



Prediction of early postoperative desaturation in extreme older patients after spinal anesthesia for femur fracture surgery: a retrospective analysis

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Background: Postoperative desaturation in older individuals is rarely addressed in the literature. The objective of this retrospective study was to investigate whether a preoperative spirometric test and arterial blood gas analysis (ABGA) might predict postoperative desaturation after spinal anesthesia in extreme older patients.

Methods: The medical records of 399 patients (age ≥ 80 yrs) who were administered spinal anesthesia for a femur neck fracture surgery were retrospectively reviewed. Early postoperative desaturation was defined as a reduction of oxygen saturation (SpO_2) below 90% within 3 days of surgery, despite O_2 supply via a nasal prong. Binary logistic regression analysis was used to identify predictors of early postoperative desaturation.

Results: The incidence of postoperative desaturation was 12.5%. Major morbidity rate was significantly higher in the desaturation group ($n = 50$) than that in the non-desaturation group ($n = 349$) (14% vs. 3.2%, $P = 0.001$) with more frequent postoperative stays in the intensive care unit (22% vs. 12%, $P = 0.004$). In a binary logistic regression analysis, preoperative ratio of arterial oxygen partial pressure to fractional inspired oxygen (PaO_2/FiO_2 ratio) (OR, 0.972; 95% CI 0.952–0.993; $P = 0.010$) and history of cardiovascular disease (OR, 2.127; 95% CI 1.004–4.507; $P = 0.049$) predicted postoperative desaturation.

Conclusions: Preoperative PaO_2/FiO_2 ratio, but not preoperative spirometry, was predictive of the postoperative desaturation in older patients after being administered spinal anesthesia for femur fracture surgery. Based on our results, preoperative ABGA may be helpful in predicting early postoperative desaturation in these patients.

Keywords: Arterial blood gas analysis; Femur neck fracture; Frail older individuals; Postoperative hypoxia; Spinal anesthesia; Spirometry.

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Introduction

Given rapid increases in older populations, frailty has become a medical issue of concern. Frailty is strongly associated with respiratory impairment and may substantially increase mortality [1]. In an analysis of the relationship between respiratory impairment (as determined by spirometry) and frailty, it was found that individuals aged 65 to 80 years with respiratory impairment were more likely to exhibit frailty and that older individuals with respiratory impairment and frailty had an elevated mortality rate [1]. Forced expiratory volume in 1 second (FEV_1) declines significantly during aging; this decline accelerates after 70 years of age and can lead to inadequate ventilation [2]. In individuals aged over 65, pulmonary function decline is independently associated with hospital admission and death [2]. Another cohort study analyzed the usefulness of forced vital capacity (FVC), FEV_1 , and FEV_1/FVC ratio data obtained by spirometry as well as respiratory symptoms as diagnostic tools for chronic obstructive pulmonary disease (COPD) and restrictive pulmonary disease [3] and concluded that severe and moderate COPD and restrictive lung disease were significantly associated with a higher risk of death [3]. Preoperative arterial blood gas analysis (ABGA) is not recommended as a routine preoperative evaluation, but due to the high incidence of pulmonary complications in older individuals with hip fractures, some clinicians recommend preoperative ABGA as a routine preoperative work-up in these patients [4].

Femur fractures are closely associated with frailty, also defined as a state of increased vulnerability due to age-related declines in physiological reserves [5]. In a clinical report, up to 72% of femur neck fracture patients were found to have postoperative hypoxia 1 day after surgery [6]. Although a recent analysis of data on 7,585 individuals (median age 80 years) reported that the mortality rates after general and regional anesthesia in older patients with hip fracture were similar [7–9], spinal anesthesia might be preferred in those at risk of postoperative respiratory impairment, as recovery of lung volume is probably greater after spinal anesthesia [10].

Despite the importance of post-anesthetic care in older individuals who represent a high health care burden, little information is available in the literature regarding the prediction of postoperative hypoxia after administering spinal anesthesia for femur fracture surgery in older patients. We hypothesized that a preoperative spirometric test and ABGA results might predict postoperative desaturation in extreme older individuals (≥ 80 years old) after spinal anesthesia administration for femur neck fracture surgery.

