditiy, n (%)					
Diabetes Mellitus	2	18%	7	17%	0.931
Hypertension	5	45%	20	49%	0.845
COPD (chronic obstructive pulmonary disease)					
Asthma					
Chronic kidney disease	0	0%	7	17%	0.141
Smoker n (%)	0	0%	5	12%	0.223
Previous ipsilateral renal surgeries n (%)	2	18%	7	17%	0.619
Pre-operative Serum Creatinine (mg/dl) mean +-SD	4.5 ± 6.9		1.73 ± 1.47		0.027
Laterality n (%)					0.652
Left	4	36%	20	49%	
Right	6	55%	16	39%	
Bilateral	1	9%	5	12%	
Guys stone classification n (%)					0.463
I	0	0%	1	2%	
II	0	0%	7	17%	
III	5	45%	16	39%	
IV	6	55%	17	41%	
Stone diameter size (cm) mean +- SD	5.4 ± 1.96		4.5 ± 1.93		0.207
No. of tracts					0.374
Single	11	100%	37	90%	
Two	0	0%	4	10%	
More than two					
Operative time (minutes) mean +-SD	49.27 ± 13.79		49.48 ± 14.19		0.207
Estimated blood loss (ml) mean +-SD	300 ± 143		357 ± 330		0.579
Patients received blood transfusion, n (%)	2	67%	5	42%	0.446
# of hospital days from the day of OR until discharge (days) mean, +_SD	12 ± 5		6 ± 4		0

A total of 67 postoperative pulmonary complications were evident in this study wherein some patients had two complications at the same time. Table 4 shows the association between preoperative and intraoperative factors and specific pulmonary complications. A total of 35 (52.2%) out of the 67 pulmonary complications were pleural effusion, 16 cases of atelectasis, 14 (6.7%) of hospital-acquired pneumonia and 2 (3%) developed acute respiratory distress syndrome (ARDS).

Table 4. Association between pre-operative and intra-operative factors and specific pulmonary complications.

Pre-operative and intra-operative factors n (%)	Pleural effusion 35 (52.2%)		Pneumonia 14 (6.7%)		ARDS 2 (3%)		Atelectasis 16 (24%)	
Sex								
Male n (%)	21	60%	7	50%	9	56%	0	0%
Female n (%)	14	40%	7	50%	7	44%	2	100%
Age (years), Mean +-SD	49.11 ± 15.03		45.86 ± 15.40		50.5 ± 11.67		42 ± 11.31	
BMI (kg/m^2) Mean +-SD	26.6 ± 5.05		25.91 ± 3.77		26.37 ± 5		22.92 ± 12.14	
Co-morbiditiy, n (%)								
Diabetes Mellitus	5	14%	3	21%	3	19%	0	0%
Hypertension	16	46%	5	36%	10	63%	0	0%
COPD (chronic obstructive pulmonary disease)								
Asthma								
Chronic kidney disease	3	9%	2	14%	3	19%	0	0%
Smoker n (%)	4	11%	3	21%	1	6%	0	0%
Previous ipsilateral renal surgeries n (%)	7	20%	2	14%	2	13%	1	50%
Pre-operative Serum Creatinine (mg/dl) mean +-SD	2.14 ± 3.03		1.18 ± 0.52		1.8 ± 2.06		2.2 ± 0.42	
Laterality n (%)								
Left	14	40%	8	57%	8	50%	1	50%
Right	16	46%	6	43%	7	44%	0	0%
Bilateral	5	14%	0	0%	1	6%	1	50%
Guys stone classification n (%)								
I	0	0%	0	0%	1	6%	0	0%
II	2	6%	2	14%	3	19%	0	0%
III	15	43%	6	43%	6	38%	0	0%
IV	18	51%	6	43%	6	38%	2	100%
Stone diameter size (cm) mean +- SD	5.03 ± 1.87		4.43 ± 1.95		4.56 ± 2.10		6.5 ± 0.71	
No. of tracts								
Single	34	97%	14	100%	12	75%	2	100%
Two	1	3%	0	0%	4	25%	0	0%
More than two								
Operative time (minutes) mean +-SD	157 ± 63		139 ± 80		158 ± 59		96 ± 43	
Estimated blood loss (ml) mean +-SD	351 ± 281.81		296.43 ± 201.4		378.13 ± 380.34		350 ± 70.71	
Patients received blood transfusion, n (%)	5	45%	0	0%	4	50%	0	0%
# of hospital days from the day of OR until discharge (days) mean, +_SD	8.17 ± 4.25		7.79 ± 3.95		7.13 ± 4.36		8 ± 4.24	

