Original Article

Seven preoperative factors have strong predictive value for postoperative pneumonia in patients undergoing thoracoscopic lung cancer surgery

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Background: Postoperative pneumonia (POP) is a hospital acquired pneumonia that occurs >48 hours after tracheal intubation. The diagnosis of POP should be based on clinical and radiological findings within 30 days after surgery. It is a common complication after thoracoscopic surgery for lung cancer patients. However, the specific impact of preoperative comorbidities on the incidence of POP remains unclear. This study aimed to analyze the preoperative data of patients with lung cancer to help surgeons predict the risk of incidence of POP after thoracoscopic lung resection.

Methods: This study is a prospective study that included patients with lung cancer who were scheduled for thoracoscopic surgery in 1 year. All cases came from two medical centers. Preoperative demographic information, tumor information, preoperative comorbidities, quality of life scores, and incidence of POP were collected. Variables were screened by univariate analysis and multivariate regression. Finally, a prediction model was constructed. A total of 53 preoperative factors were included as candidate predictors. The binary outcome variable was defined as the presence or absence of POP. The incidence of POP was the primary outcome variable. The predictive performance of the model was verified internally through 1,000 iterations of bootstrap resampling.

Results: A total of 1,229 patients with lung cancer who underwent thoracoscopic surgery were enrolled. In addition, 196 cases (15.95%) had POP; 1,025 (83.40%) patients had comorbid conditions. The total number of comorbidity diagnosed in all samples was 2,929. The prediction model suggested that patients with advanced age, high body mass index (BMI), smoking, poor physical condition, respiratory diseases, diabetes, and neurological diseases were more likely to develop POP. The area under the curve (AUC) and Brier scores were 0.851 and 0.091, respectively. The expected and observed results were in strong agreement, according to the likelihood of POP calibration curve.

Conclusions: The constructed model is capable of evaluating the probability of POP occurrence in patients with lung cancer. Seven preoperative factors in patients with lung cancer were found to be associated with increased probability of having pneumonia after thoracoscopic lung resection. This model can help predict the incidence of POP after surgery.

Keywords: Lung cancer; thoracoscopic surgery; comorbidities; pneumonia

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Introduction

Comorbidity, also known as multimorbidity, refers to the condition in which the case has one or more chronic diseases or health problems (1). Comorbidity can affect the treatment outcomes and quality of life for patients with the primary diagnosed disease (2-5). Lung cancer is second most common cancer, but with the highest mortality. Patients with lung cancer often have preexisting comorbidities (6,7), such as age-related conditions and other diseases. Various assessment tools have been developed to predict postoperative risk based on these comorbidities. However, these tools are more suitable for evaluating long-term prognosis rather than short-term outcomes (8,9). Therefore, there is a need for comorbidity assessment tools that can accurately predict short-term prognosis after lung cancer surgery. Furthermore, many patients experience postoperative pneumonia (POP) after lung cancer surgery. The aim of this study was to investigate the impact of preoperative comorbidities on the occurrence of POP in lung cancer patients undergoing thoracoscopic surgery. We present this article in accordance with the TRIPOD reporting checklist (available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-23-512/rc).

Highlight box

Key findings

- This study developed a highly accurate model for predicting the incidence of postoperative pneumonia (POP) in patients undergoing thoracoscopic lung resection for lung cancer. A numerical risk stratification for POP was established, assigning points to various factors.

What is known and what is new?

- Age, chronic obstructive pulmonary disease, cardiovascular diseases, cerebrovascular diseases, and diabetes were identified as negative prognostic factors for lung cancer.
- The study emphasized the importance of evaluating these risk factors and implementing preventive measures in high-risk patients.

What is the implication, and what should change now?

- Multidisciplinary collaboration and personalized care were highlighted as crucial in optimizing outcomes for thoracoscopic lung resection patients.

Methods

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by Ethics Committee of Tianjin Medical University General Hospital (No. IRB2021-YX-242-01) and Affiliated Hospital of Chifeng University was informed and agreed on this study. Informed consent was taken from all the patients. Data collection was carried out by specialized personnel without any intervention in clinical diagnosis and treatment.

In this study, the patients with lung cancer who underwent thoracoscopic surgery were prospectively enrolled from Tianjin Medical University General Hospital and Affiliated Hospital of Chifeng University from October 2021 to September 2022. Inclusion criteria in this trial were as follows: (I) patients with suspected or diagnosed lung cancer; (II) patients who were prepared for thoracoscopic lung resection; and (III) the patients and their families agreed to participate in the study. This study excluded patients who met the following criteria: (I) cases of secondary lung surgery; (II) cases with non-lung cancer diagnosed by postoperative pathology; (III) cases with critical information missing; and (IV) patients with locally advanced lung cancer which were evaluated after two cycles of neoadjuvant therapy (*Figure 1*).

