Original Article

# Postoperative delirium and its influencing factors in elderly patients with lung cancer in the intensive care unit

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**Background:** In 2020, there were 2,206,771 new cases of lung cancer worldwide, ranking first in mortality rate postoperative delirium (POD) is a common surgical complication and typically occurs 1–3 days after surgery which leads to prolonged hospital stay. The currently available research on POD in elderly patients was mainly carried out in cardiac surgery, orthopedic, and gastroenterology departments. It is necessary to study the incidence and risk factors of delirium in intensive care unit (ICU) elderly patients after lung cancer surgery.

**Methods:** This study is a single-center and singe-arm observational study which examined the incidence of and factors affecting POD in elderly patients with lung cancer in ICU at our center from September 2019 to May 2020. 22 relevant variables including arterial oxygen partial pressure, postoperative sedative drug use, and other data were collected. The Confusion Assessment Method of Intensive Care Unit was used to assess the occurrence of POD, the Chinese version of the Richards-Campbell Sleep Questionnaire was used to assess patients' postoperative sleep quality, and the Mini-Mental State Examination was used to assess patients' preoperative cognitive level. Univariate and multivariate logistic regression analyses were conducted to identify the factors affecting POD in elderly ICU patients with lung cancer.

**Results:** Among the 208 elderly ICU patients who underwent surgery for lung cancer, 32 (15.38%) had POD. The results showed that postoperative blood oxygen level, preoperative cognitive level score and postoperative sleep quality score in delirium group were significantly lower than those in non-delirium group (P values were 0.002, 0.000, 0.000, respectively). The proportion of previous coronary heart disease and postoperative sedation use in delirium group was significantly higher than that in non-delirium group (P=0.008 and 0.008, respectively).

**Conclusions:** It was observed that the preoperative Mini-Mental State Examination (MMSE) score and postoperative Richards-Campbell Sleep Questionnaire (RCSQ) score of the delirium group were significantly lower than those of the non-delirium group, and this trend was still observed after adjusting for influencing factors. It is suggested that the difference of cognitive level in elderly lung cancer population has a significant effect on the occurrence of POD. In clinical work, we should pay more attention to patients with preoperative cognitive impairment, hypoxic state, and postoperative sleep disturbance.

**Keywords:** Lung cancer; intensive care unit (ICU); elderly patients; postoperative delirium (POD); factors

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## Introduction

According to Global Cancer Statistics, lung cancer remained the leading cause of cancer-related deaths in 2020 (1). Most individuals (about 65%) diagnosed with lung cancer are aged ≥60 years (2,3). Surgery remains the mainstay treatment for this malignancy (4). Postoperative delirium (POD) is a common surgical complication and typically occurs 1–3 days after surgery (5). It manifests as cognitive impairment and attention decline, which affect the quality of life of patients after surgery (6). According to the *Guidelines on Risk Reduction and Management of Delirium* released by the Scottish Intercollegiate Guidelines Network (SIGN) in 2019, several predisposing factors increase the risk of delirium, including an older age, dementia, frailty, the presence of multiple comorbidities, male sex, sensory impairments, a history of depression, a history of delirium, and alcohol misuse (7).

Few Chinese studies have explored POD in elderly lung cancer patients, and the currently available research on POD in elderly patients was mainly carried out in cardiac surgery, orthopedic, and gastroenterology departments. It is generally believed that the prevention of delirium lies in correcting the predisposing factors, and multidisciplinary teamwork using non-pharmacological preventive measures should be applied. The value of POD prevention has gained increasing recognization in China; however, there is still a lack of clinical research on the risk factors of POD in elderly lung cancer patients. In this study, we investigated POD and the factors affecting POD in elderly intensive care unit (ICU) patients with lung cancer. Our findings may inform the development of delirium prevention programs in the future. We present the following article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-259/rc).

### Highlight box

**Key findings**

- Hypoxic state, a history of coronary artery disease, a sedative use, preoperative cognitive impairment, and postoperative sleep disturbance were all factors affecting POD in elderly ICU patients with lung cancer.

