Postoperative Pulmonary Complications after Percutaneous Nephrolithotomy Under Spinal Anesthesia

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Purpose: To evaluate risk factors and outcomes of Pulmonary Complications (PCs) in Percutaneous Nephrolithotomy (PCNL) under Spinal anesthesia (SA).

Material and method: 286 patients who underwent PCNL under SA between 2017 and 2021 were identified retrospectively and divided into group 1 (clinically significant PCs) and group 2 (no clinically significant PCs). Demographic, preoperative, and intraoperative variables and postoperative outcomes were compared between both groups. Independent risk factors for PCs were evaluated by univariable and multivariable logistic regression analyses.

Results: PCs were noted in 90 patients (31.5%). Advanced age ($P = .011$), high body mass index (BMI) ($P < .001$), and the presence of chronic obstructive pulmonary disease (COPD) ($P < .001$) were risk factors for PCs.

Conclusion: SA is an effective method of anesthesia for all PCNL patients and carries a lower rate of PCNL-associated PCs. Risk factors for PCs after PCNL were advanced age, obesity, and preoperative COPD.

Keywords: pulmonary complication; percutaneous nephrolithotomy; spinal anesthesia

INTRODUCTION

Percutaneous nephrolithotomy (PCNL) has been established as a minimally invasive treatment for the removal of kidney stones[1]. However, PCNL is associated with several complications, including extravasation of fluid and urine, need for blood transfusion, and septicemia. Postoperative pulmonary complications (PCs) include atelectasis, pneumothorax, hemo or hydrothorax, pleural effusion, pulmonary edema, pneumonia, and acute respiratory distress syndrome[2]. Patients undergoing PCNL are at increased risk for PCs due to several factors. First, the surgical site is near the diaphragm. Hence, the pleural cavity and lung can be injured, especially when approaching the stone through the upper pole of the kidney[3]. Second, the urologist uses large volumes of irrigation fluids during the procedure which may cause pulmonary congestion and edema[4]. The overall rate of pleural injury ranges between 0.3 and 1% during percutaneous access puncture for PCNL. Injury may manifest as hydro or hemothorax, pneumothorax, or hydropneumothorax and as many as 64% of patients with pleural injury require chest tube drainage[4,5]. PCs are a significant cause of postoperative mortality[4].

PCNL is commonly performed under general anesthesia (GA). PCs such as respiratory tract infection, respiratory failure, pleural effusion, atelectasis, pneumothorax, bronchospasm, aspiration pneumonitis, and acute respiratory distress syndrome are more commonly associated with GA than with regional anesthesia. Other risk factors include comorbidities such as cardiovascular system disease (CVD), hypertension (HT), diabetes mellitus (DM), chronic obstructive pulmonary disease (COPD), and obesity[6,7]. Previous studies on PCs following PCNL focussed on PCNL under GA[3-5,8,9]. No study has assessed PCs following PCNL under spinal anesthesia (SA). We hypothesized that performing this procedure under SA may help protect pulmonary function. In this study, we aimed to evaluate risk factors for PCs following PCNL under SA.

PATIENTS AND METHODS

Study population

Our study retrospectively reviewed 420 patients who underwent PCNL in our clinic between 2017 and 2021. All patients were scheduled for PCNL operation under spinal anesthesia by two urologists. Typically patients with any contraindication to spinal anesthesia (e.g. spinal deformity) underwent general anesthesia and were excluded from the study. 134 patients were excluded from the study due to any contraindication to spinal anesthesia, repeated PCNL, absent preoperative and postoperative chest X-rays, or incomplete medical records. Patients were evaluated with renal function tests, blood counts, coagulation profiles, urine analyses, and

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Table 1. Patient Demographics