The preoperative evaluation and treatment process of all patients were carried out according to the British Thoracic Society surgical selection guidelines (10) and the American College of Chest Physicians' lung cancer diagnosis and treatment guidelines (3rd ed.) (11). All patients with preoperative comorbidities underwent multidisciplinary

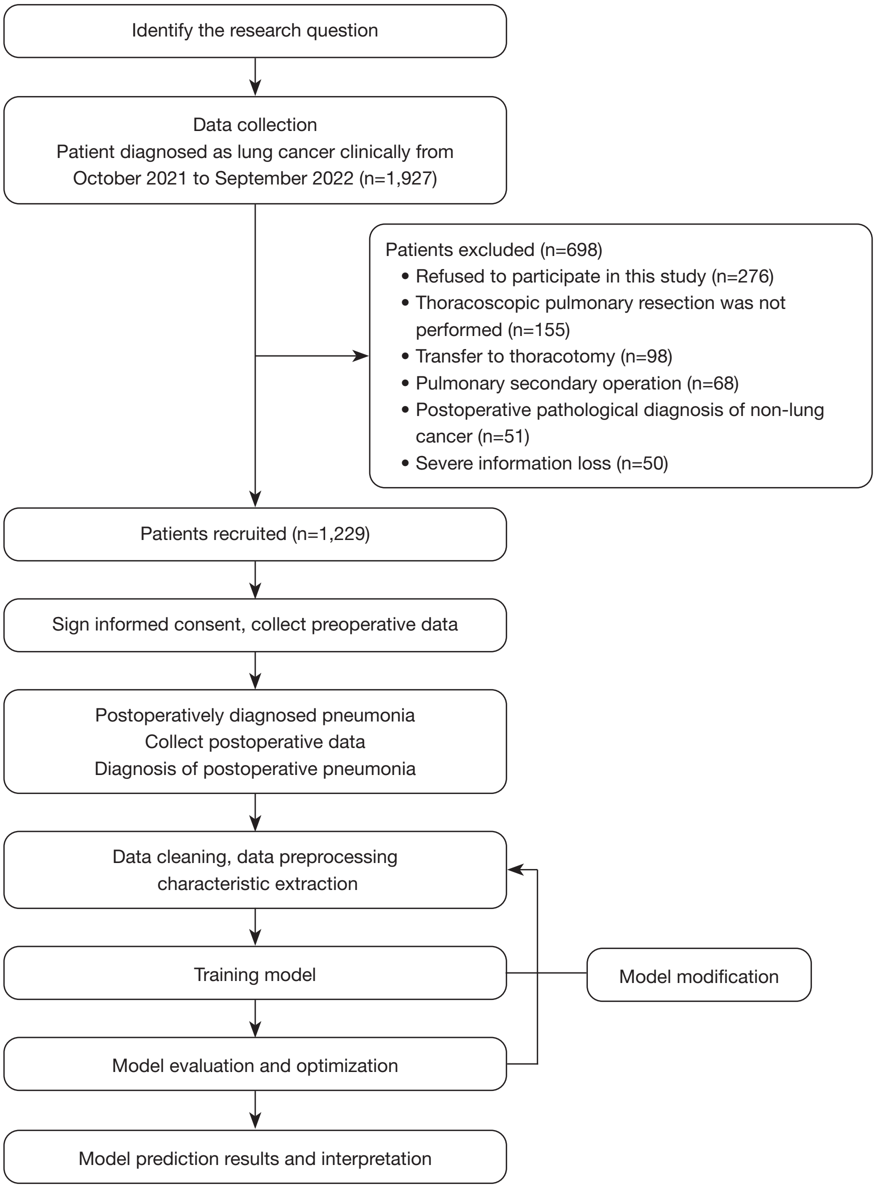

Figure 1 The study designs.

consultation, and the comorbidities were well controlled before the surgery. Patients were followed up from the first admission to 3 months after the surgery. Demographic characteristics, such as gender, age, body mass index (BMI), smoking status, and Quality-of-Life Questionnaire (QLQ)-C30 (12) and Lung Cancer Module (LC13) scores, were recorded before the surgery. The code of International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) was extracted from the patients' medical records as the basis for the diagnosis of the main disease, comorbidity and POP. Based on the level of ICD-10 code, organs with comorbidities, the number and characteristics of the diagnosed comorbidities, were reduced again in the form of artificial clustering according to professional judgment and previous data from the literature. The clustered comorbidity data were formatted in length-width format and factorized. The variable name was made with the binary variable of the comorbidity group (13,14). The pathology report and ICD codes for surgery were also extracted from the first page of medical records which showed tumor and surgical information. All lung resections were performed by thoracoscopy under general anesthesia with a double-lumen endotracheal tube. The surgical procedures included wedge resection, segmental resection, lobectomy, and pneumonectomy. In this study, many patients were diagnosed with multiple nodules in the lung, making it challenging to categorize their surgical procedures. Therefore, the proportion of lung tissue resection was used to describe the surgical characteristics of the patients in a more accurate way (8,9). Pathological reports were used as the basis for tumor classification and staging. All medical data were obtained from the hospital's electronic medical record system, and QLQ-C30 and LC13 scores were obtained from the phone questionnaire.

The study end point was whether POP occurred in patients with lung cancer after thoracoscopic surgery. We used the most common definition (15) of pneumonia established by the U.S. Centers for Disease Control and Prevention, according to Horan *et al.* (16). Pneumonia was diagnosed in postoperative patients within 30 days after surgery with the following criteria: (I) at least two chest imaging examinations were performed within 30 days after surgery, with new or progressive and persistent pulmonary infiltrates, consolidation, or cavitation. (II) With at least one of the following conditions: (i) fever (body temperature >38 ℃) without other clear reasons; (ii) peripheral white blood cell counts $>12\times10^9$/L or $<4\times10^9$/L; and (iii) aged ≥70 years with mental changes without other clear reasons. (III) With at least two of the following features: (i) new purulent sputum or changes in sputum character; (ii) increased respiratory secretions and the requirement for additional sputum suctions; (iii) new cough, dyspnea, and increased respiratory rate; (iv) preexisting cough, dyspnea, and gas exchange deteriorating; and (v) increased oxygen demand or the need of mechanical ventilation support.