**What is known and what is new?**

- Current research on POD in elderly patients is mainly carried out in cardiac surgery, orthopedics and gastroenterology.
- Among the 208 elderly ICU patients who underwent surgery for lung cancer, 32 (15.38%) had POD. In our study we found five factors affecting POD in elderly ICU patients with lung cancer.

**What is the implication, and what should change now?**

- This study analyzed the influencing factors of delirium in elderly lung cancer population. And, the early identification of POD and the implementation of interventions for POD in high-risk populations could help to reduce the occurrence of POD and promote postoperative recovery.

## Methods

### *Subjects*

This study is a pilot study to observe the incidence of POD in lung cancer patients ≥60 years from September 2019 to May 2020. All patients who met the inclusion criteria during this time period were observed in this study. And the investigator will guide the next multi-center two-arm prospective study design according to the incidence and risk factors of this study. The data of 208 patients admitted to the ICU after lung tumor resection at the Shanghai Chest Hospital, School of Medicine, Shanghai Jiao Tong University were included in this analysis. To be eligible for inclusion in this study, the patients had to meet the following inclusion criteria: (I) be aged ≥60 years; (II) have been sent directly from the operating room to the ICU after surgery; and (III) have a diagnosis of lung cancer confirmed by intraoperative pathology. Patients were excluded from the study if they met any of the following exclusion criteria: (I) could not verbally communicate with the staff; and/or (II) had a postoperative ICU stay <24 hours or >7 days. Video-assisted thoracic surgery (including da Vinci robotic surgery) and/or open surgery were performed, and the specific surgical procedures included wedge resection, lobectomy, segmentectomy, sleeve resection, and total pneumonectomy. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by institutional ethics committee of Shanghai Chest Hospital, School of Medicine, Shanghai Jiao Tong University (No. IS22077) and informed consent was taken from all the patients.

### *Assessment of clinical covariates*

The following demographic and clinical data were obtained by searching the electronic medical records and asking patients or their families for information: gender, age, smoking history, diabetes history, hypertension history, coronary heart history, brain disease history, depression, forced expiratory volume in the first second ($FEV_1$), receiving surgery for the first time (yes/no),

**Table 1** Postoperative delirium in elderly ICU patients with lung cancer

| Condition of delirium | n=208 | Percentage (%) |
|---|---|---|
| Type of postoperative delirium | 32 | 15.38 |
| Hyperactive | 12 | 37.50 |
| Hypoactive | 6 | 18.75 |
| Mixed | 14 | 43.75 |
| Time to delirium | | |
| On the operating day | 2 | 6.25 |
| Postoperative day 1 | 6 | 18.75 |
| Postoperative day 2 | 13 | 40.63 |
| Postoperative day 3 | 10 | 31.25 |
| Postoperative day 4 | 1 | 3.12 |
| Duration of delirium | | |
| 1 day | 3 | 9.37 |
| 2 days | 18 | 56.25 |
| 3 days | 10 | 31.25 |
| 4 days | 1 | 3.13 |

ICU, intensive care unit.

preoperative cognitive score, partial pressure of oxygen ($PaO_2$), partial pressure of carbon dioxide ($PaCO_2$), potassium concentration, sodium concentration, calcium concentration, sedative use, blood transfusion history, hemoglobin concentration, white blood cell (WBC) count, and length of ICU stay. The Confusion Assessment Method of Intensive Care Unit (CAM-ICU) was used to assess the occurrence of POD (8). The Chinese version of the Richards-Campbell Sleep Questionnaire (RCSQ) was used to assess patients' postoperative sleep quality (9). The Mini-Mental State Examination (MMSE) was used to assess patients' preoperative cognitive level (10).