Materials and Methods

After obtaining approval from the ethics committee of our institute (GBIRB 2017-059), we reviewed the archived medical records of 534 patients treated at our hospital (a 1400-bed tertiary referral hospital) from January 2007 to November 2017. The keywords used for searching were “femur neck fracture” or “intertrochanter fracture” and an age of ≥ 80 years. Of the 534 records initially identified, 135 were excluded from the analysis (general anesthesia, 54 records; no spirometric results, 67; medical record loss, 14). Accordingly, the records of 399 patients were analyzed (349 of non-desaturation group and 50 of desaturation group). In accordance with our institute’s surgical evaluation protocol, all enrolled patients underwent a spirometric test and ABGA preoperatively. However, if patients were unable to undergo these tests due to their medical condition (such as unconsciousness, tracheostomy, or bed-ridden state), the patients were excluded from the analysis.

Spirometric testing included FVC, FEV_1 , and FEV_1/FVC ratio, and ABGA included arterial oxygen (PaO_2), PaO_2/FiO_2 ratio, carbon dioxide tension ($PaCO_2$), base deficit and lactate. Demographic data included preoperative histories that were categorized as cardiovascular, pulmonary, and central nervous system (CNS) diseases. Cardiovascular diseases included angina pectoris, myocardial infarction, congestive heart failure, valvular heart disease, atrial fibrillation, and high degree atrioventricular block. Pulmonary diseases included COPD, asthma, recent pneumonia, and advanced lung cancer. CNS diseases included cerebrovascular attack, Parkinson’s disease, intracranial hemorrhage, and advanced dementia. Perioperative data included pre or post-operative hypoxia, delirium, and major complications, such as hospital-acquired pneumonia, pulmonary embolism, cerebrovascular attack, uncompensated cardiac events, and mortality within three months after surgery. Other major morbidities were defined as life threatening conditions with or without major complications excluding mortality.

Spinal anesthesia was administered to patients in the lateral decubitus position using 0.5% heavy bupivacaine by anesthesiologists. Target sensory block levels were under the 6th thoracic segment (T6). During the spinal anesthesia administration, hemodynamic data and oxygen saturation (SpO_2 determined by pulse oximetry) were monitored. Most extreme older patients were not sedated during spinal anesthesia. However, if necessary, low doses of midazolam or dexmedetomidine were used according to the patient’s medical condition.

Patients were discharged from our post-anesthetic care unit when mean arterial pressure and heart rate were maintained within $\pm 20\%$ of baseline values, SpO_2 was $\geq 95\%$ with or without administration of O_2 at 1–3 L/min via a nasal prong, and sensory block level was $< T10$. Perioperative transfusion of

packed red blood cells was performed considering the hemodynamic parameters and hematocrit (target 30%). Early postoperative desaturation was defined as a SpO₂ of < 90% despite O₂ via a nasal prong within 3 days of surgery [11]. Hypotension was defined as a mean arterial pressure of < 80% of baseline and a systolic blood pressure of < 90 mmHg.

Patients were recommended O₂ at 1–3 L/min via a nasal prong as appropriate immediately postoperatively and SpO₂ was monitored bedside for all. On the day of surgery, the caregiver was trained to notify the nurse when SpO₂ was low (< 90%). When a desaturation event occurred, the nurses checked the patient and then notified the doctor. From 1-day postoperatively, SpO₂ was only monitored in bed-ridden patients during sleep and/or in patients who required a persistent oxygen supply according to previous SpO₂ or results of ABGA. Postoperative pain was controlled by intravenous injection of tramadol 100 mg or diclofenac 75 mg, when the pain score was over 5 using an 11-point numeric rating score (0–10).