Statistical analysis

In this study, demographic characteristics, oncology characteristics, lung resection proportion, and comorbidity characteristics were used as predictive variables, and the occurrence of POP was used as the response variable to establish a prediction model. Averages and standard errors for continuous attributes and absolute value and frequency distributions for categorical attributes were used to define the based features of the study population. To compare numerical data, the Student's *t*-test and Wilcoxon rank testing were utilized. To compare variations in the percentages of categorical variables, χ^2 or Fisher's exact test was employed. Bilateral P values <0.05 were considered statistically significant. Prior to regression modeling, the collinearity of candidate variables was investigated by correlation analysis. No strongly correlated variables were found. Univariate logarithmic probability regression was used to select potential predictors of POP, and variables with P<0.05 were retained as candidate variables for logistic regression with multivariate variables. A nomogram was drawn based on the model, and 1,000 bootstrap resampling was performed for internal verification to evaluate the prediction accuracy of the model. Discrimination and calibration were used to evaluate the model's performance. The area under the curve (AUC) analysis was used to evaluate the discrimination ability of the model. For clinical validity, decision curve analysis (DCA) was used to quantify the net benefits under different probability thresholds. All statistical analyses were conducted using R version 4.2.2 (The R Foundation for Statistical Computing, Vienna, Austria; https://www.r-project.org/; accessed on October 31, 2022). The R packages used in this study mainly included the following types: tidyverse, compareGroups, rms, stats, MASS, pROC, ROCR, rmda, etc.

Results

In this study, a total of 1,927 individuals were clinically diagnosed with lung cancer, and 1,229 patients who were scheduled to undergo thoracoscopic surgery were enrolled between October 2021 and September 2022. In total, 196 cases (15.95%) had POP (*Table 1*). We found a high incidence of having POP in lung cancer surgical patients. This may be due to the large number of elderly patients and multiple preoperative comorbidities in our cohort, as well as other unidentified factors. Among the included patients, seven patients received neoadjuvant therapy, two patients were diagnosed with stage Via lung cancer in whom pleural nodules were found intraoperatively and metastases (M1a) was suggested pathologically, 16 patients with severe POP required tracheal intubation and mechanical ventilation; they were cured within 2 weeks after surgery, of which 13 patients were in remission within 2 weeks after surgery, and the other three patients were in serious condition with secondary lung infection, but all of them were successfully cured and discharged from hospital within 2 months after surgery. Fortunately, there were no deaths during the study period.

In addition, 1,025 (83.40%) patients had comorbid

Table 1 Baseline demographic characteristics of patients with POP

Characteristics	Pneumonia		P value
	No, n=1,033 (84.1)	Yes, n=196 (15.9)	
Gender			<0.001
Female	716 (69.3)	83 (42.3)	
Male	317 (30.7)	113 (57.7)	
Age (years)	58.45 (11.70)	64.73 (10.00)	<0.001
BMI (kg/m^2)	23.89 (3.85)	25.43 (4.46)	<0.001
Smoke index (cigarettes-year)	75.30 (178.60)	376.58 (396.80)	<0.001
Pathological type			0.001
A	956 (92.5)	166 (84.7)	
S	66 (6.4)	27 (13.8)	
O	11 (1.1)	3 (1.5)	
TNM			0.306
0	5 (0.5)	0 (0.0)	
I	866 (83.8)	159 (81.1)	
II	143 (13.8)	34 (17.3)	
III	18 (1.7)	2 (1.0)	
IV	1 (0.1)	1 (0.5)	
Tumor location			0.21
Left upper lobe	222 (21.5)	44 (22.4)	
Left lower lobe	140 (13.6)	34 (17.3)	
Left lung	89 (8.6)	19 (9.7)	
Right middle lobe	61 (5.9)	3 (1.5)	
Right lower lobe	118 (11.4)	22 (11.2)	
Right upper lobe	253 (24.5)	49 (25.0)	
Right lung	150 (14.5)	25 (12.8)	
Lung resection (%)	18.98 (6.78)	19.83 (6.72)	0.11
Physical function	98.01 (3.98)	96.41 (5.20)	<0.001
Role function	97.00 (6.41)	95.58 (7.38)	0.006
Emotional function	87.52 (7.07)	88.18 (6.64)	0.226
Cognitive function	74.86 (16.39)	75.94 (15.67)	0.398
Social function	82.93 (11.67)	82.91 (11.75)	0.981
Fatigue	4.76 (7.57)	6.35 (7.80)	0.008
Insomnia	43.14 (40.27)	36.56 (39.02)	0.035
Appetite loss	12.78 (16.21)	10.71 (15.61)	0.101
Constipation	1.48 (7.03)	3.23 (9.89)	0.003

Table 1 (*continued*)

Table 1 (*continued*)

Characteristics	Pneumonia		P value
	No, n=1,033 (84.1)	Yes, n=196 (15.9)	
Financial difficulties	16.36 (16.67)	16.16 (16.70)	0.875
Coughing	2.19 (8.65)	3.74 (11.08)	0.029
Hemoptysis	0.03 (0.60)	0.23 (2.24)	0.018
Dyspnea	6.29 (10.69)	14.28 (13.78)	<0.001