### *Diagnosis of POD*

CAM-ICU was developed by the American Association for Mental Illness DSM (Diagnostic and Statistical Manual of Mental Disorders·Fourth Edition) as the gold standard for POD assessment in ICU. The first session of delirium assessment was performed by a professional investigator immediately after each patient awoke in the ICU, and the subsequent delirium assessments were administered at 8-hour intervals (i.e., at 6.00 am, 2.00 pm, and 10.00 pm); the last delirium assessment was performed at the time of discharge from the ICU. The CAM-ICU tool assesses the following 4 features: (I) the acute onset of mental status changes, or a fluctuating course; (II) inattention; (III) altered levels of consciousness; and (IV) disorganized thinking. A diagnosis of delirium was made if a patient manifested features I and II, plus either of features III or IV. Patients on sedative medications were evaluated for agitation/sedation using the Richmond Agitation-Sedation Scale (RASS) (11), and a CAM-ICU-based delirium assessment was only performed if the RASS score was ≥–3. The RASS scores can range from +4 to –5 points, with positive scores indicating agitation, negative scores indicating sedation, and a score of 0 indicating "Alert and calm." Except for the score of 0, the other scores indicate that the patient manifested feature IV. The time to delirium and the duration of delirium are presented in "days".

### *Statistical analysis*

The statistical analysis was performed using the SPSS 24.0 software package. The normally distributed measurement data are presented as the mean ± standard deviation and were compared using the *t*-test. The non-normally distributed data are presented as the median (M) and quartile (Q) and were compared using the rank-sum test. The count data are presented as the frequency and percentage and were compared using the chi-square test. A multivariate logistic regression analysis was performed to analyze the factors affecting delirium.

## Results

The data of 208 elderly lung cancer patients were included in this analysis, including 32 patients with POD (who constituted the delirium group and accounted for 15.38% of all the patients) and 176 patients without POD (who constituted the non-delirium group). The types of delirium included hyperactive (n=12), hypoactive (n=6), and mixed (n=14). Delirium occurred on the day of surgery (n=2), postoperative day 1 (n=6), postoperative day 2 (n=13), postoperative day 3 (n=10), and postoperative day 4 (n=1). Delirium lasted 1 day in 3 patients, 2 days in 18 patients, 3 days in 10 patients, and 4 days in 1 patient. The mixed type was the most commonly observed type of delirium in the elderly ICU patients with lung cancer, and in most cases, the delirium occurred on the 2nd post-operative day and lasted 2 to 3 days (*Table 1*).

There was no significant statistical difference in the

**Table 2** Comparison of measurement data between the delirium group and non-delirium group

| Items | Delirium group (n=32), mean ± SD | Non-delirium group (n=176), mean ± SD | Statistics | P value |
|---|---|---|---|---|
| Age (years) | 69.63±5.863 | 67.78±5.405 | 1.749 | 0.082 |
| Length of ICU stay (days) | 3.94±2.627 | 3.12±1.370 | 1.72 | 0.094 |
| $FEV_1$ (%) | 89.98±18.08 | 92.05±16.03 | –0.661 | 0.509 |
| $PaO_2$ (mmHg) | 87.94±27.34 | 109.62±37.25 | –3.139 | 0.002 |
| $PaCO_2$ (mmHg) | 44.26±5.53 | 43.50±4.83 | 0.797 | 0.426 |
| $K^+$ (mmol/L) | 3.78±0.41 | 3.76±0.46 | 0.239 | 0.811 |
| $Na^+$ (mmol/L) | 140.75±2.31 | 140.60±3.19 | –0.260 | 0.796 |
| $Ca^{2+}$ (mmol/L) | 1.14±0.48 | 1.22±0.81 | 1.60 | 0.111 |
| Hemoglobin (g/L) | 12.75±1.24 | 12.31±1.70 | –1.4 | 0.163 |
| WBC count ($10^9$/L) | 12.06±4.94 | 10.65±3.42 | –1.548 | 0.130 |
| MMSE score | 27.75±2.14 | 29.56±1.18 | 6.896 | 0.000 |
| RCSQ score | 16.44±5.53 | 25.78±4.88 | 9.747 | 0.000 |

ICU, intensive care unit; FEV1, forced expiratory volume in the first second; $PaO_2$, partial pressure of oxygen; $PaCO_2$, partial pressure of carbon dioxide; WBC, white blood cell; MMSE, Mini-mental state examination; RCSQ, Richards-Campbell Sleep Questionnaire.