Data were analyzed using SPSS ver. 17 (SPSS, Inc., USA). Values are presented as mean ± SD, median (interquartile range), or as numbers of patients (%). To evaluate the significance of differences between the desaturation and non-desaturation groups, we used an independent *t*-test for continuous variables

and a chi-square test as a non-parametric test. Binary logistic regression analysis was used to identify predictors of early postoperative desaturation. Receiver operating characteristic (ROC) curves were analyzed to determine whether any factor that was found to be statistically significant by binary logistic regression analysis could predict postoperative desaturation. Optimal cut-off value for predicting postoperative desaturation was determined using Youden index. Statistical significance was accepted for *P* values < 0.05. Propensity score matched cohort balanced on age, gender, previous morbidity except pulmonary disease, and laboratory values were analyzed to predict the effect of preoperative spirometric test on postoperative desaturation.

Results

Patient characteristics and perioperative transfusion requirements are presented in Table 1. The overall incidence of postoperative desaturation was 12.5% (50 of 399 patients). Mean age was 84.9 years in both non-desaturation groups and the desaturation and American Society of Anesthesiologists (ASA) physical statuses and previous histories of pulmonary diseases were similar in the two study groups.

Preoperative spirometric and ABGA results are detailed in Table 2. Preoperative PaO₂/FiO₂ ratio was significantly lower in the desaturation group than in the non-desaturation group (395 ± 79 vs. 366 ± 66, *P* = 0.006).

Postoperative courses are presented in Table 3. Overall 3-month mortality was 3.8% (15 of the 399 patients), and no intergroup difference was observed between the desaturation and non-desaturation groups (8% [4 of 50 patients] and 3% [11

Table 1. Patient Characteristics and Perioperative Transfusion

	Desaturation (n = 50)	Non- desaturation (n = 349)	<i>P</i> value
Age (yr)	84.9 ± 4.3	84.9 ± 5.9	0.940
Gender (M/F)	7/43	70/279	0.551
Weight (kg)	52.1 ± 11.9	52.6 ± 10.0	0.789
Height (cm)	153.4 ± 6.2	155.3 ± 7.9	0.119
Body mass index (kg/m ²)	22.1 ± 4.7	21.7 ± 3.7	0.507
ASA ≥ 3	29 (58)	166 (48)	0.167
Blocked level (thoracic segment)	6.0 (6.0–7.8)	6.0 (5.3–8.0)	0.193
Preoperative laboratory tests			
Low albumin (< 3.5 g/dl)	14 (28)	122 (35)	0.332
Abnormal BUN	20 (40)	165 (47)	0.334
Hemoglobin (g/dl)	11.1 ± 1.8	11.2 ± 1.7	0.712
Medical histories			
Cardiac diseases	12 (24)	53 (15)	0.114
Pulmonary diseases	2 (4)	36 (10)	0.155
CNS diseases	17 (34)	96 (28)	0.341
Intra-operative sedation			
Midazolam/dexmedetomidine	3/11	22/60	0.923
Postoperative PCA	49 (98)	337 (97)	0.983
Perioperative RBC transfusion	43 (86)	267 (77)	0.131

Values are presented as means ± SD, medians (interquartile range), or number of patients (%). ASA: American Society of Anesthesiologists, CNS: central nervous system. Low albumin: preoperative albumin level < 3.5 g/dl; Abnormal BUN: preoperative BUN level of < 8 or > 21 mg/dl, RBC: packed red blood cell, Postoperative PCA: postoperative opioid-based patient-controlled analgesia.

Table 2. Preoperative Spirometric Test and Arterial Blood Gas Analysis

	Desaturation (n = 50)	Non- desaturation (n = 349)	<i>P</i> value
Spirometry			
FEV ₁ (L)	1.15 ± 0.44	1.21 ± 0.44	0.396
FEV ₁ (%)	68.3 ± 23.1	74.5 ± 27.5	0.135
FVC (L)	1.56 ± 0.53	1.67 ± 0.58	0.214
FVC (%)	60.8 ± 17.4	65.8 ± 20.8	0.214
FEV ₁ /FVC ratio (%)	72.2 ± 11.2	72.2 ± 10.6	0.977
Arterial blood gas analysis			
pH	7.45 ± 0.04	7.45 ± 0.04	0.970
PaO ₂ (mmHg)	77.8 ± 23.8	81.2 ± 22.4	0.314
PaO ₂ /FiO ₂ ratio	366 ± 66	395 ± 79	0.006
PaCO ₂ (mmHg)	32.1 ± 6.6	32.4 ± 5.7	0.738
Base deficit (mmol/L)	−0.4 ± 2.9	−0.8 ± 3.6	0.557
Lactate (mmol/L)	1.0 ± 0.5	0.0 ± 0.6	0.931