Data are presented as n (%) or mean (SD). POP, postoperative pneumonia; BMI, body mass index; A, adenocarcinoma; S, squamous carcinoma; O, other types of carcinoma; TNM, tumor-node-metastasis; SD, standard deviation.

conditions. The total number of comorbidity diagnosed in all samples was 2,929. We clustered over 700 comorbidities into 22 groups based on onset frequency, characteristics, and systemic organs involved. This subgrouping helped screen variables clearly and ensured clinical significance, sufficient sample size, and appropriate confidence intervals (CIs) for each comorbidity group. Using comorbidity groups as predictors simplified and expedited the prediction of postoperative POP risk. The number of comorbidity diagnosed in each sample was counted as the "comorbidity burden" of the sample. The maximum comorbidity burden of all samples was 14 (patients had 14 of the 22 comorbidity groups), and the minimum comorbidity burden was 0 (patient had no comorbidity diagnosed) (*Table 2*).

The potential predictors of POP were screened by univariate logistic regression (*Table 3*). The final variables used in prediction were determined by multivariate logistic regression (*Table 4*). As a result, age [odds ratio (OR), 1.045; 95% CI: 1.025–1.065; P<0.001], smoke index (OR, 1.004; 95% CI: 1.003–1.005; P<0.001), physical function (OR, 0.946; 95% CI: 0.910–0.986; P=0.007), respiratory diseases (OR, 5.918; 95% CI: 4.030–8.811; P<0.001), and nervous system diseases (OR, 2.233; 95% CI: 1.066–4.541; P=0.029) were selected. The incidence of POP was higher in patients with advanced age, high smoke index, poor physical function, with respiratory diseases, and nervous system diseases.

Model development and validation

Based on Akaike information criteria obtained by stepwise adverse selection, BMI and diabetes were further included in the final model. Age, BMI, smoke index, physical function, respiratory diseases, diabetes, and neurological diseases were selected to construct a model to predict the probability of having POP among those with lung cancer (*Table 4*). A nomogram was established based on the model (*Figure 2*).

Receiver operating characteristic (ROC) curves were drawn to evaluate the performance of the prediction model (*Figure 3*). The AUC, sensitivity, and specificity of the model were 0.851 (95% CI: 0.821–0.881), 80.1%, and 74.4%, respectively. The Brier score of the model was 0.091 (95% CI: 7.9–10.2). The calibration curve (*Figure 4*) showed a convincing agreement between the predicted and the actual results. The results showed that the model has good discrimination and correction ability and provides a convenient tool for managing patients at risk of POP (*Figure 5*).

Discussion

The diagnostic basis and manifestations of comorbidity mainly come from clinical manifestations and laboratory tests. To avoid predictor variable interaction and collinearity, we only used demographic characteristics, comorbidity diagnosis information, and lung resection proportion as predictors. For instance, poor lung function before surgery was associated with a higher rate of postoperative respiratory complications. Although we initially included indicators of preoperative pulmonary function, we recognized the potential collinearity with preoperative respiratory comorbidities. To focus on preoperative comorbidity and to save time and cost, we omitted the collection of pulmonary function indicators.

While there are various postoperative complications that can occur in patients with lung cancer, POP is often considered a significant and relevant outcome in assessment. POP is one of the most common complications from lung cancer surgery. Its high occurrence rate makes it an

Table 2 Baseline preoperative comorbidities characteristics of patients with POP

Characteristics	Pneumonia		P value
	No, n=1,033 (84.1)	Yes, n=196 (15.9)	
Respiratory system disease			<0.001
No	779 (77.9)	76 (38.8)	
Yes	254 (24.6)	120 (61.2)	
Cardiac disease			0.354
No	908 (87.9)	167 (89.3)	
Yes	125 (12.1)	29 (14.8)	
Vascular disease			0.06
No	707 (68.5)	114 (58.2)	
Yes	325 (31.5)	82 (41.8)	
Nervous system disease			< 0.001
No	1,009 (97.7)	182 (92.9)	
Yes	38 (3.68)	22 (11.2)	
Mental and behavior disorder			0.743
No	1,022 (98.9)	195 (99.5)	
Yes	11 (1.1)	1 (0.5)	
Diabetes			0.023
No	908 (87.9)	160 (81.6)	
Yes	125 (12.1)	36 (18.4)	
Thyroid benign disease			0.217
No	951 (92.1)	186 (94.9)	
Yes	82 (7.9)	10 (5.1)	
Other endocrine and metabolic abnormalities			0.827
No	984 (95.3)	188 (95.9)	
Yes	49 (4.7)	8 (4.1)	
Digestive and abdominal diseases			0.028
No	974 (94.3)	176 (89.8)	
Yes	59 (5.7)	20 (10.2)	
Hepatobiliary disease			0.215
No	971 (94.0)	179 (91.3)	
Yes	62 (6.0)	17 (8.7)	
Urinary system diseases			0.848
No	1,012 (98.0)	191 (97.4)	
Yes	21 (2.0)	5 (2.6)	

Table 2 (*continued*)

Table 2 (*continued*)