Descriptive Statistics	Variables
Gender, %	
Male	52.8
Female	47.2
Age (Year) mean ± SD	50,985 ± 15,718
Side %	
Right kidney	46.5
Left kidney	53.5
BMI (kg/m^2) mean ± SD	29.92±6.01665
Comorbidities %	
• HT	43.4
• DM	23.4
• COPD	17.5
• CVD	17.1
Preop Hemoglobin (g/dL) mean±SD	13.57 ± 1.86
Postop Hemoglobin (g/dL) mean±SD	12.25 ± 1.9
Preop Creatinine (mg/dL)mean±SD	1.03 ± 0.58
Postop Creatinine (mg/dL) mean±SD	1.03 ± 0.33
Stone Burden (mm2)mean±SD	428 ± 423
Operation time (minute)mean±SD	46 ± 24

urine culture sensitivity. Patients with positive urinary cultures were given appropriate antibiotic treatment and underwent surgery after urine cultures were sterile. The Hemoglobin and creatinine levels were measured 24 hours preoperatively and 24 hours postoperatively. The stone surface area was calculated as the maximum diameter ×width ×π × 0.25. The hospital stay time was calculated from the day before surgery to the day of discharge.

All patients were examined by non-contrast abdominal computed tomography (CT), and chest radiography before surgery. Pulmonary functional test was performed for patients who had respiratory distress and a history of COPD. Chest X-ray was performed on all patients one day after PCNL. Patients with PCs were called for follow-up one week later.

Surgical technique

A ureteric catheter was placed via cystoscopy into the upper ureter or renal pelvis. Renal access was achieved in a prone position under fluoroscopic guidance. The access tract was dilated with an Amplatz dilator or telescopic metal dilator to 30 Fr at which point the Amplatz sheath was placed. A 24 Fr nephroscope was introduced to the collecting system and the stone was pulverized witan h ultrasonic or pneumatic lithotripter. Stone fragments equal to or smaller than 4 mm were considered clinically insignificant residual fragments. After the lithotripsy, re-entry Malecot nephrostomy or Double J catheter was inserted over the Amplatz wire within the kidney and the ureteral catheter was withdrawn. The operative time was defined as the time from the introduction of the 18-gauge coaxial needle into the patient's skin to the placement of the nephrostomy tube.

SA Procedure

After receiving 3-5 mg midazolam and 15 mL/kg saline intravenously for 15 min, all patients were positioned laterally onto the operating side and a mixture of 15-20 mg of 0.5% bupivacaine hydrochloride and 25 mcg fentanyl was given via a spinal needle inserted into the subarachnoid space through the L3-L4 intervertebral space. Patients with PCs determined by postoperative chest X-ray were examined by a pulmonologist. PCs were diagnosed as follows criteria: sinus blunting, pleural effusion, pulmonary consolidation, atelectasis, and diaphragm elevation.

Statistical Analysis

The research data were uploaded and evaluated using IBM Statistical Package for Social Sciences 21. Descriptive statistics of categorical variables are presented as numbers and percentages. Descriptive statistics of numerical variables are presented as mean (±) standard deviation for normally distributed variables and as median (min-max) for non-normally distributed variables. Cross tables were used to compare categorical variables and "Pearson chi-square test" and "Yates Continuity Correction" were applied. The conformity of numeri-

Table 2. Demographic variables by groups.

Variables	Group 1*	Group 2**	(*P*-value)
Age (Year) (mean±SD)	49.30 ± 15.72	54.72 ± 15.24	0.011[a]
Gender%			
Female	44.9	52.2	0.249[b]
Male	55.1	47.8	
Side %			
Right kidney	44.4	51.1	0.290[b]
Left kidney	55.6	48.9	
BMI (kg/m2) (mean±SD)	28.84 ± 5.24	32.65 ± 7.32	< 0.001[a]
Comorbidities %			
• DM	61.2	38.8	0.184[c]
• HT	63.7	36.3	0.124[b]
• COPD	40.0	60.0	< 0.001[b]
• CVD	51.0	49.0	0.006[c]
Preop Hemoglobin (g/dL)(mean±SD)	13.58 ± 1.89	13.56±1.81	0.940[a]
Preop Creatinine (mg/dL) mean ± SD	1.0 ± 0.49	1.1 ± 0.73	0.268[d]

*No Clinically significant PCs
**Clinically significant PCs
Numerical variables conforming to normal distribution are presented as mean ± standard deviation, and non-conforming numerical variables as median (range).
Categorical variables are expressed as number (% column percentage)
a:Independent Samples TTest
b:Pearson Chi¬-SquareTest
c: YatesContinuityCorrection Test
d: Mann-Whitney *U* Test, *P* < .05, *P* <.001

Table 3. Intraoperative variables by groups.