**Table 3** Effects of different arterial oxygen partial pressure on the occurrence of delirium

| Partial pressure of oxygen | ≤60 mmHg | 60–80 mmHg | 80–100 mmHg | ≥100 mmHg |
|---|---|---|---|---|
| Delirium group | 3 (9.37%) | 10 (31.25%) | 11 (34.38%) | 8 (25.00%) |
| Non-delirium group | 3 (1.70%) | 32 (18.19%) | 53 (30.11%) | 88 (50.00%) |
| F value | 11.639 | – | – | – |
| P value | 0.009 | – | – | – |

$PaO_2$, partial pressure of oxygen.

continuous variables including age, duration of ICU stay, FEV1%, $PaCO_2$, potassium ($K^+$), sodium ($Na^+$), calcium ($Ca^{2+}$), hemoglobin (Hb), postoperative inflammatory markers (including WBC count) between the two groups while there was significant statistical difference in the $PaO_2$ and RCSQ scores. $PaO_2$ was significantly lower in the delirium group than the non-delirium group, which suggests that a decrease in $PaO_2$ might precipitate POD (*Table 2*). To further examine the effect of $PaO_2$ on POD, $PaO_2$ was stratified into ≤60, 60–80, 80–100, and ≥100 mmHg. The results showed that the incidence of delirium increased significantly when the postoperative $PaO_2$ was ≤60 mmHg (*Table 3*).

There was no significant statistical difference in the categorical variables including gender, smoking history, hypertension history, diabetes history, receiving surgery for the first time (yes/no) and brain disease history between the two groups. It was found that coronary heart disease history and sedative use differed significantly between the delirium and non-delirium groups (*Table 4*).

Mosk *et al.* have found a strong correlation between age and POD, in which an older age (especially, an age >75 years) was found to be associated with a higher incidence of delirium (12). In the current study, the age of the patients was stratified into <65, 65–75, and >75 years. The incidence of delirium did not differ significantly among the age-stratified groups, which might be because all the enrolled patients were ≥60 years (*Table 5*).

A model of RCSQ scale and delirium risk was established. After a variety of factors affecting the regression model of the RCSQ scale had been adjusted, we found that patients with an RCSQ score of >20 points had a 25% lower risk

**Table 4** Comparison of the count data between the delirium group and non-delirium group

| Items | Delirium group (n=32) | | Non-delirium group (n=176) | | Statistics | P value |
|---|---|---|---|---|---|---|
| | n | Percentage, % | n | Percentage, % | | |
| Gender | | | | | 0.091 | 0.763 |
| Male | 20 | 62.50 | 105 | 59.66 | | |
| Female | 12 | 37.50 | 71 | 40.34 | | |
| History of smoking | | | | | 1.281 | 0.258 |
| Yes | 9 | 28.12 | 34 | 19.32 | | |
| No | 23 | 71.88 | 142 | 80.68 | | |
| History of diabetes | | | | | 0.039 | 0.843 |
| Yes | 5 | 15.62 | 19 | 10.80 | | |
| No | 27 | 84.38 | 157 | 89.20 | | |
| History of hypertension | | | | | 0.158[a] | 0.691 |
| Yes | 13 | 40.62 | 65 | 36.93 | | |
| No | 19 | 59.38 | 111 | 63.07 | | |
| History of brain disease | | | | | 1.006 | 0.302 |
| Yes | 4 | 12.50 | 10 | 5.68 | | |
| No | 28 | 87.50 | 166 | 94.32 | | |
| History of coronary heart disease | | | | | 6.980 | 0.008 |
| Yes | 9 | 28.13 | 19 | 10.80 | | |
| No | 23 | 71.87 | 157 | 89.20 | | |
| Sedative use | | | | | 6.955 | 0.008 |
| Yes | 3 | 9.37 | 1 | 0.57 | | |
| No | 29 | 90.63 | 175 | 99.43 | | |
| History of depression | | | | | | |
| Yes | 2 | 100 | 30 | 14.56 | 11.107[a] | 0.001 |
| No | 0 | 0 | 176 | 85.44 | | |

[a], Fisher's exact test.