Characteristics	Pneumonia		P value
	No, n=1,033 (84.1)	Yes, n=196 (15.9)	
Gynecological diseases			0.369
No	1,022 (98.8)	196 (100.0)	
Yes	11 (1.1)	0 (0.0)	
Other malignancies			0.102
No	969 (93.8)	177 (90.3)	
Yes	64 (6.2)	19 (9.7)	
Other benign disease			0.624
No	927 (89.7)	173 (88.3)	
Yes	106 (10.3)	23 (11.7)	
Stomatological and ENT diseases			0.289
No	977 (94.6)	181 (92.3)	
Yes	56 (5.4)	15 (7.7)	
Injuries/sequela			0.386
No	1,010 (97.8)	189 (96.4)	
Yes	23 (2.2)	7 (3.6)	
Congenital disease			1
No	1,028 (99.5)	195 (99.5)	
Yes	5 (0.5)	1 (0.5)	
Arthritis			1
No	983 (95.2)	186 (94.9)	
Yes	50 (4.8)	10 (5.1)	
Dermatopathy			1
No	1,030 (99.7)	195 (99.5)	
Yes	3 (0.3)	1 (0.5)	
Abnormal performance			0.028
No	970 (93.9)	175 (89.3)	
Yes	63 (6.1)	21 (10.7)	
Personal history			0.45
No	610 (59.1)	122 (62.2)	
Yes	423 (40.9)	74 (37.8)	
Comorbidities burden	2.22 (1.89)	3.26 (2.19)	<0.001

Data are presented as n (%) or mean (SD). POP, postoperative pneumonia; ENT, ear, nose, and throat; SD, standard deviation.

Table 3 POP patients' predictive factors: a single-variable logistic regression analysis

Variables	Univariable analysis	
	OR (95% CI)	P value
Gender		
Female	Ref.	
Male	0.326 (0.238–0.444)	<0.001
Age (years)	1.057 (1.041–1.075)	<0.001
BMI (kg/m^2)	1.099 (1.058–1.141)	<0.001
Smoke index (cigarettes-year)	1.004 (1.004–1.005)	<0.001
Pathological type		
A	Ref.	
S	2.356 (1.442–3.758)	<0.001
O	1.571 (0.353–5.093)	0.492
Tumor location		
Left upper lobe	Ref.	
Left lower lobe	1.190 (0.704–2.050)	0.524
Left lung	1.281 (0.661–2.451)	0.457
Right middle lobe	0.296 (0.069–0.882)	0.053
Right lower lobe	1.119 (0.598–2.084)	0.724
Right upper lobe	1.163 (0.696–1.984)	0.574
Right lung	1.458 (0.831–2.586)	0.192
Lung resection (%)	1.019 (0.996–1.043)	0.111
Physical function	0.928 (0.899–0.958)	<0.001
Role function	0.971 (0.951–0.992)	0.006
Emotional function	1.014 (0.992–1.036)	0.227
Cognitive function	1.005 (0.995–1.014)	0.398
Social function	1.000 (0.987–1.014)	0.981
Fatigue	1.026 (1.007–1.045)	0.008
Appetite loss	0.992 (0.983–1.002)	0.102
Constipation	1.025 (1.008–1.041)	0.005
Financial difficulties	1.000 (0.991–1.009)	0.876
Coughing	1.016 (1.001–1.031)	0.032
Hemoptysis	1.120 (1.001–1.281)	0.053
Dyspnea	1.052 (1.040–1.065)	<0.001
Respiratory system disease		
No	Ref.	
Yes	4.843 (3.524–6.693)	<0.001
Cardiac disease		
No	Ref.	
Yes	1.262 (0.803–1.927)	0.297
Vascular disease		
No	Ref.	
Yes	1.567 (1.144–2.140)	0.005
Nervous system disease		
No	Ref.	
Yes	3.311 (1.886–5.687)	0.001
Mental and behavioral disorder		
No	Ref.	
Yes	0.477 (0.026–2.471)	0.479
Diabetes		
No	Ref.	
Yes	1.635 (1.076–2.434)	0.019
Thyroid benign disease		
No	Ref.	
Yes	0.624 (0.299–1.169)	0.171
Other endocrine and metabolic abnormalities		
No	Ref.	
Yes	0.855 (0.370–1.736)	0.687
Digestive and abdominal diseases		
No	Ref.	
Yes	1.876 (1.079–3.142)	0.021
Hepatobiliary disease		
No	Ref.	
Yes	1.488 (0.826–2.548)	0.165
Urinary system diseases		
No	Ref.	
Yes	1.262 (0.418–3.140)	0.645
Other malignancies		
No	Ref.	
Yes	1.626 (0.928–2.729)	0.077

Table 3 (*continued*)

Table 3 (*continued*)

Variables	Univariable analysis	
	OR (95% CI)	P value
Other benign disease		
No	Ref.	
Yes	1.163 (0.705–1.846)	0.538
Stomatological and ENT diseases		
No	Ref.	
Yes	1.446 (0.775–2.548)	0.222
Injuries/sequela		
No	Ref.	
Yes	1.627 (0.638–3.660)	0.268
Congenital disease		
No	Ref.	
Yes	1.055 (0.055–6.585)	0.962
Arthritis		
No	Ref.	
Yes	1.057 (0.498–2.035)	0.877
Dermatopathy		
No	Ref.	
Yes	1.761 (0.087–13.832)	0.625
Abnormal performance		
No	Ref.	
Yes	1.848 (1.077–3.058)	0.021
Personal history		
No	Ref.	
Yes	0.875 (0.637–1.195)	0.404
Comorbidities burden	1.268 (1.180–1.363)	<0.001