Variables	Group 1*	Group 2**	(*P*-value)
Operation time, minute mean ± SD	45 ± 23	48 ± 25	0.586[c]
Stone burden, mm2 mean ± SD	428 ± 430	429 ± 410	0.831[c]
Access point, %			
Upper pole	63.5	36.5	0.586[a]
Middle pole	69.2	30.8	
Lower pole	71.4	28.6	
Surgical approach, %			
Supracostal	59.7	40.3	0.103[b]
Subcostal	71.2	28.8	
Hospitalization, day(mean±SD)	1.30 ± 0.73	1.27±0.70	0.775[c]

*No Clinically significant PCs
**Clinically significant PCs
Numerical variables that do not conform to normal distribution are presented as median (range)
Categorical variables are expressed as numbers (% column percentage).
a: Pearson Chi¬-SquareTest
b: YatesContinuityCorrection Test
c: Mann-Whitney *U* Test

cal variables to normal distribution was examined using visual (histogram and probability graphs) and analytical methods (Kolmogorov Smirnov / Shapiro-Wilk tests). "Independent samples *t*-test" was used for statistical significance between groups for variables that fit a normal distribution. The homogeneity of the intergroup variances of normal variables was evaluated using the "Levene test". The "Mann-Whitney U" test was used to compare numerical variables that were not normally distributed. "Univariable and Multivariable Binary Logistic Regression Analysis" was used to determine the risk factors affecting postoperative pulmonary complications. Statistical significance levels were accepted as $P < .05$.

RESULTS

Our study examined 151 male and 135 female patients who underwent PCNL under SA. Mean Age ± SD was 50,985 ± 15,718 years. PCNL was performed on the right renal unit in 133 patients and the left renal unit in 153 patients. 27 patients underwent PCNL with 2 punctures. The mean BMI was 29,92 kg/m2. Comorbidities were observed with a frequency of 17.1% to 43.4% as seen in Table 1. Patients were evaluated for PCs after PCNL and divided into groups with clinically significant PCs (Group 1) and no clinically significant PCs (Group 2).

No patient had severe pulmonary symptoms after PCNL. PCs were defined according to the postoperative chest X-ray and examination of the pulmonologist and noted in 31.5% of patients. 27 (9.4 %) patients had left costophrenic angle blunting due to minimal pleural effusion, 20 (6.9 %) had moderate pleural effusion, 10 (3.4 %) had ipsilateral diaphragm elevation, 21 (7.3%) had atelectasis and 12 (4.1 %) had pulmonary consolidation. The mean age and BMI of the patients who developed atelectasis were high. In addition, 14 of these patients had chronic obstructive pulmonary disease, 15 had coronary artery disease, and 15 had DM. No patient had a pneumothorax. All patients with PCs were followed conservatively and did not require additional intervention such as chest tube insertion.

There were significant differences in age, BMI, and incidence of preoperative COPD between the two groups ($P = .011$, $P < .001$, and $P < .001$, respectively). Demographic variables by groups have been illustrated in Table 2.

No significant differences were found between the two groups in terms of the operation time, stone burden, access site, and hospitalization time. Intraoperative variables by groups have been illustrated in **Table 3**.

Independent risk factors for PCs were evaluated by univariable and multivariable logistic regression analyses and outlined in **Table 4**. A univariable logistic regression analysis revealed that advanced age, high BMI, supracostal approach, and the presence of preoperative CVD and COPD were associated with PCs after PCNL under SA. A multivariable logistic regression analysis revealed that a high BMI (OR = 1.084, $P < .001$) and the presence of preoperative COPD (OR = 3.402, $P = .004$) were significantly associated with PCs after PCNL under SA (**Table 4**).

During supracostal access, 17 patients (5.9 %) complained about ipsilateral shoulder pain during the puncture. The access point was changed immediately to prevent the development of PCs.