Values are presented as mean ± SD. FEV₁: forced expiratory volume in 1 second, FVC: forced vital capacity, PaO₂/FiO₂ ratio: the ratio of arterial oxygen partial pressure to fractional inspired oxygen.

of 349 patients], respectively, $P = 0.092$). Fifteen patients died within three months of surgery due to the following reasons: sudden cardiac arrest ($n = 3$), septic shock ($n = 10$; 9 from pneumonia and 1 from a urinary tract infection), acute kidney injury ($n = 1$), and previous malignancy ($n = 1$). The causes of major morbidities (excluding death) were pneumonia, pulmonary thromboembolism, and upper gastrointestinal bleeding, and all of these morbidities occurred in the desaturation group. Overall major morbidity (including death) rates in the desaturation and non-desaturation groups were 14% (7 of 50 patients) and 3.2% (11 of 349 patients), respectively ($P = 0.001$). Hypotension was the most frequent postoperative complication in the desaturation and non-desaturation groups (46% [23 of 50 patients] and 45% [157 of 349 patients], respectively; $P = 0.906$). The occurrence of delirium was significantly higher in the desaturation group (40% [20 of 50 patients] vs. 26% [91 of 349 patients], $P = 0.04$), and postoperative ICU admission was more frequent in the desaturation group (22% [11 of 50 patients] vs. 12% [41 of 349 patients], $P = 0.004$). However, median durations [interquartile range] of ICU stay were similar in the desaturation and non-desaturation groups (5.5 [3–10.5] and 4 [2–7]; $P = 0.762$).

Regression analysis results for the prediction of postoperative

desaturation are presented in Table 4. Of the variables listed in Tables 1 and 2, peri-operative transfusions of RBCs, FEV₁ (%), FVC (%), preoperative PaO₂/FiO₂ ratio, and histories of cardiovascular and pulmonary diseases were found to differ in the two study groups with P values of < 0.2 by univariate regression analysis. In the multivariate regression analysis, PaO₂/FiO₂ ratio (OR, 0.972; 95% CI 0.952–0.993; $P = 0.010$) and histories of cardiovascular disease (OR, 2.127; 95% CI 1.004–4.507; $P = 0.049$) predicted postoperative desaturation after femur neck surgery under spinal anesthesia (Nagelkerke $r^2 = 0.08$). The ROC curve of PaO₂/FiO₂ ratio revealed that the area under the curve for predicting postoperative desaturation was 0.602 (95% CI 0.519–0.684, $P = 0.020$) and the optimal cut-off value was 351 (sensitivity, 63.3%; specificity, 60.0%).

Discussion

The incidence of early postoperative desaturation was 12.5% in older patients (aged ≥ 80 years) after femur neck surgery under spinal anesthesia in this retrospective study. Preoperative PaO₂/FiO₂ ratio, but not preoperative FVC and FEV₁ value of spirometry, was predictive of postoperative desaturation after femur neck surgery under spinal anesthesia. The incidences of major morbidities and delirium were higher in patients who experienced postoperative desaturation events. To the best of our knowledge, the present study represents the first attempt to determine the relationship between preoperative pulmonary function and postoperative desaturation in extreme older individuals.