**Table 5** Incidence rates of delirium in elderly patients as stratified by age

| Age strata | <65 years | 65–75 years | >75 years |
|---|---|---|---|
| Delirium group | 8 (25.00%) | 17 (53.13%) | 7 (21.87%) |
| Non-delirium group | 67 (38.07%) | 92 (52.27%) | 17 (9.66%) |
| F value | 4.788 | – | – |
| P value | 0.091 | – | – |

**Table 6** Results of the binary logistic multivariate regression analysis

| Variables in the equation | Variables | B | Standard error | Wald test | Degree of freedom | Significance | Exp (B) | 95% confidence interval | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lower limit | Upper limit |
| Step 1[a] | RCSQ score | –0.281 | 0.139 | 4.101 | 1 | 0.043 | 0.755 | 0.576 | 0.991 |
| | History of sedative drug use | 2.371 | 1.283 | 3.416 | 1 | 0.065 | 10.713 | 0.867 | 132.433 |
| | Age stratification (<65 years) | | | 3.892 | 2 | 0.143 | | | |
| | Age stratum (65–75 years) | 1.314 | 0.673 | 3.816 | 1 | 0.05 | 3.72 | 0.996 | 13.899 |
| | Age stratum (>75 years) | 0.919 | 0.617 | 2.217 | 1 | 0.136 | 2.507 | 0.748 | 8.405 |
| | $PaO_2$ stratification (≤60 mmHg) | | | 5.773 | 3 | 0.123 | | | |
| | $PaO_2$ stratum (60–80 mmHg) | –2.281 | 1.132 | 4.063 | 1 | 0.044 | 0.102 | 0.011 | 0.939 |
| | $PaO_2$ stratum (80–100 mmHg) | –1.014 | 0.589 | 2.964 | 1 | 0.085 | 0.363 | 0.114 | 1.151 |
| | $PaO_2$ stratum (≥100 mmHg) | –0.565 | 0.573 | 0.971 | 1 | 0.324 | 0.568 | 0.185 | 1.748 |
| | History of coronary heart disease | 0.902 | 0.598 | 2.274 | 1 | 0.132 | 2.464 | 0.763 | 7.956 |
| | Gender | –0.318 | 0.491 | 0.419 | 1 | 0.517 | 0.728 | 0.278 | 1.904 |
| | History of brain disease | –1.184 | 0.739 | 2.568 | 1 | 0.109 | 0.306 | 0.072 | 1.302 |
| | Receiving surgery for the first time (yes/no) | 0.091 | 0.514 | 0.031 | 1 | 0.859 | 1.095 | 0.4 | 3 |
| | $PaCO_2$ | | 0.046 | 0.155 | 1 | 0.694 | 0.982 | 0.898 | 1.074 |
| | Constant | | 28,405.781 | 0 | 1 | 0.999 | 0 | | |

[a], variables entered in step 1: RCSQ score, sedative use, age strata, oxygen, coronary heart disease, depression, gender, brain disease, receiving surgery for the first time (yes/no), and $PaCO_2$. $PaO_2$, partial pressure of oxygen; $PaCO_2$, partial pressure of carbon dioxide; RCSQ, Richards-Campbell Sleep Questionnaire.

of POD than those with an RCSQ score of <20 points. In addition, patients aged >75 years had a 3-fold higher risk of POD than those aged <65 years. Thus, active interventions should be implemented in patients aged >75 years with RCSQ scores of <20 points to decrease the occurrence of delirium (*Table 6*).