POP, postoperative pneumonia; OR, odds ratio; CI, confidence interval; Ref., reference; BMI, body mass index; A, adenocarcinoma; S, squamous carcinoma; O, other types of carcinoma; ENT, ear, nose, and throat.

important consideration when evaluating postoperative outcomes. POP can lead to significant morbidity rates. It can prolong hospital stays, increase healthcare costs, and potentially result in respiratory failure or even death (17-21), making it a crucial outcome to monitor. While not all complications can be prevented, there are various strategies available to reduce the risk of POP. By focusing on preventing this specific complication, healthcare providers can potentially improve overall postoperative outcomes. POP is often linked with other postoperative complications, such as atelectasis or respiratory failure. By monitoring and managing POP, healthcare providers can indirectly address and potentially prevent other related complications.

After screening the predictive variables of the enrolled participants, it was determined that respiratory diseases, diabetes, and nervous system diseases, age, BMI, smoking index, physiological function, were independent risk factors for POP in patients with lung cancer undergoing thoracoscopic surgery. Dutkowska *et al.* (22), in their review of the comorbidity characteristics of patients with lung cancer, pointed out that age, chronic obstructive pulmonary disease (COPD), cardiovascular diseases, cerebrovascular diseases, and diabetes are all negative prognostic factors for lung cancer, which are consistent with the findings of this study.

Respiratory diseases, especially various lower respiratory tract diseases, are important risk factors for POP in patients with lung cancer. COPD is the most common comorbidity of lung cancer (23). Many studies have confirmed that COPD is an independent risk factor for perioperative lung cancer (24-27). Lin *et al.* (28) compared 24,109 surgical patients who had asthma before surgery to 24,109 non-asthmatic patients who underwent major surgery. Their results showed a significant increase in postoperative complications and mortality in patients with asthma. Nowadays, exacerbation of postoperative interstitial pneumonia in patients with interstitial lung disease and lung cancer has become a serious problem (29). Carr *et al.* (30) also confirmed that acute exacerbation of idiopathic interstitial pneumonia and POP are important postoperative complications in thoracic and nonthoracic surgery groups through their perioperative study of patients with idiopathic interstitial pneumonia. Hata *et al.* (31) performed a chart review of 250 patients with lung cancer who underwent lung resection to study the efficacy of radical surgery for lung cancer combined pulmonary fibrosis and emphysema (CPFE). Their results showed that the prognosis of CPFE patients identified on computed tomography scans was worse than that of patients with emphysema or normal lungs. When patients with lung cancer have CPFE before the surgery, radical surgery should be carefully selected because of the associated poor prognosis.

Many studies have reported that diabetes significantly affects the survival of non-small cell lung cancer (NSCLC) patients (22,32). However, the pathogenesis of POP of lung

Table 4 Variables discovered by multivariate logistic regression analysis

Variables	Multivariable analysis		Factors selected for model	
	OR (95% CI)	P value	OR (95% CI)	P value
Gender				
Female	Ref.			
Male	1.496 (0.850–2.684)	0.169		
Age (years)	1.041 (1.016–1.068)	<0.001	1.045 (1.025–1.065)	<0.001
BMI (kg/m^2)	1.047 (0.993–1.106)	0.091		
Smoke index (cigarettes-year)	1.005 (1.004–1.007)	<0.001	1.004 (1.003–1.005)	<0.001
Pathological type				
A	Ref.			
O	0.747 (0.343–1.525)	0.441		
S	0.359 (0.055–1.662)	0.232		
Physical function	0.949 (0.906–0.994)	0.025	0.946 (0.910–0.986)	0.007
Role function	1.024 (0.992–1.057)	0.145		
Fatigue	0.996 (0.972–1.020)	0.723		
Insomnia	0.997 (0.993–1.002)	0.266		
Constipation	1.007 (0.984–1.029)	0.531		
Coughing	1.008 (0.988–1.026)	0.412		
Dyspnea	1.004 (0.985–1.023)	0.680		
Respiratory system disease				
No	Ref.		Ref.	
Yes	5.841 (3.587–9.632)	<0.001	5.918 (4.030–8.811)	<0.001
Vascular disease				
No	Ref.			
Yes	0.863 (0.554–1.334)	0.510		
Nervous system disease				
No	Ref.		Ref.	
Yes	2.545 (1.173–5.370)	0.016	2.233 (1.066–4.541)	0.029
Diabetes				
No	Ref.			
Yes	1.623 (0.940–2.762)	0.077		
Digestive and abdominal diseases				
No	Ref.			
Yes	1.639 (0.808–3.221)	0.160		
Abnormal performance				
No	Ref.			
Yes	1.804 (0.865–3.622)	0.105		
Comorbidities burden	1.027 (0.889–1.184)	0.713		

OR, odds ratio; CI, confidence interval; BMI, body mass index; A, adenocarcinoma; S, squamous carcinoma; O, other types of carcinoma.