Spirometry provides valuable information on the dynamics of pulmonary function. FEV₁ decline starts at age 30–40 years at a rate of 25–30 ml/year, but after age 70 this rate of decline doubles to 60 ml/year [4]. Some controversy exists regarding the ability of preoperative spirometry to predict postoperative pulmonary complications. In an earlier analysis, patients with an abnormal FEV₁ were observed to have higher pulmonary complication rates after vascular surgery [12], and in another analysis, six-fold increases in non-respiratory complications,

Table 3. Postoperative Morbidities and Mortalities in the Two Study Groups

	Desaturation (n = 50)	Non-desaturation (n = 349)	P value
Postoperative 3-month mortality	4 (8)	11 (3)	0.092
Delirium	20 (40)	91 (26)	0.040
Hypotension	23 (46)	157 (45)	0.906
Other major morbidities	3 (6)	0 (0)	< 0.001
Postoperative ICU admission	11 (22)	41 (12)	0.004
Length of ICU stay (days)	5.5 (3.0–10.5)	4.0 (2.0–7.0)	0.762

Values are presented as numbers of patients (%) or median (interquartile range). ICU: intensive care unit. Other major morbidities included pneumonia, pulmonary thromboembolism, and upper gastrointestinal bleeding.

Table 4. Regression Analysis for Predicting Postoperative Desaturation

Variables	Univariate analysis			Multivariate analysis		
	OR	95% CI	P value	OR	95% CI	P value
Perioperative transfusion	1.887	0.817–4.354	0.137	1.910	0.813–4.486	0.137
PaO ₂ /FiO ₂ ratio	0.974	0.954–0.995	0.015	0.972	0.952–0.993	0.010
FEV ₁ (%)	0.991	0.979–1.003	0.135	1.000	0.971–1.029	0.979
FVC (%)	0.987	0.972–1.003	0.108	0.989	0.952–1.027	0.568
Cardiac diseases	1.764	0.866–3.594	0.118	2.127	1.004–4.507	0.049
Pulmonary diseases	0.362	0.084–1.554	0.172	0.303	0.067–1.372	0.121

OR: odds ratio, 95% CI: 95% confidence interval, PaO₂/FiO₂ ratio: the ratio of arterial oxygen partial pressure to fractional inspired oxygen, FEV₁: forced expiratory volume in 1 second, FVC: forced vital capacity, Transfusion: perioperative packed red blood cell transfusion.

such as newly developed arrhythmia, congestive heart failure, upper gastrointestinal bleeding, wound infection, and prolonged hospital stay, were found to be associated with impaired FEV₁ or FVC (< 70%) [13]. However, in a study in patients aged > 60 years who underwent laparoscopic gastrectomy, it was concluded that preoperative spirometry findings do not predict postoperative pulmonary complications [14].

Normal aging causes PaO₂ and functional residual capacity to decrease and closing volume to increase. In a cross-sectional population-based survey, the strongest predictors of low oxygen saturation (SpO₂ < 95%) at a single-point measurement in the general adult population were found to be low predicted FEV₁ (< 50%) and a body mass index of > 35 kg/m²; other predictors were male gender, an age > 65 years, and smoking history [15]. In addition, Vold et al. [16] reported that low oxygen saturation was independently associated with all-cause mortality and lung disease-related mortality in an age- and sex-adjusted cohort study. But, when their analysis included predicted FEV₁% values, the strength of the association with lung disease-related mortality diminished but still remained significant [16]. No previous study has sought to identify predictors of postoperative desaturation in the extremely old. However, when considering the fact that age-adjusted analysis revealed the FEV₁% weakened the strength for predicting mortality [16], it would appear age-related changes in FEV₁ as well as the value of FEV₁% might be closely associated with mortality. Meanwhile, there was no correlation between the preoperative spirometry and early postoperative desaturation events, but there was a correlation with the preoperative PaO₂/FiO₂ ratio in the extreme older patients of this study. In a previous clinical study, the preoperative low PaO₂/FiO₂ ratio has been reported to significantly increase the postoperative complications [17].

General anesthesia tends to increase the rates of respiratory complications, such as airway hyperactivity, increased dead space volume, and changes in lung volume and dynamic parameters [18]. In a meta-analysis of 31 studies involving 3,231 patients who underwent hip fracture surgery, the incidence of deep vein thrombosis was significantly lower after regional than that after general anesthesia [19]. Thus, if regional anesthesia is possible, it may be preferred over general anesthesia in older individuals. In a comparison of pulmonary function changes in the young (20–59 years) and older (60–85 years) adults after spinal anesthesia, FVC, FEV₁, and FEF_{25–75} results were significantly reduced in the older but not in the younger adults [9]. However, unlike a previous study in which sensory block levels were > T6 [9], our target block levels for femur neck fracture surgery were < Th6, and thus, the effect of spinal anesthesia *per se* on pulmonary function may have been minimal in our study.

