



# Prediction of postoperative pulmonary complications in older patients undergoing lobectomy for lung cancer based on skeletal muscle mass

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**Background:** This retrospective study was designed to evaluate preoperative pulmonary function test (PFT) results and skeletal muscle mass, represented by the erector spinae muscle (EM), as predictors of postoperative pulmonary complications (PPCs) in older patients undergoing lobectomy for lung cancer.

**Methods:** The medical records, including preoperative PFT, chest computed tomography (CT) and PPCs, of patients older than 65 years undergoing lobectomy for lung cancer were retrospectively examined at Konkuk University Medical Center from January 2016 to December 2021. The sum of cross-sectional areas (CSAs) of the right and left EMs at the level of the spinous process with the 12<sup>th</sup> thoracic vertebra was used as the skeletal muscle mass (CSA<sub>Both</sub>).

**Results:** Data from a total of 197 patients were included in the analyses. In total, 55 patients had PPCs. The preoperative functional vital capacity (FVC) and forced expiratory volume in 1 second (FEV1) showed significantly poorer values and the CSA<sub>Both</sub> had significantly lower values in patients with than in those without PPCs. The preoperative FVC and FEV1 showed significant positive correlations with CSA<sub>Both</sub>. Multiple logistic regression analysis identified age, diabetes mellitus (DM), preoperative FVC and CSA<sub>Both</sub> as risk factors for PPCs. The areas under the curves for FVC and CSA<sub>Both</sub> were 0.727 (95% CI, 0.650–0.803; P<0.001) and 0.685 (95% CI, 0.608–0.762; P<0.001), respectively. The optimal threshold values of FVC and CSA<sub>Both</sub> to predict PPCs based on a receiver operating characteristic curve analysis were 2.685 L (sensitivity =64.1% and specificity =61.8%) and 28.47 mm<sup>2</sup> (sensitivity =62.0% and specificity =61.5%), respectively.

**Conclusions:** PPCs in older patients undergoing lobectomy for lung cancer were associated with lower preoperative FVC and FEV1 values and a lower skeletal muscle mass. Skeletal muscle mass, represented by the EM, was significantly correlated with the preoperative FVC and FEV1. Therefore, skeletal muscle mass may be useful for the prediction of PPCs in patients undergoing lobectomy for lung cancer.

**Keywords:** Pulmonary function test (PFT); skeletal muscle mass; older patient; lobectomy; lung cancer

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## Introduction

Despite continuous developments in the diagnosis and treatment of lung cancer, postoperative pulmonary complications (PPCs) are the major causes of morbidity and mortality following lung cancer surgery. There has been a great deal of effort to develop ways to prevent PPCs after lung cancer surgery (1,2). Preoperative risk stratification can help to predict the possibility of PPCs after lung cancer surgery and allow the implementation of strategies to prevent them. Preoperative pulmonary function tests (PFTs) are commonly used for the evaluation of preoperative PPC risk after lung cancer surgery.

Previous studies have demonstrated that low skeletal muscle mass is associated with morbidity after major surgery (3-5). Moreover, low skeletal muscle mass has been shown decreased lung function in patients with lung diseases (6,7). Low skeletal muscle mass, referred to as sarcopenia, is one of the most important causes of functional decline with a loss of independence in the elderly. Therefore, low skeletal muscle mass in older patients is expected to be associated with low pulmonary function and PPCs after lung cancer surgery. However, the relevant study has not been yet conducted.

We hypothesised that patients with PPCs after lung cancer surgery may have low preoperative PFT results and

a low skeletal muscle mass compared to patients without PPCs after lung cancer surgery. This retrospective study was designed to evaluate preoperative PFT and skeletal muscle mass, represented by the erector spinae muscle (EM), as predictors of PPCs in older patients undergoing lobectomy for lung cancer. We present the following article in accordance with the STARD reporting checklist (available at <https://jtd.amegroups.com/article/view/10.21037/jtd-22-1156/rc>).

## Methods

### Study population

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). This retrospective study was performed using the medical records of patients older than 65 years old undergoing lobectomy for lung cancer at Konkuk University Medical Center from January 2016 to December 2021 after receiving approval from the Institutional Review Board of Konkuk University Medical Center (approval No. KUMC 202207071) and registration at <https://cris.nih.go.kr> (registration number: KCT0007474). The patient data were obtained from chart reviews, and the requirement for written informed consent from the patients was waived. All data, extracted from chart reviews, were deidentified prior to analysis. The exclusion criteria were previous thoracic surgery, metastasis from other organs, concurrent other surgery, previous respiratory disease except lung cancer, history of heart failure, left or right ventricular ejection fraction below the normal range, sequelae of cerebrovascular disease and low renal function with elevated creatinine above the normal range (*Figure 1*).