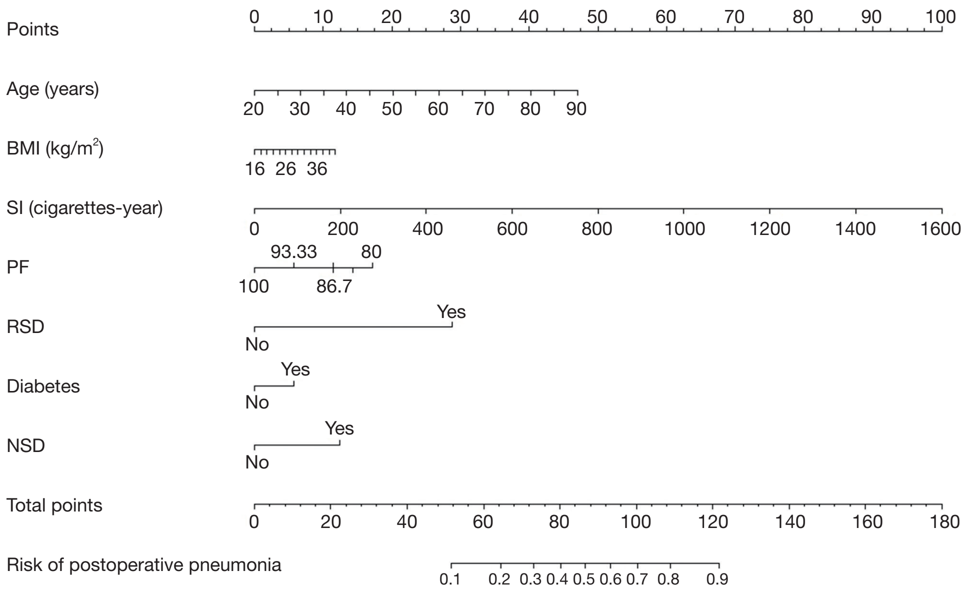

Figure 2 The values of each predictive factor were assigned a point scale axis for predicting POP among those with lung cancer. Using the point scale axis, each predictive factor was assigned a score. The points were added together to determine the final score. The final score is projected to the lower total point scale after that. The likelihood of POP could be calculated. BMI, body mass index; SI, smoke index; PF, physical function; RSD, respiratory system disease; NSD, nervous system disease; POP, postoperative pneumonia.

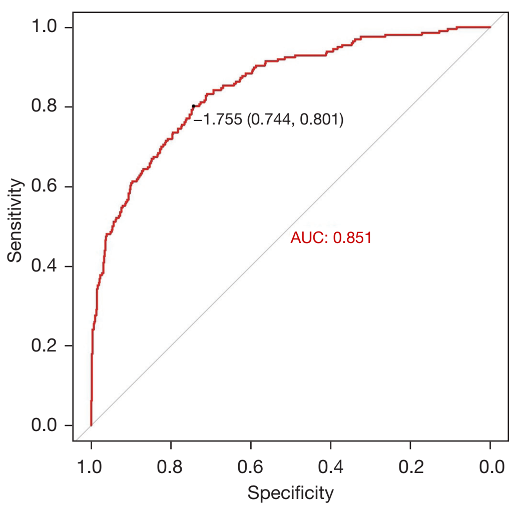

Figure 3 Model ROC curve. Maximum Youden index: 0.545; corresponding diagnostic cutoff value: −1.755; sensitivity: 80.1%; specificity: 74.4%. AUC, area under the curve; ROC, receiver operating characteristic.

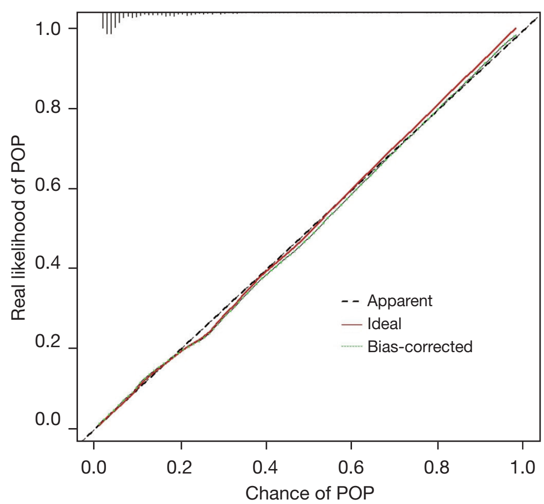

Figure 4 Calibration curve. The chance of POP is indicated on the X-axis, and the real likelihood of POP is represented on the Y-axis. The dotted line in the figure, which shows that the projected probability is perfectly consistent with the real probability, represents the prediction model's ideal state. The hypothetical prediction capability is shown by the red line, whereas the improved model's prediction capability is represented by the green line. There is little difference between the three lines, indicating that the forecast performance is good. POP, postoperative pneumonia.

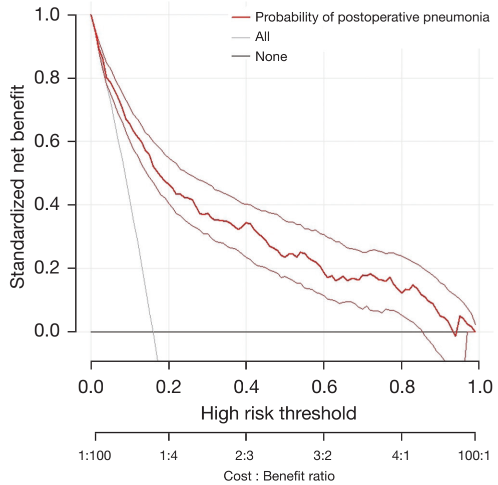

Figure 5 Decision curve. The Y-axis is the net benefit. The red line represents the prediction model results, the gray line represents the hypothesis that all patients had a positive preoperative predictor, and the black line represents the hypothesis that all patients had a negative preoperative predictor. The analysis of decision curve shows that the model can predict POP well when the threshold probability is between 2% and 93%. POP, postoperative pneumonia.

cancer caused by diabetes remains unclear. It may be related to the complex complications of diabetes.