Although no correlation was observed between preoperative pulmonary function and postoperative desaturation events,

these events are known to be related to more events of delirium and major morbidities, including death, pneumonia, pulmonary thromboembolism, and upper gastrointestinal bleeding, and more frequent ICU stays. Furthermore, in the present study, 61% (11/18) of major morbidities were due to pulmonary complications. It is no surprise that hypoxia is accompanied by a neurologic manifestation such as restlessness or confusion and that delirium is present in many patients with hypoxia [20]. As aging progresses, older individuals become more vulnerable to respiratory complications because basal proinflammatory cytokine levels increase, respiratory function decreases, and immune response is progressively blunted [21–24]. In a recent retrospective analysis involving 140 patients aged ≥ 80 years who underwent emergency general surgery, ASA physical status was found to be the most powerful independent predictor of postoperative in-hospital mortality, and chronologic age and numbers of comorbidities were not found to predict surgical outcomes [25]. In this previous study, the overall mortality rate was 14.7% and the proportion of subjects with an ASA physical status of 3 or 4 was 90% [25]. However, the proportion of subjects in the present study with an ASA physical status of ≥ 3 was only 48% and we excluded patients without spirometric results due to a fragile medical condition or poor cooperation, and thus, our results cannot be applied generally to patients ≥ 80 years.

The present study has some limitations that warrant consideration. First, it is inherently limited by its retrospective nature. We could not find any conditions that might affect postoperative respiratory function, such as postoperative opioid consumption and a history of smoking or sleep apnea. In particular, the orders for rescue analgesics were usually conducted in *pro re nata* order, and hence, we could not confirm the actual use of analgesics. Second, we defined postoperative desaturation events using only SpO₂ that may have underestimated the occurrence of desaturation as pulse oximeters that can easily slip off fingers may not give accurate measurements. In addition, it might be difficult to define postoperative hypoxia only with pulse oximetry in older individuals who are vulnerable to poor peripheral blood circulation. Also, pulse oximetry might be inadequate for the diagnosis of hypoxia because there are many factors that may cause measurement errors, such as hypotension, hypothermia, and the use of vasopressors. Some clinical reports defined postoperative hypoxia as a PaO₂/FiO₂ ratio < 200 [26], but we have defined desaturation as a reduction of the SpO₂ instead of the PaO₂/FiO₂ ratio. A previous report has defined postoperative hypoxia as SpO₂ of < 90% [11]. Third, we analyzed medical records of patients who underwent spinal anesthesia and excluded patients with contraindications to neuro-axial anesthesia, such as bleeding diathesis or lack of cooperation, and exclusion of these patients with a severe underlying disorder may have influenced our results. Finally, Nagelkerke r², a goodness-of-fit mea-

sure for linear regression models, was only 0.08 in this study. This low value indicates that the percentage of the variances in the dependent variable that the independent variables explain collectively is low, and hence, a further large cohort study might be required to generalize our results.

In conclusion, preoperative PaO₂/FiO₂ ratio, but not preoperative spirometry, was predictive of the postoperative desaturation in older patients who were administered spinal anesthesia for femur fracture surgery. Based on our results, preoperative ABGA may be helpful in predicting early postoperative desaturation in such patients. Because postoperative desaturation is positively associated with morbidity, careful monitoring and appropriate management to prevent desaturation is essential in extreme older individuals.

Conflicts of Interest

No potential conflict of interest relevant to this article was

reported.

Author Contributions

Youn Yi Jo (Conceptualization; Writing–original draft)

Chun Gon Park (Data curation; Formal analysis)

Ji Yeon Lee (Data curation)

Sun Koo Kwon (Data curation)

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