DISCUSSION

PCs are a significant cause of postoperative mortality and strategies to reduce them are under continual study[10]. In our study, PCs were noted in 31.5% of patients. No PCs required surgical intervention in our series. Yu et al. classified PCs according to the definition of Kronke et al[11] and they reported that the incidence of clinically significant PCs was 32.5%[3]. Palnizky et al. reported that 8 patients (8%) had PCs, 7 with pneumothorax managed with a chest drain, and 1 patient had atelectasis and pleural effusion and died on the 24th postoperative day due to respiratory failure[4]. Annaji et al. reported that 7 patients (6.3%) had PCs, 6 with pneumothorax, and 1 with atelectasis who died on the first postoperative day due to respiratory failure; all 6 occurrences of pneumothorax were managed with a chest drain[5]. Munver et al. reported that 8 patients had PCs, 7 with intraoperative hemothorax/hydrothorax, 2 with deep venous thrombosis/pulmonary embolus, and 1 with pneumothorax[8]. Khrishna et al. reported that 12 patients had PCs, all of them with pneumothorax and they were managed with a chest drain[9]. Solakhan et al., compared two different anesthesia methods in patients

Table 4. Univariable and multivariable logistic regression analyses.

Variables	Univariable analysis OR (%95 CI)	(P-value)	Multivariable analysis OR (%95CI)	(P- value)
Age (year)	1.021 (1.005-1.038)	0.012	0.996 (0.976-1.017)	0.719
Gender	1.341(0.813-2.212)	0.250		
Side	0.763(0.463-1.259)	0.290		
Preop Hemoglobin (g/dL)	0.995 (0.870-1.138)	0,940		
Preop Creatinine (mg/dL)	1.097 (0.722-1.666)	0,664		
Postop Hemoglobin (g/dL)	1.025 (0.899-1.169)	0.711		
Postop Creatinine (mg/dL)	0.701(0.319-1.541)	0.377		
BMI (kg/m^2)	1.107(1.060-1.156)	< 0.001	1.084(1.032-1.139)	0.001
Comorbidities				
DM	1.536(0.868-2.719)	0.141		
HT	1.481(0.896-2.447)	0.125		
CVD	2.487(1.327-4.661)	0.004	0.911(0.391-2.123)	0.829
COPD	4.400(2.327-8.321)	< 0.001	3.402 (1.481-7.811)	0.004
SWL history	1.057(0.517-2.159)	0.880		
Stone burden (mm^2)	1.000(0.999-1.001)	0.988		
Surgical approach (Supracostal, Subcostal)	1.671(0.946-2.953)	0.077	1.245 (0.666-2.326)	0.492
Operation time (minute)	1.004(0.994-1.014)	0.428		

OR: $P < .05$; $P < .001$; $P < .10$

undergoing PCNL, it was reported that atelectasis developed in 8 patients (1.4%) only in the GA group(12). The common feature of the previous 6 studies is that PCNL was performed under GA.

In our retrospective study, we evaluated PCs after PCNL under SA. It is well known that many PCs, such as atelectasis and pneumonia, seem to be related to GA-induced impairment of respiratory activity[13]. Regional anesthesia eliminates the need for airway manipulation and one study associated it with a 50% reduction in PCs[14]. In SA, spontaneous breathing is preserved causing less cephalad displacement of the diaphragm and less atelectasis. Consequentially, closing capacity and functional residual capacity are less affected and pulmonary gas exchange is better maintained[15]. Moreover, it is known that SA offers less cardiopulmonary depression, improved perioperative hemodynamic stability, decreased intraoperative blood loss, improved postoperative analgesia, decreased opioid consumption, decreased postoperative nausea and vomiting, and therefore reduced PACU and duration of hospital stay[16]. These factors make regional anesthesia a popular alternative.

In our study, 44% of patients had a BMI of >30 kg/m2 and we found that BMI was associated with PCs according to univariable and multivariable analysis. Yu et al. also found a similar association between BMI and PCs(3). In obese patients, functional residual lung capacity and total lung capacity are compromised. Further, venous return is reduced due to inferior vena cava compression. Intubation difficulties may also occur in obese patients. Due to highly probable complications in morbidly obese patients, SA may be a better alternative for these patients[12].

In our study, increased age was associated with PCs according to univariable analysis. Age is an independent risk factor for the development of PCs even after adjustment for comorbid conditions. More detailed age stratification shows an increased risk of PCs as age increases. Compared with patients < 60 years, the OR (95% CI) for PCs for 60- to 69-year-olds was 2.1 (1.7-2.6) and for 70- to 79-year-olds, it was 3.1 (2.1-4.4). Older patients are more likely to be frail, and frailty has also been shown to be associated with PCs, even when adjusted for age[17].