### Preoperative PFTs

PFTs were performed within 1 week before lobectomy for lung cancer. Functional vital capacity (FVC), forced expiratory volume in 1 second (FEV1), forced expiratory flow (FEF), forced expiratory flow between 25% and 75% (FEF25–75%) and maximal voluntary ventilation (MVV) were measured according to institutional protocols.

### Preoperative chest computed tomography (CT)

Chest CT was performed within 1 week before surgery for lung cancer. Images were obtained in steps of 2.5 mm according to our institutional protocol.

### Highlight box

#### Key findings

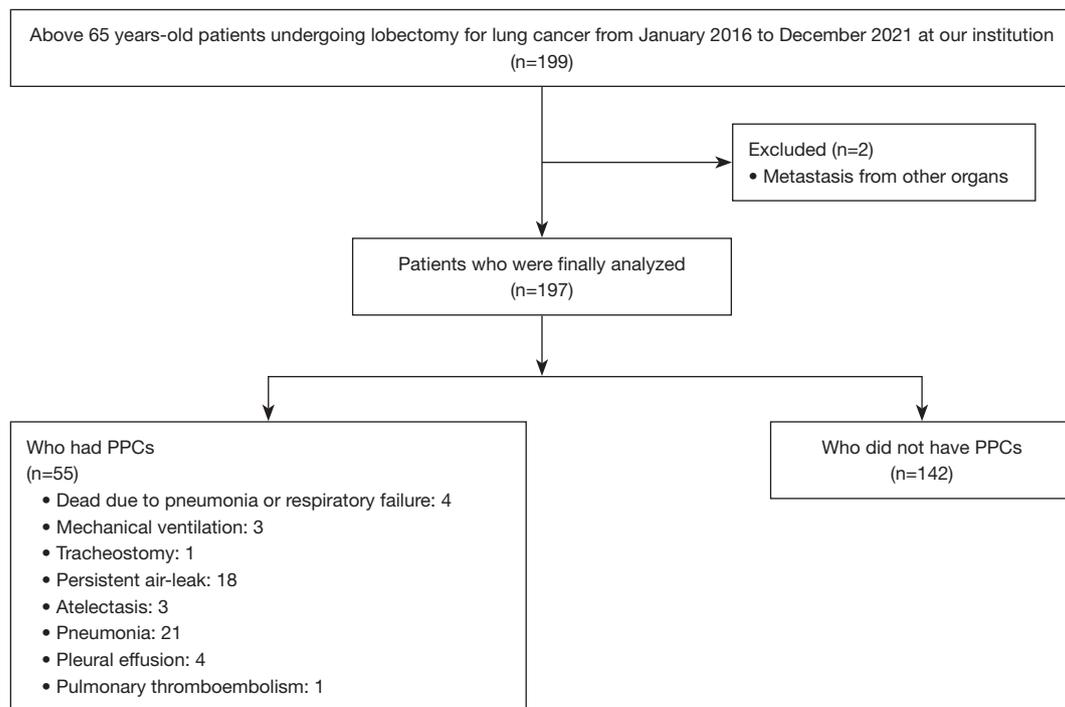
- Independent risk factors for postoperative pulmonary complications (PPCs) after lobectomy for lung cancer were age, smoking history, diabetes mellitus, functional vital capacity (FVC) and skeletal muscle mass.

#### What is known and what is new?

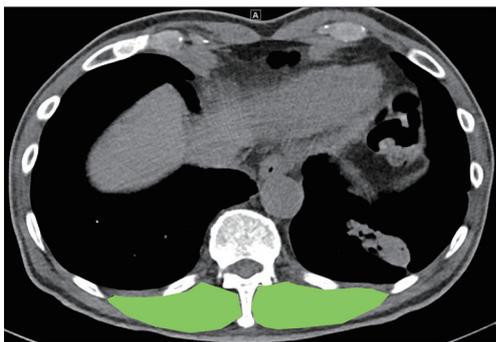
- Preoperative pulmonary function tests (PFTs) are commonly used for the evaluation of preoperative PPC risk after lung cancer surgery.
- Previous studies have demonstrated that low skeletal muscle mass is associated with morbidity after major surgery.
- The present study shows that older patients with PPCs after lobectomy for lung cancer had significantly lower FVC and forced expiratory volume in 1 second (FEV1) values than those without PPCs. They also had a significantly lower skeletal muscle mass, represented by the erector spinae muscle.

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

- Preoperative PFT and measurement of skeletal muscle mass are useful tools to predict PPCs in patients undergoing lobectomy for lung cancer.



**Figure 1** Flow chart of patient selection and classification. PPCs, postoperative pulmonary complications.



**Figure 2** Measurement of total skeletal muscle mass in the erector spinae muscles at the level of the spinous process with the 12<sup>th</sup> thoracic vertebra. Erector spinae muscles are represented in green colour.