One patient who had ARDS was 34-year-old female with no co-morbid conditions, who underwent a uPPCNL for a staghorn calculus on the left. On postoperative day one, the patient had difficulty of breathing, tachycardia, and febrile episodes with Tmax of 39ºC. Creatinine was elevated at 3.8mg/dl; hemoglobin was at 9.1 with leukocytosis of 29.18 with stabs of 26 and platelet count of 67. Patient was on broad-spectrum antibiotics Piperacillin- Tazobactam 4.5gm IVq6. On day 3, she was intubated and manifested signs of septic shock. On day 4, the patient expired. Another patient was a 50-year-old female with no co-morbidities, and a non-smoker. She underwent bilateral synchronous PCNL utilizing a multi-tract approach. The operative time was 126 minutes with 300 ml estimated blood loss. On postoperative day one, patient had difficulty breathing with episodes of desaturation less than 90%. Patient was intubated and was transferred to intensive care unit. CBC post-op showed hgb of 11.1, hct 36, wbc 39.94 and platelet count of 174. Meropenem was started. Impression was ARDS secondary to septic shock. On day 2, patient was extubated, responded to antibiotics. Patient eventually recovered and was discharged on postoperative day 11.

There were no cases of pneumothorax during the time period of the study. Due to the limited sample size, there was no sufficient evidence to conclude association of any most specified factors to any type of pulmonary complication. However, with little incidence rates, results showed that higher Guy's stone classification of at least a score of 3 or 4, a stone size of 5.0 cm or more, and longer hospital stay of at least 8 days or more were significant risk factors of having pleural effusion complication.

Discussion

Upper pole access PCNL (uPPCNL) is the preferred approach in the management of complex renal calculi, particularly staghorn. It provides a higher stone clearance rate because of the panoramic view that it provides and easy access to most calyces. In a prospective study involving 94 patients, comparing upper vs. lower pole access PCNL, Singh, et al. demonstrated a success rate of 76.47% for those in the lower, and 90.70% for those in the upper calyceal access group. Further, the authors found a very low pulmonary complication rate of 2.3% for the upper pole access.[1] Gupta, et al. also prospectively analyzed the safety and efficacy of a supracostal approach for PCNL.[2] The indications for the upper pole access included staghorn, upper ureteric, superior calyceal stones and high-lying kidneys. Overall, 90% of the patients were rendered stone-free or had clinically insignificant residuals with PCNL alone. Significant chest complications developed in three (5%) patients, which required insertion of a chest tube but all patients recovered uneventfully. The authors concluded that the upper pole access should not be feared because of the potential for chest complications.

The pulmonary complication rate in this series is also quite low (5.2%) and majority of these were managed conservatively. Among those requiring interventions, these were limited to 11/922 (1.2%) which required ultrasound-guided aspiration of pleural effusion. None of these patients required insertion of a chest tube nor a thoracotomy. There were two serious life-threatening pulmonary events requiring ventilatory support and there was one mortality. These, however, were secondary to sepsis and did not result from hydrothorax or hemothorax. The low incidence of pulmonary complications in uPPCNL has also been confirmed in both retrospective and prospective studies.[3-5] Present findings seem better than the report of Treewattanakul, et al. who documented a pulmonary complication rate of 13.6%, among which only 3% needed intercostal drainage.[3] Analyzing for risk factors, their group found that a low BMI, and a mean age of less than 27 years old were factors predictive of developing pleural complication.[3] They stated that obesity and more perirenal fat seems to be protective during the access.