Systemic diseases such as HT, CVD, DM, and COPD have previously been associated with a higher risk for PCs[18]. The presence of comorbid disease in our patients ranged from 17.1% to 43.4% and PCs were associated with COPD according to multivariable analysis. In a previous report, patients with COPD were 300-700 % more likely to suffer PCs compared to patients without COPD[19]. Surgery conducted only with epidural anesthesia demonstrated a 50% reduction in the risk of postoperative pneumonia in COPD patients(14). In contrast, the anterior spread of local anesthetic may result in phrenic nerve palsy causing diminished respiratory function, especially in COPD patients, so the level of anesthesia should be carefully controlled[20].

In this present study, the stones of 63 (22 %) patients were located in the upper pole of the kidney. The puncture was performed supracostally in 67 patients (23.4 %). In supracostal access, our findings suggest that SA is effective in preventing PCs. In GA, authors found that PCs occurred more frequently upon intercostal access compared to subcostal access[3]. SA was sufficient in patients who performed supracostal access. It is known that SA can be used to anesthetize up to the T4 level and may allow adequate access to supracostal and intercostal spaces and is suitable for PCNL, particularly for stones in the upper pole of the kidney[21]. Basiri et al. reported that only increasing anesthesia duration is associated with increased pain during operation but they could not find other statistically significant predictors of insufficient analgesia based on patients' demographics, stone characteristics, or access location[22]. Also, Dar et al. reported that there was no significant difference between the epidural and general anesthesia groups in terms of stone localization and stone burden[23]. One advantage of SA in preventing PCs is that during PCNL, the patient can immediately report sudden difficulty breathing and shoulder pain suggestive of a pleural puncture[24]. Whereas, pleural injuries in GA are mostly diagnosed in the immediate postoperative period with shortness of breath, fever, and radiological evidence[25]. Although our patients had no severe pulmonary symptoms postoperatively, pulmonary changes were detected in the chest X-ray. This result demonstrated the importance of chest X-rays after PCNL. In this present study, we noticed ipsilateral shoulder pain in 17 patients (5.9 %) during the puncturing when using a supra coastal access. Puncturing was immediately stopped and the patient was instructed to slightly inhale and hold their breath while we changed the access point, using the triangulation technique to reach the upper pole of the kidney. We changed the puncture point using the triangulation technique and our success and complication rate did not change since we could enter the same calyx. Tepeler et al. compared the bull-eye and triangulation techniques in terms of success and complication rates. They demonstrated that both access techniques were associated with similar operative times, hospitalization times, and success and complication rates(26). During a supracostal approach, in particular, patients under SA can follow verbal commands and control their respiration to the prevention of pulmonary events(27). Because the patients can report these symptoms during access, lung or pleural injuries can be detected early, and the development of PCs can be prevented. For this reason, the choice of anesthesia matters to fast-track the patient in a safe condition.

To prevent PCs, patients need to breathe comfortably after the surgery. Therefore, the use of deep breathing exercises and incentive spirometry is recommended in the postoperative period to prevent PCs(28). Patients undergoing SA practice deep breathing exercises and incentive spirometry more readily than GA because they have less postoperative pain and lower analgesic requirements(29). Solakhan et al. reported that the narcotic analgesic requirement was 33.4 % in the GA group and 10.9 % in the SA group(12). Finally, it has been suggested that SA and epidural anesthesia are more beneficial for pulmonary functions in both obese and advanced COPD patients(15,30). For these reasons, SA can mitigate PCs in PCNL.

Limitations of this study include the fact that we didn't have a GA group and no postoperative pulmonary function tests were performed.

CONCLUSIONS

In this study, we found that SA is an effective anesthesia method for all PCNL patients and carries a lower rate of PCs. Risk factors for PCs following PCNL were advanced age, obesity, and preoperative COPD.

Patients should be evaluated with pulmonary function tests and chest X-rays in terms of pulmonary functions in the preoperative and postoperative period, with pulmonary symptoms. Especially elderly, obese and COPD patients should be carefully monitored for PCs.

CONFLICT OF INTEREST

The author declares no conflict of interest.

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