For skeletal muscle mass, the cross-sectional areas (CSAs) of the right and left EMs were measured. The contours of both EMs were identified at the level of the spinous process with the 12<sup>th</sup> thoracic vertebra. CSAs of the right and the left EMs were checked and the sum ( $CSA_{Both}$ ) was used as the skeletal muscle mass (*Figure 2*). All procedures were performed by a radiologist who was blinded to the

study, using software, Centricity PACS Radiology RA1000 Workstation (GE Healthcare Inc., Chicago, IL, USA).

### *Perioperative care*

Perioperative management was standardised and followed the institutional protocol. Lobectomy for lung cancer was performed using the video-assisted or open technique under general anaesthesia after discussion with the thoracic surgeon and attending anaesthesiologist. One-lung ventilation was secured using a double-lumen endotracheal tube or endobronchial blocker. Video-assisted thoracoscopic surgery (VATS) was performed through a 4-cm utility incision at anterior or middle axillary line of the fifth intercostal space (ICS) by using Alexis wound protector (Applied Medical, USA), a 12-mm trocar port at the eighth ICS and a 5-mm port at the subscapular area. Thoracotomy was performed through a posterolateral incision that spared the serratus anterior muscle. The chest cavity was entered through the fifth ICS with segmental resection of the sixth rib. A chest tube was inserted to check the drainage and air leakage after lobectomy under general anaesthesia. The chest tube was connected to an underwater seal chest

drainage system. Postoperative pain was controlled with an intravenous patient-controlled analgesia pump. After emergence from general anaesthesia for lobectomy, the patient was transferred into the intensive care unit (ICU). Postoperative care was performed by the thoracic surgeon following our institutional protocol, including the decision of transfer from the ICU to the general ward. The chest tube was removed after confirmation that there was no drainage and no air leakage.

### PPCs

The following PPCs within 30 days after lobectomy for lung cancer were evaluated: mortality, need for mechanical ventilation, tracheostomy, persistent air leakage, atelectasis, pneumonia, pleural effusion, haemothorax, chylothorax, pyothorax, pulmonary thromboembolism and nerve injury (e.g., phrenic nerve and recurrent laryngeal nerve).

PPCs were defined as above grade III in The Clavien-Dindo Classification (8).

Postoperative chest radiography was performed daily until discharge from the hospital. Any new-onset abnormal findings detected on postoperative chest radiography or pulmonary symptoms or signs that were not observed before lobectomy for lung cancer were checked, evaluated and managed by the thoracic surgeon using additional evaluation tools, including chest CT, if needed.

Continuous negative suction was applied to the bottle for the chest tube in patients with persistent air leakage. Pleurodesis was performed at the discretion of the thoracic surgeon in cases in which continuous negative suction was not effective.

### Statistical analysis

Demographic data, including preoperative PFT, CSAs of the right and left EMs and CSA<sub>Both</sub>, were analysed according to the presence of PPCs.

Statistical analyses were conducted using SPSS for Windows (ver. 27.0; IBM Corp., Armonk, NY, USA). Categorical variables were analysed using the chi-square or Fisher's exact test, and continuous variables were analysed using the independent *t*-test.

The correlation between preoperative PFT and CSA<sub>Both</sub> was confirmed using Pearson's correlation coefficient. A univariate analysis was performed for each potential risk factor of PPCs using logistic regression. Factors with  $P < 0.05$  in univariate analysis were included in a multivariate

conditional logistic regression model using the backward stepwise regression procedure. Odds ratios (ORs) with the 95% confidence interval (CI) were calculated based on the final model. To obtain cut-off values for preoperative PFT and CSA<sub>Both</sub> for the prediction of PPCs, the area under the curve (AUC) with receiver operating characteristic (ROC) curve analysis was determined with Youden's index.

Data are expressed as the number of patients, mean [standard deviation (SD)]. In all analyses,  $P < 0.05$  was taken to indicate statistical significance.

### Results

During the study period, 199 patients older than 65 years old underwent lobectomy for lung cancer at our centre. Two patients were excluded due to metastasis from other organs. Therefore, data from a total of 197 patients were included in the analyses (*Figure 1*). In total, 55 patients had PPCs: 4 died due to pneumonia or respiratory failure within 30 days after lobectomy, 3 required mechanical ventilation, 1 required tracheostomy, 18 had persistent air leakage, 3 had atelectasis, 21 had pneumonia, 4 had pleural effusion and 1 patient had pulmonary thromboembolism (*Figure 1*).

Preoperative PFT and chest CT were performed within 3 [3–4] and 3 [3–4] days, respectively.

The patients with PPCs were significantly older than those without PPCs (*Table 1*). The patients with PPCs significantly showed the higher rates of smoking history, including ex-smokers and active smokers (*Table 1*). The patients with PPCs had significantly higher rates of underlying diseases, such as hypertension (HTN) and diabetes mellitus (DM) (*Table 1*). The rates of medication with angiotensin-converting enzyme inhibitor (ACEi) or angiotensin receptor blocker (ARB) and hypoglycaemic agents were also significantly higher in patients with PPCs (*Table 1*). The patients with PPCs significantly showed the lower rate of pathological stage I and the higher rate of pathological stage II (*Table 1*).