Lung cancer surgery in patients with neurological comorbidities is a major challenge in anesthesia and postoperative management, as cerebrovascular disease increases POP and mortality compared to patients with lung cancer without such comorbidities. Aging is a very adverse prognostic factor for thoracic surgery for elderly lung cancer patients. According to Dominguez-Ventura *et al.* (33), the risk of death increased 4-fold in patients aged ≥80 years with a history of stroke.

Although there are few studies specifically investigating the correlation between demographic factors and POP in lung cancer patients, we can indirectly understand the association between age and POP in lung cancer patients from a large body of literature discussing age and postoperative complications in this population.

Wang *et al.* (34) evaluated the use of first-line guideline-recommended therapy in 20,511 veterans aged ≥65 years with NSCLC. More predictors, including age and comorbidities, are needed for individualized decision-making to target the treatment to benefit older patients with lung cancer. However, the results of Pei *et al.*'s (35) yielded promising results regarding the occurrence of postoperative complications in elderly patients with NSCLC after undergoing lung resection. Pneumonectomy procedures and longer surgical durations were found to be positively associated with an increased likelihood of developing postoperative complications, while thoracoscopic minimally invasive surgery for NSCLC in elderly patients was linked to fewer complications and shorter hospital stays compared to traditional thoracotomy approaches.

BMI has different effects on short- and long-term prognosis after lung cancer surgery. Benker *et al.* (36) recruited 1,219 patients who underwent NSCLC resection between 2000 and 2015. They concluded that advanced age, low BMI, and low forced expiratory volume in 1 second (FEV1) could predict greater complication risk and shorter survival. However, Li *et al.* and Nitsche *et al.* (37,38) came up with opposite results, showing that obesity has beneficial effects on in-hospital outcomes and the long-term survival of surgical patients with lung cancer. The "obesity paradox" can potentially exist in lung cancer surgery. Launer *et al.* (39) and Kaw *et al.* (40) had another conclusion that obese patients have an increased risk for postoperative pulmonary complications.

The impact of smoking on lung cancer is widely recognized in the medical field. Not only is smoking being considered as the primary causative factor for lung cancer, but it is also closely associated with respiratory comorbidities and serves as a significant risk factor for POP (41). The detrimental effects of smoking extend beyond lung cancer. It is a major risk factor for various respiratory diseases, including COPD, emphysema, and bronchitis. Additionally, smoking has been linked to an increased risk of cardiovascular diseases, such as heart attacks and strokes. Moreover, it negatively impacts the overall respiratory function, leading to decreased lung capacity and impaired gas exchange. This viewpoint has been incorporated into major diagnosis and treatment guidelines (10,11,21,42) and is also deeply ingrained among physicians.

Russotto *et al.* (6) pointed out that poor functional status, defined as a decline in the ability to perform activities of daily living, is a recognized factor that increases morbidity and mortality and has been reported as a risk factor for pneumonia in previously developed models. In addition, patients with poorer functional status are at an increased risk for aspiration pneumonia. In addition, many studies have confirmed the impact on quality of life of postoperative lung cancer (43,44) and proposed that optimizing preoperative functional status can improve postoperative status (45,46).

There are several limitations in this study. Due to the limited sample size, the dataset was not divided into a training set and a validation set; only internal validation was performed. This is a main limitation of this study. On the other hand, the influence of preoperative factors on intraoperative conditions, such as operation time and intraoperative bleeding, was not discussed in this paper. In addition, we did not explicitly discuss the comparison with the cited study's mortality rate in our text. However, we will consider addressing this point in future research or in the limitations section of our study. Finally, given the constraints of the established research framework, it proves challenging to deconstruct respiratory diseases with the currently available data. However, the model developed in this study exhibited an acceptable level of accuracy in predicting the incidence of POP, thus serving as a valuable tool for assessing the risk of POP in patients undergoing thoracoscopic lung resection for lung cancer. A numerical risk stratification system can be employed to calculate the likelihood of developing POP, wherein each factor is assigned a specific point value and cumulative points are tallied.

Conclusions

This study identifies several independent variables associated with POP in lung cancer patients undergoing thoracoscopic surgery. This knowledge can be applied to clinical practice. By using this model, clinicians can anticipate the risk of POP and implement planned interventions and rehabilitation treatments to reduce complications and improve patient outcomes.

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Footnote

Reporting Checklist: The authors have completed the TRIPOD reporting checklist. Available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-23-512/rc

Data Sharing Statement: Available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-23-512/dss

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tlcr.amegroups.com/article/view/10.21037/tlcr-23-512/coif). The authors have no conflicts of interest to declare.

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 Ethics Committee of Tianjin Medical University General Hospital (No. IRB2021-YX-242-01) and Affiliated Hospital of Chifeng University was informed and agreed on this study. Informed consent was taken from all the patients.

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