A model of MMSE scale and delirium risk was also established. After a variety of factors affecting the regression model of the MMSE scale had been adjusted, we found that patients with MMSE scores of >27 points had a 94% lower risk of POD than those with MMSE scores of <27 points. Patients who had used sedatives had a 13-fold higher risk of developing delirium than those who had not. The results also revealed that patients with $PaO_2$ >100 mmHg had a 93% lower risk of POD than those with $PaO_2$ between 60–80 mmHg. Thus, for patients with MMSE scores of <27 points who are using sedatives and have $PaO_2$ between 60–80 mmHg, active interventions need to be implemented to prevent the occurrence of delirium (*Table 7*).

## Discussion

The patient's predisposing factors (as old age, dementia, alcoholism, high blood pressure, etc.), the disease itself and the precipitating factors (as postoperative pain, ventilator use time, use of sedative drugs, etc.) all work together to cause delirium (13). The incidence of delirium in ICU remains high, which is also related to insufficient attention and early intervention of precipitating factors in ICU.

Delirium is a common complication following surgical interventions in elderly ICU patients with lung cancer. In our current cross-sectional survey, the incidence of POD was relatively high (15.38%; mainly the mixed type) in the elderly ICU patients with lung cancer. Delirium typically occurred 2–3 days after surgery and lasted 2–3 days, which is consistent with other findings reported in the literature. For example, He *et al.* found that the incidence of POD in elderly lung cancer patients was 7% (14). Shiono *et al.* reported that the incidence of POD was 8.4% (10/119)

**Table 7** Results of the binary logistic multivariate regression analysis

| Variables in the equation | Variables | B | Standard error | Wald test | Degree of freedom | Significance | Exp (B) | 95% confidence interval | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lower limit | Upper limit |
| Step 1[a] | MMSE stratification | –2.883 | 0.707 | 16.606 | 1 | 0 | 0.056 | 0.014 | 0.224 |
| | Sedative use | 2.569 | 1.247 | 4.241 | 1 | 0.039 | 13.05 | 1.132 | 150.438 |
| | Diabetes | –0.675 | 0.748 | 0.815 | 1 | 0.367 | 0.509 | 0.118 | 2.204 |
| | Coronary heart disease | 1.227 | 0.677 | 3.281 | 1 | 0.07 | 3.41 | 0.904 | 12.861 |
| | Brain disease | 1.181 | 0.831 | 2.018 | 1 | 0.155 | 3.256 | 0.639 | 16.598 |
| | Receiving surgery for the first time (yes/no) | 0.362 | 0.593 | 0.372 | 1 | 0.542 | 1.436 | 0.449 | 4.59 |
| | $PCO_2$ | –0.052 | 0.052 | 1.014 | 1 | 0.314 | 0.949 | 0.858 | 1.051 |
| | WBC | –0.115 | 0.062 | 3.376 | 1 | 0.066 | 0.892 | 0.789 | 1.008 |
| | Gender | –0.146 | 0.547 | 0.072 | 1 | 0.789 | 0.864 | 0.296 | 2.524 |
| | Age stratification (<65 years) | | | 0.614 | 2 | 0.736 | | | |
| | Age stratum (65–75 years) | 0.54 | 0.782 | 0.477 | 1 | 0.49 | 1.716 | 0.371 | 7.94 |
| | Age stratum (>75 years) | 0.15 | 0.704 | 0.045 | 1 | 0.832 | 1.162 | 0.292 | 4.62 |
| | $PaO_2$ stratification (≤60 mmHg) | | | 5.689 | 3 | 0.128 | | | |
| | $PaO_2$ stratum (60–80 mmHg) | –1.696 | 1.154 | 2.158 | 1 | 0.142 | 0.183 | 0.019 | 1.762 |
| | $PaO_2$ stratum (80–100 mmHg) | –1.41 | 0.651 | 4.691 | 1 | 0.03 | 0.244 | 0.068 | 0.875 |
| | $PaO_2$ stratum (≥100 mmHg) | –0.683 | 0.652 | 1.098 | 1 | 0.295 | 0.505 | 0.141 | 1.812 |
| | Constant | –32.297 | 28,293.993 | 0 | 1 | 0.999 | 0 | | |

[a], variables entered in step 1. MMSE, mini-mental state examination; $PaO_2$, partial pressure of oxygen; WBC, white blood cell.

in elderly lung cancer patients with a median age of 77 years (15). Murakawa *et al.* found the incidence of POD of postoperative patients with lung or esophageal cancer was 25% (16). Thus, the risk of POD should be closely observed in elderly lung cancer patients.