Patients with PPCs had significantly lower preoperative FVC [2.53 (0.45) *vs.* 3.00 (0.58) L, respectively;  $P = 0.001$ ] and FEV1 [1.79 (0.40) *vs.* 2.13 (0.42) L, respectively;  $P = 0.001$ ] values than those without PPCs (*Table 2*). However, there were no significant differences in FEV1/FVC, FEF, FEF25–75% or MVV between patients with and without PPCs (*Table 2*).

The CSA<sub>Both</sub> was significantly lower in patients with than without PPCs [26.91 (4.64) *vs.* 30.85 (5.88) mm<sup>2</sup>, respectively;  $P = 0.001$ ] (*Table 2*).

**Table 1** Demographic data

Variables	With PPCs (n=55)	Without PPCs (n=142)	P value
Sex (M/F)	32/23	64/78	0.099
Age (years)	75 (6.0)	73 (5.0)	0.004
Height (cm)	158 (0.09)	158 (0.07)	0.666
Weight (kg)	63.8 (10.8)	64.3 (8.6)	0.749
Smoking history			
Non-smoker	16	94	<0.001
Ex-smoker	25	43	0.013
Active smoker	14	5	<0.001
Underlying disease			
HTN	28	47	0.021
DM	21	29	0.010
Cardiovascular disease	7	10	0.066
CVA history	1	6	0.413
Current medications			
ACEi or ARB	17	21	0.010
β-blocker	8	11	0.147
CCB	6	11	0.478
Diuretic	4	6	0.382
Hypoglycaemic agent	19	21	0.002
Antiplatelet agents	12	20	0.187
Location of lesion			
Right upper lobe	21	43	0.720
Right middle lobe	4	12	0.786
Right lower lobe	6	29	0.117
Left upper lobe	11	35	0.752
Left lower lobe	13	23	0.225
VATS/thoracotomy	47/8	117/25	0.606
Operation time (min)	241 (53.0)	234 (64.0)	0.662
Type of lung cancer			
Adenocarcinoma	37	111	0.112
Squamous cell carcinoma	2	4	0.764
Large cell carcinoma	16	26	0.097
Small cell carcinoma	0	1	0.533

**Table 1** (continued)**Table 1** (continued)

Variables	With PPCs (n=55)	Without PPCs (n=142)	P value
Pathological stage			
I	35	122	<0.001
II	15	14	0.003
III	5	6	0.059

Data are expressed as number of patients or mean (SD). M, male; F, female; HTN, hypertension; DM, diabetes mellitus; CVA history, history of cerebrovascular accident; ACEi, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; CCB, calcium channel blocker; VATS, video-assisted thoracoscopic surgery; PPCs, postoperative pulmonary complications; SD, standard deviation.

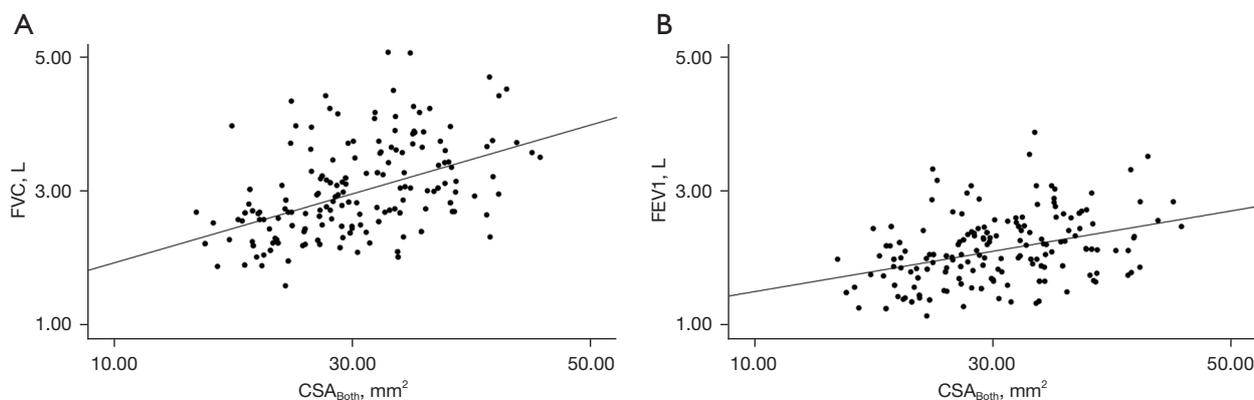
**Table 2** Preoperative PFT and the sum for cross-sectional area of the right and the left erector spinae muscles ( $CSA_{Both}$ )