The low incidence of pulmonary complications in the uPPCNL series can be attributed to the unique approach to the upper pole posterior calyx. (Figure 1). When introducing the percutaneous access needle, the authors maintained the C-arm in the zero degree in the AP (antero-posterior) position. By doing this, they approached the upper posterior calyx in a straight line using a bullseye

(hub-over-tip) technique. In the area overlying the posterior part of the kidney on either side, the pleural reflection was least compared to the kidney's posterolateral side.

The pulmonary complications reported by Yu ,et al. was also higher at 32.5%.[6] In their study involving 560 patients, multivariate logistic regression analysis revealed that the independent risk factors for pulmonary complications after percutaneous nephrolithotomy were a higher body mass index, intraoperative transfusion and an intercostal surgical approach. It is unclear if this series included all patients regardless of which calyx was used. The surgical approach was only stratified to either a subcostal or an intercostal approach. In contrast, the present study focused exclusively on patients treated with an upper pole puncture and therefore provided a more direct analysis of patients subjected to uPPCNL.

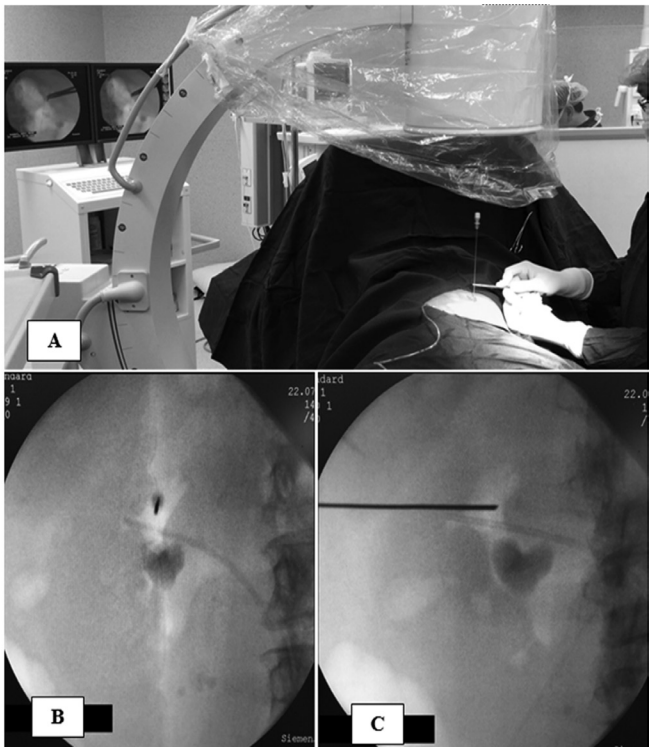

Figure 1. Bull's eye (hub-over-tip) technique being utilized in the uPPCNL.

Note that the cone of the C-arm is directly on top of the patient in the 0 degree position (1-A). This maintains a medial and posterior approach while the needle is advanced through a straight line entering the upper posterior calyx (1-B). The depth of the puncture as well as entry into the calyx is confirmed with a 20-30 degree oblique view with the cone of the C-arm (1-C). tilted away from the surgeon.

Pulmonary complications are reportedly higher among patients who had a supracostal puncture.[7,8] A supracostal puncture is usually required for left-sided PCNL an anatomical difference which can easily be attributed to the lower anatomical location of the left vs. the right because of the presence of the liver on the right. This has been confirmed in the study of Annaji, et al. showing lower pulmonary complications on right sided PCNL.[9] In the present series, however, while there is also a slight trend towards higher pulmonary complications among left sided PCNLs, the authors were unable to test its significance.

