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Size-capacity mismatch in the lung: a novel predictor for complications after lung cancer surgery

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ABSTRACT

Background: The aim of the present study was to make a combined pulmonary functional and anatomical assessment using spirometry and computed tomography (CT) to clarify the best predictor for cardiopulmonary complications after thoracoscopic major lung resection for cancer.

Methods: We retrospectively reviewed our prospective database of 304 patients undergoing thoracoscopic major lung resection for cancer. The total lung volume (TLV) was measured preoperatively using deep-inspiratory CT by summing the voxels representing −600 to −1024 Hounsfield units. Forced vital capacity (FVC) was measured by spirometry. FVC/TLV was used to diagnose a lung size-function mismatch. We compared among FVC/TLV, conventional spirometric parameters, and the risk of postoperative cardiopulmonary complications.

Results: Postoperative cardiopulmonary complications developed in 25 of 304 patients (8.2%). There were no cases of operative mortality. A stepwise logistic regression analysis revealed that a history of smoking and low FVC/TLV were independent risk factors for postoperative cardiopulmonary complications in various preoperative measurements. According to a receiver-operating characteristic analysis, FVC/TLV was the only variable that was statistically useful for predicting complications (area under the receiver-operating characteristic curve > 0.7).

Conclusions: Lung size-function mismatch was identified as the best predictor for cardiopulmonary complications after major lung resection for cancer among various spirometry- and CT-derived parameters. The usefulness of this parameter in screening for patients who are at risk of complications should be validated by a multicenter, large-scale study because it can be obtained through routine preoperative work.

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Introduction

Video-assisted thoracic surgery (VATS) major lung resection for cancer was associated with significantly lower rates of postoperative complications than open surgery based on a propensity score-matched analysis.[1,2] However, it has been reported that the cardiovascular complications that develop after VATS are more likely to result in a fatal outcome than the complications that occur after open surgery.[3] Considering that postoperative cardiopulmonary complications tend to continue for the full length of the patient's stay and require expensive medical resources,[4] the accurate prediction of cardiopulmonary complications after VATS is mandatory in the counseling of patients who will undergo VATS for lung cancer. With respect to the preoperative functional measures, forced expiratory volume in 1 s (FEV1) is considered to be the most valuable parameter in screening for patients who are at risk of postoperative cardiopulmonary complications.[5] Although the diffusion capacity for carbon monoxide (D_{LCO}) and the maximal oxygen consumption (VO_2 max) are also used in the decision-making for surgery,[6] these examinations are not routinely performed in patients undergoing lung cancer surgery in our institution. In contrast to these functional measures, we previously reported that the measurement of areas of low-attenuation, which represent emphysema on chest computed tomography (CT), contributed to the prediction of hypoxemia after lobectomy for lung cancer, which might be an interim cardiopulmonary complication.[7] Because the analysis of chest CT images helps not only to diagnose the stage of lung cancer but also to assess the underlying anatomical diseases of the lung, we must further attempt to clarify the usefulness of CT-based anatomical measures in preoperative risk assessment. In this study, we sought to clarify the role of spirometry-based functional measures in combination with CT-based anatomical measures in predicting cardiopulmonary complications after major lung resection for cancer by VATS.

Patients and methods

Patients

We retrospectively reviewed our institutional, prospective database of 304 patients who underwent VATS major lung resection for primary lung cancer from January 2009 to December 2014. There were 42 patients who underwent major lung resection in our institution during the same period but who were not included in this study. These included 31 patients who were scheduled to undergo open thoracotomy due to extended resection or induction therapy and 17 patients with total pleural adhesion or a history of ipsilateral lung resection. This study was approved by our institutional review board. We obtained the following patient data: age, gender, height, smoking habit, Eastern Cooperative Oncology Group-performance status (ECOG-PS), Fletcher-Hugh-Jones (F-H-J) grading for dyspnea,[8] spirometric variables, quantitative CT-derived parameters, [18F]fluorodeoxyglucose accumulation during positron emission tomography, and the presence of preoperative comorbidities. Postoperative complications, especially postoperative cardiopulmonary complications, were defined as those corresponding grade 2 or above based on the Clavien-Dindo classification system.[9,10] Postoperative cardiopulmonary complications were considered to be complications that arose during hospitalization or within 30 d after an operation. Cardiopulmonary complications include pulmonary complications, such as pneumonia, empyema, acute respiratory distress syndrome (ARDS), atelectasis, acute exacerbation of interstitial pneumonia, prolonged mechanical ventilation, whereas cardiovascular complications include arrhythmias (atrial fibrillation, paroxysmal supraventricular tachycardia, and ventricular tachycardia), myocardial infarction, angina pectoris, congestive heart failure, and thromboembolic events. Operative mortality was defined as any death that occurred within 30 days after surgery. The smoking data included the pack-years smoked (the average number of packages of cigarettes smoked per day multiplied by the number of years that the individual smoked).

Surgical procedure

Operability was determined based on the existing guidelines for pulmonary resection.[11] The operation was basically performed via one port and two windows (2-4 cm), without rib spreading. During lobectomy, we used an endoscopic stapler (Ethicon, Cincinnati, OH or Covidien, Minneapolis, MN) to divide the fused fissures and to excise the pulmonary artery, vein, or bronchus. During the anatomical segmentectomy, we used electrocautery or an endoscopic stapler to dissect the intersegmental plane. All patients received epidural analgesia or an intercostal nerve block for pain control.

Pulmonary function tests

Preoperative spirometric variables were obtained within 1 mo before surgery and included forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV1). The percent predicted FVC (%FVC) and percentage of predicted FEV1 (%FEV1) are expressed as the percentage of the predicted value for age, gender, and height. The percentage of predicted postoperative FEV1 (ppo%FEV1) was derived using the anatomic method in which preoperative %FEV1 is multiplied by the fraction of the functional lung subsegments that were expected to remain after lobectomy or segmentectomy. The ppo%FEV1 values were calculated using the following equation: ppo% FEV1 = measured %FEV1 × (42 − number of segments resected)/42. The number of segments that were expected to be resected was set at six for a right upper lobectomy, four for a middle lobectomy, 12 for a right lower lobectomy, 10 for a left upper lobectomy, and 10 for a left lower lobectomy.[12]

CT scanning

Helical CT scans were obtained using 64-detector (Somatom Definition or Sensation 64; Siemens, Erlangen, Germany) row CT scanners. With the patient in the supine position, we obtained 1-mm high-resolution CT images of the entire lungs during a deep-inspiratory breath hold. We used a 512 × 512 matrix, 2-mm collimation, and a scan time of 1.0 s, at 120-130 kVp, and 220-230 mA.