Variables	With PPCs	Without PPCs	P value
Preoperative PFT			
FVC (L)	2.53 (0.45)	3.00 (0.58)	0.001
FEV1 (L)	1.79 (0.40)	2.13 (0.42)	0.001
FEV1/FVC	70.77 (7.91)	71.52 (8.10)	0.554
FEF (L/s)	6.90 (2.47)	6.94 (1.92)	0.900
FEF25–75% (L/s)	1.38 (0.78)	1.46 (0.65)	0.521
MVV (L/min)	94.21 (13.28)	94.50 (11.43)	0.369
$CSA_{Both}$ ( $mm^2$ )	26.91 (4.64)	30.85 (5.88)	0.001

Data are expressed as mean (SD). PFT, pulmonary function test; FVC, functional vital capacity; FEV1, forced expiratory volume in 1 second; FEF, forced expiratory flow; FEF25–75%, forced expiratory flow between 25% and 75%; MVV, maximal voluntary ventilation; PPCs, postoperative pulmonary complications.

The preoperative FVC and FEV1 were significantly positively correlated with  $CSA_{Both}$  ( $r=0.526$ ,  $P<0.001$ ;  $r=0.404$ ,  $P<0.001$ ) (Figure 3).

A univariate analysis identified age, smoking history, HTN, DM, ACEi or ARB, hypoglycaemic agents, pathological stage, FVC, FEV1 and  $CSA_{Both}$  as risk factors for PPCs. However, multiple logistic regression analysis identified age (OR, 1.102; 95% CI, 1.001–1.213;  $P=0.048$ ), ex-smokers (OR, 4.966; 95% CI, 1.988–12.406;  $P=0.001$ ), active smokers (OR, 31.891; 95% CI, 7.152–142.195;  $P<0.001$ ), DM (OR, 8.142; 95% CI, 2.608–25.417;



**Figure 3** Correlation between the preoperative pulmonary function test and the  $CSA_{Both}$  at the level of the spinous process with the 12<sup>th</sup> thoracic vertebra. (A) FVC; (B) FEV1.  $CSA_{Both}$ , sum of the cross-sectional areas of the right and left erector spinae muscles; FVC, functional vital capacity; FEV1, forced expiratory volume in 1 second.

$P < 0.001$ ), FVC (OR, 0.295; 95% CI, 0.116–0.747;  $P = 0.010$ ) and  $CSA_{Both}$  (OR, 0.878; 95% CI, 0.796–0.967;  $P = 0.009$ ) as independent risk factors for PPCs (Table 3). The AUCs for age, FVC and  $CSA_{Both}$  were 0.620 (95% CI, 0.534–0.706;  $P < 0.05$ ), 0.727 (95% CI, 0.650–0.803;  $P < 0.001$ ) and 0.685 (95% CI, 0.608–0.762;  $P < 0.001$ ), respectively (Figure 4) (the AUC for DM was not analysed because DM was a categorical and not numerical variable). The optimal threshold values for age, FVC and  $CSA_{Both}$  to predict PPCs based on ROC curve analysis were 73.5 years (sensitivity 58.2% and specificity 59.2%), 2.685 L (sensitivity 64.1% and specificity 61.8%) and 28.47 mm<sup>2</sup> (sensitivity 62.0% and specificity 61.5%), respectively (Figure 4).

## Discussion

The present study shows that older patients with PPCs after lobectomy for lung cancer had significantly lower FVC and FEV1 values than those without PPCs. They also had a significantly lower skeletal muscle mass, represented by the EM. Preoperative FVC and FEV1 showed significant positive correlations with  $CSA_{Both}$ . Independent risk factors for PPCs after lobectomy for lung cancer were age, smoking history, DM, FVC and  $CSA_{Both}$ .

The patients who developed PPCs after lung cancer surgery had poorer long-term outcomes with a reduction in overall survival (1). With regard to the surgical technique for lung cancer surgery, VATS has been shown to be associated with a lower incidence of PPCs in comparison with thoracotomy (9). However, PPCs remain a major issue that must be resolved for the improvement of both

survival and quality of life. Old age, obesity, smoking, chronic obstructive pulmonary disease (COPD) and poor pulmonary function measured with the PFT were reported to be risk factors for PPCs after lung cancer surgery (10). However, the predictive capabilities of these factors were poor. Moreover, poor pulmonary function, as determined by the PFT, was not associated with low morbidity or mortality in patients undergoing VATS for lung cancer surgery (11,12). Berry *et al.* (13) concluded that preoperative PFT was associated with PPCs after lung cancer surgery only in thoracotomy, but not in VATS. As most recent cases of lung cancer surgery have been performed using VATS and not thoracotomy, a new objective means of predicting PPCs after lung cancer surgery via both thoracotomy and VATS is required. Most cases in the present study were treated by VATS, but preoperative FVC, one of the preoperative PFT parameters, was the most reliable predictor of PPCs after lobectomy for lung cancer. However, the process of PFT should be checked. For the precise evaluation of PFT, the patient's effort is essential (14). Therefore, although PFT is an objective means of evaluating pulmonary function, it has the possibility of misinterpretation. Moreover, it is sometimes difficult to understand and perform the entire process of PFT, especially in older patients. Therefore, measurement of skeletal muscle mass may be an alternative method, without requiring any special effort by the patient, to predict PPCs in older patients undergoing lobectomy for lung cancer, regardless of the surgical approach, VATS, or thoracotomy. Considering the patients with PPCs were older than the patients without PPCs, measurement of skeletal muscle mass might be a useful and comfort tool for