Staghorn calculi are best approached with uPPCNL because of the higher chance for maximal stone clearance. The authors prefer this approach for all their patients with staghorn for the same reason. Sukumar reinforced this recommendation in a retrospective study analyzing 110 patients who underwent a supracostal puncture, equally distributed among left and right sided cases. The stone clearance was high at 86% and increased to 97% after secondary procedures. The complication rate was low at 11.8%, half requiring aspiration and another half requiring intercostal drainage. Notably though, one required cystoscopy and evacuation of intravesical hematoma on a patient who also had significant hemothorax requiring chest tube drainage. They however insisted that whenever indicated, an uPPCNL should be attempted in all cases of staghorn. There were some manuevers mentioned that may lessen the chance for pulmonary complications such as puncturing in full expiration, sufficiently laterally, and always using a working sheath during nephroscopy and a well-draining nephrostomy tube after the procedure. The authors do not agree with all of these recommendations. For one, they do not do breath holding in any of their uPPCNL and just hit the calyx where it lies as seen on fluoroscopy. Further, they maintain their puncture as posteromedial as possible for reasons already mentioned above. Lastly, they do not always leave a nephrostomy tube (stented but without nephrostomy tube) unless they need it for further urinary drainage in the case of a persistent infection, or for hemostasis with a Foley catheter balloon.

The Guy Stone Scoring System for stone classification was introduced to by Thomas, et al.

provide a quick, easy-to-apply system for grading the complexity of PCNL. The authors found a high correlation between the GSS and the stone-free rates but not with complications.[10] The authors however found a statistically significant correlation with high GSS 3 to 4 to pulmonary complication rates. This may be explained by longer operative times compared to those with low GSS ratings. Clinically, this could also be explained by higher volumes of irrigation fluid which may be absorbed in the pleural space whenever a supracostal puncture is applied.

Patients with longer hospital stay are also associated with a need for surgical intervention (aspiration of pleural fluid). In this situation, however, it can be surmised that the extended hospital stay may have arisen from the need to manage the complication rather than the other way around. Theoretically however, patients who stay longer in the hospital are also at risk for developing hospital-acquired pneumonia, which was noted in 27% of patients. A minority of their patients developed ARDS, but these two patients eventually recovered after intensive management by pulmonary service. There was no mortality resulting from these events.

Higher pre-operative serum creatinine is also associated with a higher need for surgical intervention for the presence of pleural effusion, which may be explained by the lesser ability of patients to mobilize the fluid that may be absorbed during the PCNL. These patients with chronic kidney disease are also at risk for developing progressive renal dysfunction if bleeding was encountered intraoperatively.

The most common pulmonary complication in this study was pleural effusion which is consistent with most studies. In contrast, however, to a study done by Palnizky,[5] pneumothorax was the major complication. Pneumothorax usually occurs after a lung injury, resulting to acute collapse of the lung. Prompt reexpansion is necessary in order to avoid progression to a life-threatening tension pneumothorax. The authors did not encounter this in any of their series because of the technique they had described earlier. This allows them to get directly into the upper posterior calyx with less possibility of entering the chest cavity. As of this writing, none of their patients developed such a serious complication.

Due to the retrospective nature of the present study, the authors were unable to compare our subjects to a similar group of patients who had no pulmonary complications. Ideally, a matched paired analysis may be done for this purpose.

The actual incidence of pleural effusion may have been underestimated because imaging was only performed on those who were symptomatic. However, subclinical effusion in patients who were asymptomatic would not also require any intervention.

The authors were also unable to categorize the percutaneous access to either supracostal (intercostal) or subcostal (infracostal) approaches because this data was not available in the operative reports.

Conclusion

Upper pole access PCNL (uPPCNL) can be performed safely with an acceptable low incidence of pulmonary complications. Pleural effusion, which is the most common complication, can usually be managed conservatively unless they are symptomatic. When risks for pulmonary complications are present, the patients need to be monitored closely in order to make an early diagnosis, followed by a timely intervention.

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