Among the various surgical operations, thoracic surgery has a long operative time, large surgical trauma, and severe postoperative pain, and accordingly the incidence of POD in patients is not low after thoracic surgery (14). POD can adversely affect patients, and their families and caregivers. It has been associated with poor clinical outcomes, a lower quality of life, prolonged hospital stays, and cognitive decline, and cognitive deficits can persist even after discharge (17,18). ICU delirium is also harmful to the physical and mental health of patients' families. Breitbart *et al.* revealed that 80% of ICU patients with delirium experienced severe depression, and 76% of patients' families experienced the same degree of depression. Delirium is also a highly distressing experience for spouses and caregivers (19). For ICU medical staff who have the most direct contact with delirium patients and the caregivers of delirium patients, caring for these patients is challenging. Russ *et al.* (20) noted that caring for patients with delirium in the ICU is difficult and distressing. Thus, POD in elderly lung cancer patients in the ICU should not be neglected.

### *Effects of sleep deprivation on POD in elderly ICU patients with lung cancer*

Li *et al.* found that sleep deprivation, which is a strong stress trigger, is a high-risk factor for ICU delirium (21), and sleep management is key in the prevention and treatment of delirium. Sun *et al.* recommended a sleep duration of 7–8 hours for elderly patients aged 65 years and older (22).

In the current study, the RCSQ-based sleep assessment was performed every morning from postoperative ICU admission to ICU discharge, and the results showed that the average RCSQ score after surgery in 208 patients was

low (24.34±6.01 points). The postoperative sleep quality was low in the delirium group, which had an average RCSQ score of only 16.44±5.53 points. Of the 32 patients in the delirium group, 7 scored 0 points for the item "fall back asleep soon after waking up", indicating that they could not fall asleep again after waking up, and 6 scored 0 for the item, "overall sleep quality", indicating that their overall sleep quality was very poor. All the 32 patients in the delirium group responded that they slept shallowly at night during their stay in the ICU and were prone to sleep disruption at night due to various noises produced by instruments, such as electrocardiogram and blood pressure monitors. Of the 32 patients, 21.875% replied that they could not fall back to sleep after waking up, resulting in a significant decrease in sleep quality.

During the ICU admission after surgery, many factors may affect the sleep of elderly patients. According to Yang *et al.* (23), the noise in the ICU mainly comes from the sounds made by monitors, rescue instruments, vacuum suction device, and other machines, the communication between medical staff and patients, and metal collisions. Noise deprives patients of slow-wave sleep and fast-wave sleep, which may be one of the main causes of POD (24). For elderly patients who need to be admitted to the ICU after lung cancer surgery, their sleep status should be closely monitored. Non-drug interventions, such as a glass of milk, music therapy, and/or back massage, should be appropriately applied for patients with poor sleep quality to ensure normal rest during their ICU stay.

In the current study, the average postoperative RCSQ score of the non-delirium group was 25.78±4.88 points, and the difference between the delirium and non-delirium groups was statistically significant, which suggests that a lower RCSQ score in elderly lung cancer patients was associated with an increased risk of delirium. Thus, ICU medical staff should pay close attention to the effects of sleep quality on POD and implement appropriate prevention and management measures.

The multivariate regression analysis showed that patients with an RCSQ score of >20 points had a 25% lower risk of POD than those with an RCSQ score of <20 points. In addition, patients aged >75 years had a 3-fold higher risk of developing delirium than those aged <65 years. Thus, the sleep quality of patients aged >75 years with RCSQ scores of <20 points should be carefully assessed, and early interventions should be implemented to prevent the occurrence of POD.