**Table 3** Predictors of postoperative pulmonary complications in older patients undergoing lobectomy for lung cancer

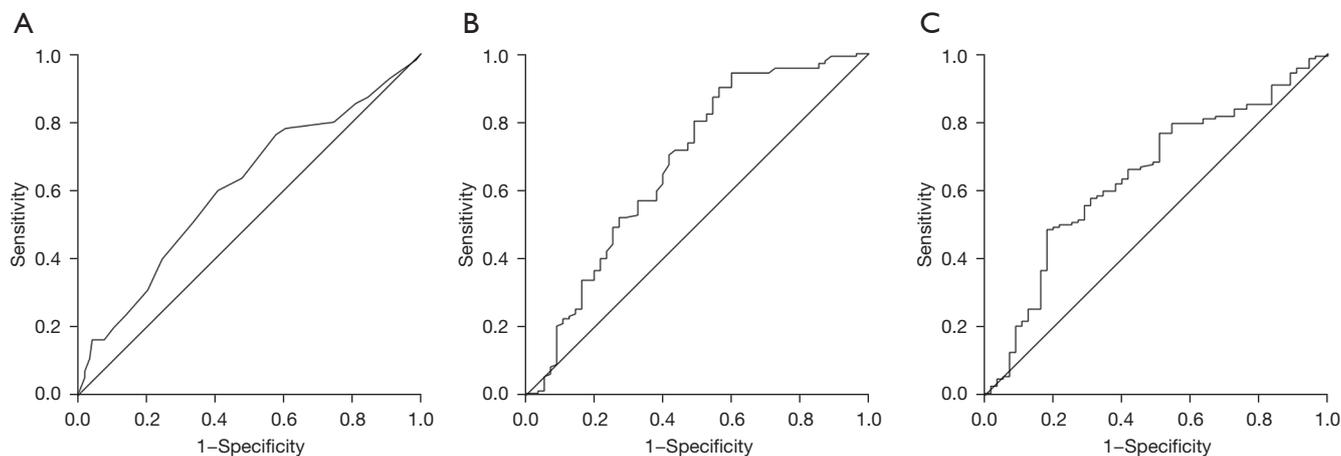
Variables	Univariable		Multivariable	
	Odd ratio	P value	Odd ratio	P value
Sex (M/F)	0.590 (0.314–1.107)	0.100		
Age (years)	1.095 (1.027–1.168)	0.006	1.102 (1.001–1.213)	0.048
Height (cm)	1.408 (0.018–107.56)	0.877		
Weight (kg)	0.994 (0.960–1.028)	0.712		
Smoking history				
Non-smoker	0.186 (0.093–0.369)	<0.001		
Ex-smoker	3.935 (0.960–1.028)	<0.001	4.966 (1.988–12.406)	0.001
Active smoker	16.293 (5.075–52.314)	<0.001	31.891 (7.152–142.195)	<0.001
Underlying disease				
HTN	1.888 (1.003–3.555)	0.047		
DM	2.407 (1.219–4.750)	0.010	8.142 (2.608–25.417)	<0.001
Cardiovascular disease	0.519 (0.187–1.442)	0.209		
CVA history	2.382 (0.280–20.256)	0.427		
Current medications				
ACEi or ARB	2.238 (1.069–4.683)	0.033		
$\beta$ -blocker	0.493 (0.187–1.301)	0.153		
CCB	0.686 (0.241–1.955)	0.480		
Diuretic	0.563 (0.152–2.075)	0.388		
Hypoglycaemic agent	3.041 (1.475–6.270)	0.003		
Antiplatelet agents	0.587 (0.265–1.302)	0.190		
Lesion of lung cancer*				
Right upper lobe	Not applicable	–		
Right middle lobe	0.733 (0.210–2.557)	0.626		
Right lower lobe	0.455 (0.163–1.270)	0.133		
Left upper lobe	0.776 (0.334–1.806)	0.557		
Left lower lobe	1.243 (0.525–2.942)	0.620		
VATS/thoracotomy	0.797 (0.335–1.892)	0.606		
Operation time	1.002 (0.993–1.012)	0.655		
Type of lung cancer <sup>†</sup>				
Adenocarcinoma	Not applicable	–		
Squamous cell carcinoma	1.500 (0.264–8.526)	0.647		
Large cell carcinoma	1.846 (0.894–3.814)	0.098		
Small cell carcinoma	1.103 (0.202–2.944)	0.843		

Table 3 (continued)

Table 3 (continued)

Variables	Univariable		Multivariable	
	Odd ratio	P value	Odd ratio	P value
Pathological stage				
I	0.270 (0.130–0.562)	<0.001		
II	3.735 (1.646–8.476)	0.002		
III	2.905 (0.836–10.087)	0.093		
Preoperative PFT				
FVC (L)	0.173 (0.083–0.360)	0.001	0.295 (0.116–0.747)	0.010
FEV1 (L)	0.087 (0.034–0.226)	0.001		
FEV1/FVC	0.964 (0.924–1.005)	0.091		
FEF (L/s)	0.990 (0.852–1.151)	0.900		
FEF25–75% (L/s)	0.845 (0.529–1.350)	0.482		
MVV (L/min)	1.017 (0.986–1.038)	0.367		
CSA <sub>Both</sub> (mm <sup>2</sup> )	0.876 (0.822–0.933)	0.001	0.878 (0.796–0.967)	0.009

Data are expressed as 95% CI. \*, in the present study, most common lesion of lung cancer was right upper lobe. Odd ratio was obtained from right upper lobe as baseline. †, in the present study, most common type of lung cancer was adenocarcinoma. Odd ratio was obtained from adenocarcinoma as baseline. M, male; F, female; HTN, hypertension; DM, diabetes mellitus; CVA history, history of cerebrovascular accident; ACEi, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; CCB, calcium channel blocker; VATS, video-assisted thoracoscopic surgery; PFT, pulmonary function test; FEV1, forced expiratory volume in 1 second; FVC, functional vital capacity; FEF, forced expiratory flow; FEF25–75%, forced expiratory flow between 25% and 75%; MVV, maximal voluntary ventilation; CSA<sub>Both</sub>, sum of the cross-sectional areas of the right and left erector spinae muscles; CI, confidential interval.



**Figure 4** ROC curve for the prediction of PPCs from age, preoperative FVC and the CSA<sub>Both</sub> at the level of the spinous process with the 12<sup>th</sup> thoracic vertebra CSA<sub>Both</sub>. (A) Age; (B) FVC; (C) CSA<sub>Both</sub>. ROC, receiver operating characteristic; PPCs, postoperative pulmonary complications; FVC, functional vital capacity; CSA<sub>Both</sub>, sum of the cross-sectional areas of the right and left erector spinae muscles.

the elderly patients with lung cancer to predict PPCs after lung cancer surgery. Moreover, the evaluation for PPCs after lung cancer surgery was able to be simultaneously obtained at the first scanning for diagnosis of lung cancer, using CT. It meant that no additional assessment for PPCs after lung cancer surgery was needed.

Psoas muscle has been popularly chosen as a predictor in previous studies for the association between muscle mass and morbidity after major surgeries (15,16). However, psoas muscle is originated from T12 and inserted to femur. Scanning from chest to lower limbs is required for the exact evaluation of psoas muscle and muscle mass at the mid-level of psoas muscle, taken from abdominal scanning, has been used in the previous studies (17,18). Additionally, scanning increased the risk for the exposure of biohazard. Therefore, we thought that psoas muscle was not suitable in the patient undergoing lung cancer surgery, although the usefulness as predictor for morbidity after major surgeries has been demonstrated. We checked the EMs at the level of the spinous process with the 12<sup>th</sup> thoracic vertebra to measure skeletal muscle mass in the present study. Previous studies have demonstrated the usefulness of the EMs for the evaluation of sarcopenia. Nakano *et al.* (19) reported that CSA was a useful predictor of prognosis in patients with idiopathic pulmonary fibrosis. Oh *et al.* (20) reported that CSA was significantly associated with 30-day postoperative major complications in patients undergoing isolated tricuspid valve surgery. Poor clinical outcomes in a previous study were significantly associated with poor preoperative pulmonary function (19). Therefore, the measurement of skeletal muscle mass by examination of the EMs at the level of the spinous process with the 12<sup>th</sup> thoracic vertebra may be a useful proxy for preoperative pulmonary function.

PPCs after lobectomy for lung cancer are directly associated with respiratory muscles (21). Therefore, respiratory muscles may be better choices for the evaluation of skeletal muscle mass. However, it is necessary to take into account the technical difficulty of the evaluation. Respiratory muscles directly or indirectly affected by lung cancer surgery are associated with changes in respiratory function, which can result in decreases in chest wall compliance and increases in the work of breathing (22). PPCs are the clinical manifestations of functional changes in the respiratory system after lung cancer surgery, although VATS is associated with less damage to the respiratory muscles than thoracotomy. Therefore, preoperative training of respiratory muscles is important to prevent PPCs by increasing the strength of the inspiratory and

expiratory muscles in patients undergoing lung cancer surgery (23,24). Using respiratory muscles as a surrogate for the measurement of skeletal muscle mass instead of EMs would be expected to better predict PPCs, but the evaluation would be more technically difficult. It is impossible for simple anatomical measurements of skeletal muscle mass to accurately represent the grade of muscle action or function. However, skeletal muscle mass is positively correlated with muscle strength in individuals above 50 years old, independent of age and sex (25). Therefore, the measurement of skeletal muscle mass based on the EMs in the present study was regarded as a valid surrogate for the physical activity of the patient.