### *Effects of cognitive impairment on POD in elderly ICU patients with lung cancer*

Xu *et al.* conducted a meta-analysis on whether cognitive exercise can improve the occurrence of delirium in ICU patients, and the results showed that cognitive exercise in ICU can reduce the incidence and duration of delirium in hospitalized ICU patients and shorten the length of stay (25). Du *et al.* (26) found that cognitive impairment was an independent risk factor for POD in elderly patients. Similarly, the present study showed that the risk of POD was significantly increased in patients with preoperative cognitive impairment (i.e., a MMSE score of <27 points). Notably, 10 (31.25%) of the 32 patients in the delirium group had a preoperative MMSE score of <27 points, but only 3 (1.71%) of the 176 patients in the non-delirium group had cognitive impairment before surgery. Elderly patients with preoperative cognitive impairment should receive active interventions. Once POD occurs, it can lead to prolonged ICU stays, limit patients' activities, and delay their surgical recovery. Even worse, it can have adverse effects on patients' long-term cognition and seriously undermine their clinical outcomes. Lu *et al.* (27) showed that elderly patients with POD had a greater decline in daily-living activities and a higher mortality rate within 36 months.

In the present study, a model of MMSE scale and delirium risk was established. After a variety of factors affecting the regression model of the MMSE scale were adjusted, we found that patients with an MMSE score of >27 points had a significantly lower risk of POD than patients with an MMSE score of <27 points. Patients who had used sedatives had a 13-fold higher risk of developing delirium than those who had not. The data stratification also revealed that the risk of POD in patients with $PaO_2$ >100 mmHg had a 93% lower risk of POD than those with $PaO_2$ between 60–80 mmHg. Thus, for elderly patients with cognitive impairment before surgery, the use of postoperative sedative should be minimized. Additionally, postoperative oxygenation should be monitored to avoid hypoxemia, and active and effective interventions should be implemented to prevent the occurrence of POD.

### *Effects of hypoxemia on POD in elderly ICU patients with lung cancer*

Li *et al.* (21) reported that the hypoxic duration was a risk factor for ICU delirium duration. Xiang *et al.* (28) revealed

that hypoxia affected the duration of POD in elderly patients. The apoptosis of neurons and the deterioration of brain tissue functions gradually occur with aging. The decreased cerebral blood flow and the decline in glucose metabolism function make elderly individuals more sensitive to hypoxia. As a result, the incidence of delirium is high in elderly populations, especially in those aged >65 years. In the current study, the mean $PaO_2$ after surgery was 106.28±36.69 mmHg, and it was 87.94±27.34 mmHg in the delirium group, which was significantly lower than that in the non-delirium group. Thus, elderly patients with postoperative hypoxia are more likely to develop delirium. ICU medical staff should pay special attention to this condition and implement timely and effective interventions.

## Conclusions

Lung cancer is one of the most common malignancies worldwide, and surgical resection is the mainstay of treatment for lung cancer. However, POD can seriously impair the postoperative recovery of elderly ICU patients with lung cancer. This cross-sectional investigation revealed that the risk factors of POD in elderly lung cancer patients included hypoxia, a history of coronary heart disease, poor postoperative sleep quality, and preoperative cognitive impairment. The early identification of POD and the implementation of interventions for POD in high-risk populations could help to reduce the occurrence of POD and promote postoperative recovery.

This single-center, single-arm observational study found that preoperative cognitive level and postoperative sleep quality have clinical significance in predicting the incidence of postoperative delirium and the occurrence of postoperative delirium in ICU elderly patients with lung cancer. However, the present study was limited by its single-center design and small sample size. This conclusion is only applicable to the elderly patients after lung cancer surgery. Since this study only investigated the incidence and risk factors of postoperative delirium in elderly lung cancer patients in a single center, a prospective study with a large sample size is needed to clarify the weight of risk factors for delirium in this study, so as to provide clinical guidance for further identifying the construction of postoperative delirium prevention programs for elderly lung cancer patients.

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## Footnote

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*Ethical Statement:* The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by institutional ethics committee of Shanghai Chest Hospital, School of Medicine, Shanghai Jiao Tong University (No. IS22077) and informed consent was taken from all the patients.



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