Sarcopenia was defined as CSAs of the specific muscles indexed with body surfaced area less than the median, as in previous studies (20,26). These previous studies evaluated the outcomes after surgical procedures according to the presence or absence of sarcopenia and concluded that sarcopenia was a reliable predictor of clinical outcome after surgical procedures. However, sex and individual physical activity level were not considered in the determination of the cut-off, using the median value of CSAs of the specific muscles indexed to the body surface area in these previous studies. Moreover, a consensus definition of sarcopenia has not been established. The European consensus statement recommendations are based on healthy young adults (27), and were therefore not utilised in this study. However, the evaluation from larger population for association between sarcopenia defined by age, sex, and individual activity and PPCs after lung cancer surgery might be helpful.

In the present study, age, smoking, and DM were shown to be risk factors for PPCs after lobectomy. Age and smoking has been shown previously to be a predictive factor (28,29), but there has been some controversy regarding DM. Komatsu *et al.* (30) reported that DM did not influence postoperative recovery in the acute phase. Moreover, Wang *et al.* (31) reported that lung cancer patients with DM had significantly prolonged progression-free survival compared to patients without DM. Although DM led to lower postoperative survival rates in patients with non-small cell lung cancer (30,32,33), the control of glucose, not just binary division of positive or negative for DM diagnosis, may be more clinically meaningful. Therefore, the findings in the present study indicating that DM was a risk factor for PPCs should be re-evaluated in future studies using data regarding the control of glucose. However, we did not have such data in the present study.

Preoperative careful physiologic assessment is essential

to identify the patient with risk of PPCs after lung cancer surgery and enable appropriate management immediately after the surgery. Preoperative physiologic assessment includes cardiovascular evaluation, PFT, diffusing capacity of lung for carbon monoxide ( $DL_{CO}$ ) and so on. The limitations of preoperative PFT were mentioned above, but predictive postoperative (ppo) values of PFT, especially FEV1 (ppoFEV1), or  $DL_{CO}$  (ppo $DL_{CO}$ ) has been traditionally regarded as the most reliable predictor for PPCs after lung cancer surgery (34,35). However, the process of ppoFEV1 or ppo $DL_{CO}$  is not simple or intuitive because the formula for ppoFEV1 or ppo $DL_{CO}$  requires the number of functional remained segments after lung cancer surgery or normal value of FEV1 or  $DL_{CO}$  for individual patient. Although the association with skeletal muscle mass, and ppoFEV1 or ppo $DL_{CO}$  for predictability of PPCs was not evaluated in the present study, it might be helpful to confirm skeletal muscle as a predictor for PPCs.

The present study had several considerations. First, its retrospective study with relatively small sample size from a single centre had inevitable limitation. Important factor for PPCs after lung cancer surgery has the chance to be missed in the retrospective study. For evaluation of the exact association between preoperative PFT, and skeletal muscle mass and PPCs after lung cancer surgery, the patient with previous respiratory disease was excluded. However, it should be reminded that lung cancer had the common pathological mechanism with COPD (36). In the present study, the values of preoperative PFT were expressed by absolute values, not adjusted values by sex, age, height, weight and so on, following the guideline by European Respiratory Society and American Thoracic Society (37), although institutional protocol used equation for Korean population by Choi *et al.* (38). The guideline showed that the inappropriate selection of equation for reference values led misinterpretation and serious problems. Moreover, various equations, not universal equation, has been introduced for Korean population. Therefore, we described absolute values of PFT, not absolute value/reference value (%). Second, the interactions among the events might be existed, although the events of PPCs were defined and listed. Third, CSA of EM was measured by a radiologist and the data for interobserver agreement was not available, although the previous studies also did not have the data (39,40). Fourth, the median of CSA<sub>Both</sub> in the groups showed largely overlap and it seemed that the possibility of threshold to distinguish the two groups was low.

In conclusion, PPCs in older patients undergoing

lobectomy for lung cancer were associated with a lower preoperative FVC, FEV1 and skeletal muscle mass. Skeletal muscle mass, represented by the EMs, was significantly correlated with preoperative PFT. Therefore, skeletal muscle mass may be a useful predictor of PPCs in patients undergoing lobectomy for lung cancer.

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### Footnote

*Reporting Checklist:* The authors have completed the STARD reporting checklist. Available at <https://jtd.amegroups.com/article/view/10.21037/jtd-22-1156/rc>

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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) and approved by the Institutional Review Board of Konkuk University Medical Center (approval No. KUMC 202207071). The patient data were obtained from chart reviews, and the requirement for written informed consent from the patients was waived.

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